# Analysing Learning Behaviour to Inform the Pedagogical Design of e-Learning Resources

## A Case Study Method Applied to Computer Programming Courses

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# Abstract

The work presented in this thesis is motivated by the need to develop practical guidelines to inform the pedagogical design of learning objects and the instructional contexts in which they are used. The difficulty is that there is no standard definition for pedagogical design or appropriate guidelines, in contrast with technical guidelines. Researchers and academic practitioners hold different understandings of the pedagogical values in the design of learning objects that determine their quality and effectiveness as educational software. Traditionally, empirical studies for the evaluation of learning objects gather rating data from the main consumers (i.e. instructional designers, teachers, and students) to assess a variety of design aspects. In this research, it is argued that, in order to evaluate and improve pedagogical design, valuable information can be extracted by analysing existing differences between students and how they use learning objects in real instructional contexts. Given this scenario, investigating the pedagogical aspects of the design of learning objects and how the study of students' behaviour with them can serve to inform such design became the main research interest of this thesis.

The exploratory research presents a review of standard technical guidelines and seven evaluation frameworks for learning objects that emerged in the period from 2000 to 2013, revealing a wide spectrum of criteria used to assess their quality and effectiveness. The review explores the advantages and faults of well-known methodologies and instruments for the evaluation of learning materials and presents a selection of 12 pedagogical attributes of design, with a detailed analysis of their meanings and implications for the development of learning objects. The 12 pedagogical attributes of design are: *Learning Objective*, *Integration*, *Context*, *Multimedia Richness*, *Previous Knowledge*, *Support*, *Feedback*, *Self-direction*, *Interactivity*, *Navigation*, *Assessment*, and *Alignment*.

The empirical research is based on two case studies where blended learning techniques are used as a new teaching approach for first-year Computer Programming courses at the Austral University of Chile. A virtual learning environment was customized and used in these courses to deliver different types of learning contents and assignments. Three studies were carried out for each course: the first study shows the relationships between students' interactions with different materials; the second study demonstrates the influence that learning styles exert upon these interactions, and the third study collects students' scores about the twelve pedagogical aspects of the learning resources used during the course.

The results demonstrate that a relationship exists between the pedagogical attributes of the design of different learning resources and students' interactions with them. Regardless of the learning style preferences of individuals in both cohorts, the design attributes that have the greatest effect on students' behaviour with learning objects and with the whole instructional context are *Interactivity*, *Support*, *Feedback*, and *Assessment*. From the

three sources of data only a combination of two of them, behavioural data and students' scores, are valuable sources of empirical data to inform pedagogical design aspects of learning resources. However, it is necessary to establish a direct mapping between design attributes and expected behavioural indicators to facilitate the identification of improvements in the pedagogical design of learning resources.

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# List of Publications

- De La Maza, M. E., Álvarez-González, L., Campos, A., & Vásquez, C. (2014). *Sistema detector de estilos de aprendizaje en la Universidad Austral de Chile*. Presented at TISE, La XIX Conferencia Internacional de Informática en Educación, Fortaleza, Brasil. December 8–11, 2014 (volume in press).

- Álvarez-González, L., Campos, A., & Araya, E. (2014). *Project IGUAL: Results and analysis in Austral University of Chile*. Proceedings of the VII International GUIDE Conference. ISBN 9788897772033. Universidad Panamericana, Guatemala – April 10–11, 2014.

- Campos, A., Álvarez-González L., & Araya, E. (2013). *IGUAL: Una Iniciativa para apoyar el Aprendizaje de la Programación en Universidades de América Latina.* Proceedings of Novena Expedición EDUWEB 2013. ISBN 978-980-12-6592-4. Universidad de Carabobo, Venezuela.

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# List of Acronyms

| | |
|---|---|
| ADL | Advanced Distributed Learning |
| AGORA | Help for Managing Reusable Learning Objects (in Spanish) |
| ARIADNE | Alliance of Remote Instructional Author and Distribution Networks |
| CLOE | Co-operative Learning Object Exchange |
| CLT | Cognitive Load Theory |
| DCMI | Dublin Core Metadata Initiative |
| DEA | Detector of Learning Style (in Spanish) |
| DLESE | Digital Library for Earth System Education |
| EdNA | Education Network Australia |
| EML | Educational Modelling Language |
| FSLSM | Felder–Silverman Learning Style Model |
| GEM | Gateway to Educational Materials |
| HCI | Human–computer interaction |
| HTML | Hypertext Markup Language |
| ICT | Information and Communication Technologies |
| IEEE | Institute of Electrical and Electronics Engineers |
| IEEE LOM | IEEE Learning Object Metadata |
| IEEE LTSC | Institute of Electrical and Electronics Engineers Learning Technology Standards Committee |
| IGUAL | Project "Innovation for Equality in Latin American Universities" (in Spanish) |
| IMDL | Instructional Material Description Language |
| IMS | Instructional Management Systems Learning Global Consortium |
| IMS CP | IMS Content Package |
| IMS LD | IMS Learning Design |
| IMS LIP | IMS Learner Information Package |
| IMS QTI | IMS Question and Test Interoperability |
| JISC | Joint Information Systems Committee |
| KMO | Kaiser-Meyer-Olkin |
| KUOLE | Kingston University Online Learning Environment |
| LMS | Learning Management System |
| LOAD | Learning Objectives, Activities and Designs |

| | |
|---|---|
| LOAM | Learning Object Attribute Metric |
| LOEI | Learning Object Evaluation Instrument |
| LOEM | Learning Object Evaluation Metric |
| LOM | Learning Object Metadata |
| LOR | Learning Objects Repository |
| LORDEC | Learning Object Research, Development and Evaluation Collaboratory |
| LORI | Learning Object Review Instrument |
| MERLOT | Multimedia Educational Resources for Learning and Online Teaching |
| NSDL | National Science Digital Library |
| PCA | Principal Component Analysis |
| PDF | Portable Document Format |
| RELOAD | Reusable eLearning Object Authoring & Delivering |
| SMETE | Science, Mathematics, Engineering, and Technology Education |
| SIVEDUC | Virtual System of Education of UACh (in Spanish) |
| SPSS | Statistical Package for the Social Sciences |
| TML | Tutorial Markup Language |
| UACh | Austral University of Chile (in Spanish) |
| VLE | Virtual Learning Environment |
| XML | eXtensible Markup Language |

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# CHAPTER 1

# Introduction

## 1.1 Research Background and Motivation

The growth of online and Blended Learning in educational institutions, especially universities, during the last decades is undeniable (Barbour, 2012; Hadjerrouit, 2008). Current instructional strategies combine face-to-face lectures with the usage of some virtual learning environment, which aims to provide students with tools and resources necessary for them to work in a much more autonomous manner. However, many criticisms are raised and a certain scepticism is observed within the academic and research community, concerning the pedagogical quality and effectiveness of e-learning platforms and their associated resources.

The need to create pedagogically informed learning objects for Computer Programming courses has inspired this investigation. From the academic community's perspective, technical-based approaches towards the design of learning objects are far from being pedagogically acceptable. Pedagogical trends in the design and evaluation of learning objects claim that learning systems, as well as learning objects, must support the desired learning objectives, students' learning processes, and their learning needs and interests.

In Computer Programming, as in most disciplines, tutors are responsible for creating an important part of the overall instructional context of these courses. They author learning materials, find additional resources, design activities and assessments, and assemble these elements into a comprehensive structure of learning units, according to established learning objectives and a particular teaching strategy. Existing pedagogical guidelines on the design of learning objects are strongly supported by both theoretical bases and empirical evidence; however, they also suggest that the effectiveness of these materials is not isolated from the instructional context in which they are meant to be used. There is a need for research-validated criteria that help to inform the design of learning objects in specific educational settings and, simultaneously, comply with desired pedagogical requirements. The following questions thus arise:

- How can the design of learning objects be improved from the experience and practice of using them?
- Which empirical data sources can be used and for what purpose?
- Is there a way of assessing and informing pedagogical design from empirical data sources such as students' behaviour with learning objects?

The following sections introduce the reader to this scenario, explaining the principles and purposes that ground the design and evaluation of learning objects from both technical and pedagogical perspectives. Methodological issues and research work proposed by pedagogical studies are presented to form the basis of this investigation's research objective and the way in which it has been undertaken.

### 1.1.1. Learning Resources

The design of educational resources for e-learning solutions, commonly referred to in the literature as learning objects, has been constrained by the different understandings that authors possess of the concept of 'learning object'. This term was first described by Gerard in the late 1960s although it is associated with Hodgins (Polsani, 2006). Since its appearance, researchers across the global academic community have focused their efforts on reaching a common understanding of this term, giving rise to a wide variety of definitions. The following is a small sample:

- "[…] any entity, digital or non-digital, which can be used, re-used or referenced during technology-supported learning" (IEEE LOM, 2002)
- "[…] any digital resource that can be reused to support learning" (Wiley, 2002)
- "One or more digital assets combined and sequenced to create or support a learning experience addressing a curricular outcome(s) for an identified audience(s). A learning object can be identified, tracked, referenced, used and reused for a variety of learning experiences." (Alberta Learning, 2002, as cited in McGreal, 2004)
- "A Learning Object is a relatively small, reusable digital entity that can be selectively applied – alone or in combination – by computer software, learning

facilitators or learners themselves, to meet individual needs for learning or performance support." (Shepard, 2000, as cited in Ashley et al., 2008)

- "A Learning Object is, as the name implies, the smallest reasonable unit of learning material.[…] Learning material can include such things as […]. Regardless of the type, each individual learning material has its own user interface, the usability of which can be evaluated, as well as a definable learning goal." (Nokelainen, 2006)

Because of the variations in definitions, many terms have emerged to refer to educational content (McGreal, 2004): Asset, Learning Resource, Content Object, Knowledge Object, Media Object, Learning Object, Assessment Learning Object, Reusable Learning Object, Unit of Learning, etc. The purpose of this chapter, or this thesis, is not to join the debate about which is the most appropriate term or to propose a formal definition. However, these definitions usually reveal what the author considers the characteristics and functional requirements of a learning object should be. Avoiding confusion with previous definitions, the title of this thesis uses the term e-learning resource to refer to any digital content material that can be used for learning. The reader will find that expressions like learning object or learning resources are effectively synonymous and are used to refer to the same concept.

### 1.1.2. Technically-oriented Design of Learning Resources

Authors who have investigated and reflected deeply on the purpose of learning objects in technology-based education suggest that the concept of reusability is responsible, to a large extent, for the definition and design of learning objects (Boyle & Cook, 2001; Polsani, 2006; Wiley, 2002). In fact, some of the most commonly used definitions in the literature include words like "reused" or "reusable", for example, definitions provided by Alberta Learning (2002), IEEE LOM (2002–2005), McGreal (2004), Polsani (2006), and Wiley (2002).

Lifelong learning requires a vast amount of resources to be widely accessible. The development of such resources may require a considerable investment of time and resources for academic institutions, however, especially those including interactive multimedia (Cochrane, 2005; Haughey & Muirhead, 2005; Kay & Knaack 2005; Krauss & Ally 2005). Therefore, practitioners and institutions are encouraged to reuse learning materials to obtain economic – and pedagogical – advantages (Koper, 2003; Littlejohn & Buckingham, 2003). The power of this idea is such that some researchers and content designers defend a design that is oriented to foster the reusability of learning objects (e.g. Cochrane, 2005; Windle, Wharrad, Leeder, & Morales, 2007). The general design recommendation to improve reusability is to develop small learning objects with a single concept in common. This way, learning objects can be re-purposed and sequenced with other resources to meet the needs of different learning contexts (Downes, 2001; Griffiths & Garcia, 2003). Another important technical aspect of design is the description of the learning object in compliance with metadata specifications (e.g. RELOAD or Aqurate), this, apart from supporting their reusability, allows interoperability between learning tools and platforms (i.e., VLEs, repositories, authoring tools, etc.)

Parallel to these design recommendations, their inherently software-based nature requires that learning resources satisfy the basic usability attributes derived from the principles of software engineering and human–computer interaction (HCI) (Albion, 1999; Cooper, Colwell, & Jelfs, 2007; Hadjerrouit, 2010; Nokelainen, 2006). The guidelines proposed by software usability experts (e.g., Nielsen, 1994; Preece, 1996) and HCI (e.g., Schneiderman, 1987, or Mandel, 1997, as cited in Pressman, 2005, pp. 270–271), have provided a solid base for designers and researchers to improve the design of learning resources. Meeting these requirements is essential for educational technology – either in the form of platforms or contents – to become an enabler for learning instead of a barrier (Jeffels, 2011). One of the major challenges of usability in e-learning is making resources accessible to all learners, especially those with physical or psychological disabilities (Cooper et al., 2007; Haughey & Muirhead, 2005; Jeffels, 2011).

Nevertheless, these benefits in the context of e-learning are not enough: learning systems and resources may be technically usable but not pedagogically usable and vice versa (Silius, Tervakari & Pohjolainen, 2003; Zaharias & Poulymenakou, 2006). The following section introduces an overview of the implications of pedagogical approaches towards e-learning solutions for their design process.

## 1.1.3. Pedagogically-oriented Design of Learning Resources

The pedagogical vision held by the academic community towards the design of e-learning resources can be clearly observed by studying related evaluation frameworks and criteria available in the literature. Learning objects have been evaluated in pursuance of a wide variety of purposes (Kay & Knaack, 2008) and all of these evaluations define, to a greater or lesser extent, the pedagogical aspects to consider in designing e-learning solutions. Such aspects have been identified by researchers who have focused on the following:

- "What key features of a learning object support and enhance learning?" (Sosteric & Hesemeirer, 2002, as cited in Kay & Knaack, 2008);
- The design attributes that support instruction and learning objectives and, foster the reusability of pedagogical practices among teachers (Cochrane, 2005; Krauss & Ally, 2005; Windle et al., 2007).
- Identify the factors that influence the learning processes of an individual and design the learning objects accordingly. These factors include: individuals' prior learning experiences, background knowledge, preferred learning styles, metacognitive skills, learning independence, emotional aspects towards learning, motivation to learn, and constructivist and socio-constructivist learning tenets (Reeves, 1994; Quinn, 1996; Squires & Preece, 1996, 1999; Albion, 1999; Nokelainen, 2006; García-Quismondo, Prado, & Osti, 2008; Hadjerrouit, 2010; Alharbi, Paul, Henskens, & Hannaford, 2011; Campos, Álvarez-González, & Araya, 2013).

The challenges that these aspects create for instructional designers are complex to overcome. Zaharias and Panagiotis (2006) presented a case study to inform the specific tasks required to apply learner-centred design (LCD) (Brna & Cox, 1998) to an e-learning course prototype. For their study, during the stage of analysis of needs, special emphasis was put on considering individuals' differences. The authors claim that, by applying HCI and usability methodologies, it is not clear how to address users as learners with their respective learning differences and needs, given the necessity to provide an effective integration between HCI methods and instructional design concepts, models, and techniques. They also claim that "more research-validated pedagogical heuristics are needed" to inform the design process in both e-learning projects and contents (Zaharias & Panagiotis, 2006). Authors of evaluation criteria, who have reviewed pre-existing pedagogical evaluation frameworks and models, seem to agree (Hadjerrouit, 2010; Kay & Knaack, 2005; Nokelainen, 2006). Additional limitations that occur suggest that improvements are required in the methodologies applied to existing frameworks. These limitations can be summarized as follows (Chawla, Gupta, & Singla, 2012; Kay & Knaack, 2005):

- Learning objects are usually developed or selected from a repository and delivered to students during a lesson. However, the evaluation usually occurs at the end of the course;
- The evaluation of learning objects is mostly undertaken in an informal manner, through informal interviews with participants and concentrates upon the survey and analysis of overall learning outcomes;
- Studies investigate how participants value the usage of learning objects during the learning process, but they do not provide systematic and formal models to evaluate them pedagogically.

Despite the fact that the evaluation frameworks described in the literature have been constituted upon comprehensive theoretical models used to inform design, other faults have been identified (Chawla et al., 2012; Kay & Knaack, 2005, 2008; Kilic & Gurol, 2011; Nokelainen, 2006):

i) Most models have not been tested in practical settings, like the model proposed by Haughey and Muirhead (2005), Morales (2009) or Eguigure and Zapata (2011);

ii) The impact of separate components upon learning has not been assessed like the LORI criteria (Vargo et. al. 2003) and its following versions, the MERLOT criteria or Nokelainen's pedagogical usability evaluation criteria, or;

iii) Criteria such as reliability and validity estimates are not provided.

Notwithstanding these faults, evaluation frameworks constitute valuable reference instruments for designers and practitioners to inform the design of a learning object. Firstly, they help to identify the technical and pedagogical aspects of a design and, secondly, they confirm the role of the instructional context as a fundamental factor to inform pedagogical design (Cochrane, 2005; Haughey & Muirhead, 2005; Krauss & Ally, 2005; Nokelainen, 2006; Wiley, 2007). Moreover, some authors have expressed the need to focus pedagogical practices upon the design, exchange, and reuse of learning objects in different instructional contexts instead of sharing the objects as purely learning content (Cochrane, 2005; Haughey & Muirhead, 2005; Krauss & Ally, 2005; Wiley, 2007; Windle et al., 2007). This suggests that there must be a relationship between the instructional context for which a learning object is designed or intended to be used and the pedagogical design of the object.

At the same time, universities are moving from an "instruction paradigm" intended to transfer knowledge from faculty to students to a "learning paradigm" where learning takes place through the students' discovery and construction of knowledge (Froyd & Simpson, 2008; Reigeluth, 2012). This transition places the learner at the centre of the stage, as an active participant responsible for his or her learning, and implies focusing the design of instructional contexts and learning courseware according to students' learning processes, preferences, interests, and specific needs. To evaluate the pedagogical aspects of the design of learning objects, in this thesis it is proposed to observe their usage within the overall instructional context for which they are originally designed. The work presents an analysis of learners' behaviour with course materials and activities delivered througha online learning environment. The main goal is to find relationships between any formal pedagogical attributes of instructional contexts and the learning styles of students so that e-learning resources and their integration into learning contexts can be designed and implemented accordingly. It is suggested that the analysis of factual data gathered from learners' behaviour and performance within this context would help to inform the pedagogical design of the learning resources and their overall instructional context.

### 1.1.4. Practitioner-led Research Approach

The work presented in this thesis adopts a practitioner-led research approach to investigate how to inform the pedagogical design of learning resources. Practitioner-led research belongs to a set of methodologies that emerge especially in higher education contexts, where practitioners are encouraged to "engage with the responsibility of offering explanations for what they are doing and generate their living educational theories of practice" (McNiff & Whitehead, 2009).

Several aspects related to the context of research, the nature of the research, and the position of the researcher, determined my selection of this approach (Costley & Armsby, 2007). The work emerges as a result of two independent contextual factors; one was the need to inform the teaching practice using blended learning approaches at Kingston University, London, and the other was the existence of a collaboration agreement between this institution and the Austral University of Chile, Valdivia (UACh) working on innovative e-learning solutions to facilitate the teaching of computer programming in first-year courses. Furthermore, it is a research based on academic practice where either the literature offered as well as collected data have been gathered from real teaching-learning contexts of introductory computer programming courses in these institutions.

## 1.2. Research Hypothesis

The following statements have been constructed from the pedagogical vision towards learning resources and how students interact with them:

i. The pedagogical design of a learning resource is informed and evaluated according to a set of attributes.

ii. A learning object's pedagogical design also needs to be planned in accordance with the other learning resources that comprise the instructional context.

iii. A learner's interactions with learning resources (i.e. objects and activities) are influenced by his or her particular learning style and needs.

Accordingly, this research aims to prove the following hypothesis:

*Data extracted from students' performance and interactions with e-learning resources can be used to inform empirically the pedagogical design of e-learning resources.*

## 1.3. Research Aims and Objectives

The ultimate aim of this investigation is to gather empirical evidence to help inform the pedagogical design of instructional resources delivered through virtual learning environments. It proposes to study the potential of data on learning behaviour to become one of these bases. To achieve this aim, research and development stages are conducted with the following objectives:

i. To identify a common set of design attributes typically used to assess the pedagogical characteristics of the e-learning resources that are delivered.

ii. To explore the kind of data that students' learning behaviour provides and how it has been used to inform instructional design from a pedagogical perspective;

iii. To utilize a suitable learning environment to deliver learning resources in a usable fashion and collect data on students' behaviour coming from their interactions with the platform and e-learning resources;

iv. To identify a suitable learning style model so that it is possible to find a relationship between students' learning styles and pedagogical design attributes.

In such a way the research aims to draw conclusions on how the implementation and design of e-learning resources can comply with both the pedagogical attributes of the e-learning resources and students' learning styles and needs.

## 1.4. Research Questions

With the conclusions drawn from the case studies presented in this investigation, this thesis will answer the following research questions:

- Do students' interactions with materials and information about their respective learning styles represent a sufficient data source to inform empirically the pedagogical design attributes of learning resources?
- Should the pedagogical attributes of learning resources be designed on the grounds of learning styles instead of existing learning theories and principles of instruction?
- Are typical activities and associated learning objects designed for introductory programming subjects an effective manner for novice students to learn programming?

## 1.5. Contributions of this research

In the course of this investigation a series of outcomes have arisen that make specific contributions towards the pedagogical design of e-learning resources, namely:

- The literature about research on the pedagogical design of learning objects is scarce and dispersed across time, therefore, a valuable contribution of this thesis is the identification of common pedagogical design aspects across studies collected from the period 2002–2012.
- The review of pedagogical evaluation frameworks has served to identify a set of methodological factors that can be used as guidance to other researchers and stakeholders to differentiate and select the most appropriate evaluation instrument

and methodology to satisfy their interests. This set of methodological factors can be applied to existing and future frameworks for the evaluation of learning objects.

- A presentation and description of six categories to represent the design dimensions of learning objects, which have been used to classify pedagogical and non-pedagogical design attributes. Such classification is open to extensions with attributes not identified in this work and can be used to guide the implementation of related evaluation instruments for learning objects.
- The development of an instrument for the evaluation of students' perception of the pedagogical usability of learning materials and activities according to a set of the main pedagogical design aspects selected from the literature. A copy of this instrument can be found in Appendix 10 at the end of this thesis.
- A novel proposal that advocates an empirical evaluation of the pedagogical attributes of learning objects based on students' behaviour. Analysis of behaviour has been conducted to improve the design and usability of learning systems but not applied to learning objects. Methodological issues discovered during this research did not permit me to confirm the main hypothesis, however, it left an open door for improvements. Therefore, there are recommendations to improve the methodology applied and validate this proposal in different practical scenarios.
- The research about the instructional design of learning objects has been undertaken following a practitioner-led approach. This brings several contributions:
    - A research work that is not only readable for fellow researchers but also comprehensible for instructional designers and teachers from all sectors in the field of education.
    - A collection of literature and methodologies constructed from real scenarios where the teaching-learning cycle takes place and falls under the influence of many controlled and uncontrolled factors. This approach, in spite of having been undertaken in a specific context, sets a valuable precedent on how to undertake and document future similar practitioner-led initiatives.
    - The data and results come from real students' behaviour with real learning materials. This means that no materials or student groups were prepared to satisfy the purposes of this investigation. The value of this circumstance

is that the pedagogical knowledge generated can be applied by other practitioners running Computer Programming courses in other institutions or extended by them to pursue their own research interests.

## 1.6. Outline of the Thesis

This introductory chapter has described an overall scenario to provide the reader with a basic understanding of the research undertaken. Within the two main trends identified in the design of e-learning contents, the complexities and issues emergent from pedagogical perspectives have been identified. A hypothetical relationship between the pedagogical design of e-learning materials and students' learning behaviour has been introduced and, accordingly, a proposal for an investigation into the empirical grounds required to address such issues has been proposed. In consequence, the methodological approach and set of the objectives required to prove this hypothesis and answer the research questions are presented.

Exploratory research on the empirical bases used to inform the pedagogical design of learning objects and how students' behaviour has been used to inform instructional design is presented in **Chapter 2**, which is divided into two main parts. The first part offers a more detailed review regarding a technically-oriented perspective surrounding design criteria for learning objects. This section addresses educational standards and specifications in contrast with criteria for frameworks which, in turn, are developed by researchers focused on the teaching practice and assess the didactic capabilities of learning objects. The practitioner-led approach adopted in this research aims to study two main factors influencing these capabilities which are addressed in the second part of Chapter 2: first, the surrounding learning objects and activities that comprise the instructional context of use of the learning object and, second, individual learning styles and needs.

**Chapter 3** focuses on describing the methodology applied to prove the hypothesis and two of the research questions listed above. The different data sources and instruments utilized to collect and analyse such data are explained in this chapter. To facilitate the reader understanding the results presented in this thesis, an explanation of statistical research methods applied is also offered in this chapter. Finally, the Computer Programming course case studies that shape the educational context of this research are described, exposing the characteristics of these courses, the characteristics of the participating students, and the teaching strategies adopted by module leaders in the respective institutions.

Following, **Chapter 4** presents the results obtained in these case studies. The results are analysed individually and discussed to answer two specific research questions associated with proving the research hypothesis. As a consequence of this analysis, both external and methodological factors that impact upon the overall achievement of the research aims are identified.

**Chapter 5** concludes this thesis with a summary of the work performed, the conclusions drawn from the results obtained and the extent to which these results help to prove the hypothesis and answer the research questions. Improvements to the methodology applied and recommendations to continue this line of investigation are also presented in this chapter. It concludes with the author's final thoughts derived from her academic practice and research experience.

# CHAPTER 2

# Empirical Bases to Inform the Design of e-Learning Resources

At the end of Chapter 1, the overall aim and of the thesis was introduced and a series of objectives outlined. According to the research hypothesis and these objectives, this chapter is focused on providing the reader with a comprehensive review of the elements required to meet the research objectives introduced: an exploration of the aspects of design of learning objects with special emphasis on those that are pedagogically valued and, an exploration of how behavioural data has been used to inform online instruction.

To introduce the reader into this scenario, an overview of the different purposes of the evaluation of learning objects is presented in Section 2.1 of the chapter. It summarizes the functional aspects of learning objects that are most valued across the research and academic community in general, which have driven the evaluation of design and usability of learning objects. Two main trends of understanding can be distinguished from these evaluation initiatives: the technical and the pedagogical perspectives, which are explained in Sections 2.2 and 2.3 respectively.

The review of evaluation frameworks helps to identify and explore those aspects of the design of learning objects that assess their capabilities as learning or teaching tools, referred to in this thesis as pedagogical design attributes. As a consequence of this review, a wide spectrum of design aspects is classified into categories that reflect the multidimensional nature of the design of learning objects. To shape the scope of the experimental research presented in this thesis, a set of common pedagogical attributes is identified. Section 2.5 presents and analyses the meaning of each attribute individually to infer the corresponding design implications.

Section 2.6 reviews specific topics relevant to this research: students' behaviour, students' learning styles, and the instructional context. Section 2.6.1 explains how learning behaviour has been traditionally used to investigate the design of educational software according to learning styles. Section 2.6.2 presents the concept of the instructional context of a learning object and learning metrics which can be extracted from analysing students' behaviour in this context. Finally, section 2.7 reviews the importance of learning systems as the main mechanism to deliver and work with learning objects in the case studies proposed in this thesis.

## 2.1. Purposes of Evaluation of Learning Objects

Chapter 1 introduced different approaches towards the design of learning objects determined by a definition of the term "learning object" and its expected functionalities or requirements. These conditions determine the context in which the design and evaluation of a learning object takes place, satisfying the diverse needs and values of participants involved and how the results obtained are going to be used (Williams, 2000; Wiley, 2002).

Generally speaking, evaluating the effectiveness of e-learning products, i.e. learning systems and learning objects, has been the aim of many research initiatives since the incorporation of learning technologies in the field of education (Burston, 2003; Halachev, 2009; Kulik, Kulik, & Bangert-Drowns, 1985). The approaches adopted in the evaluation of learning objects reveal the variety of interests existing in the research and academic community concerning the spectrum of aspects that determine effectiveness.

The reusability of learning objects can be considered as one of the most valued aspects of this spectrum. Lifelong learning requires a large amount of resources to be accessible, however, the development of such resources – especially those including interactive multimedia – may require a considerable investment of time and resources for academic institutions (Cochrane, 2005; Haughey & Muirhead, 2005; Kay & Knaack, 2005; Krauss & Ally, 2005; Littlejohn, Falconer & Mcgill 2008). Therefore, practitioners and institutions are encouraged to reuse learning materials to obtain economic and pedagogical benefits (Downes, 2001; Koper, 2003, Kurilovas & Dagiene, 2009; Parrish, 2004; Sicilia & Garcia, 2003). This is such an important motivation that some content designers and evaluators adopt approaches oriented to foster the reusability of learning objects (e.g. Cochrane, 2005; Vargo, Nesbit, Belfer, & Archambault, 2003). In pursuing these advantages, much of the research on learning objects has been based on this concept. Several evaluation studies have put special emphasis on assessing and fostering the reusability of learning objects focusing on: their technical characteristics, (e.g. Kurilovas & Dagiene, 2009; López, Escalante, & Alonso, 2007; Ochoa & Duval, 2006; Sanz-

Rodriguez, Dodero, & Sanchez-Alonso, 2011), their pedagogical characteristics (e.g. Boyle & Cook, 2001; Windle et al., 2007), the metrics extracted from their actual usage in learning tools (e.g. Chawla et al., 2012; Ochoa & Duval, 2009), the standardization of design through proposals of courseware assessment rubrics for institutional use, like the OSEL framework (Convertini, Albanese, Marengo, Marengo, & Scalera, 2006) or the guidelines proposed by Buzzetto-More and Pinhey (2006).

Secondly, the assessment of the quality of learning objects has also gained much attention among researchers. Frameworks that help to assess the overall quality of a learning object have been developed to assess technical and didactic aspects. Some examples of quality evaluation frameworks in the literature are: the LORI instrument and the Convergent Participation Model originally developed at the University of Athabasca (Leacock & Nesbit, 2007; Richards & Nesbit, 2004; Vargo et. al. 2003), the peer review evaluation process and evaluation criteria applied by the initiative Multimedia Educational Resources for Learning and Online Teaching[1] (MERLOT), the Co-operative Learning Object Exchange[2] (CLOE), and the framework proposed by Kurilovas and Dagiene (2009) based on a learning object's technical qualities and the stages of its life cycle.

Other initiatives focus on evaluating the pedagogical aspects of the design of learning objects. These studies have investigated which design features influence on students' learning processes (Hadjerrouit, 2010; Kay & Knaack, 2005, 2007, 2008); which design features impact on affective states that take place during learning, such as attention or motivation (Turel & Gurol, 2011); which design features comply with students' cognitive and learning styles (Alharbi et al., 2011; Campos 2013; Rojas & Defude, 2010); and which descriptive metadata ensure that learning objects delivered through learning platforms satisfy end-users' teaching and learning needs (Haughey & Muirhead, 2005; Nokelainen, 2006).

Finally, as software products, it is crucial to evaluate the usability of the design of learning objects regarding their graphical interface and expected functionalities. The challenge with learning objects is that these are products that need to satisfy typical software engineering principles of usability and also fulfil educational requirements (Hadjerrouit, 2010; Nokelainen, 2006; Squires & Preece, 1999; Zaharias, 2006). It is

[1] http://www.merlot.org/merlot/index.htm
[2] http://www.educause.edu/library/resources/co-operative-learning-object-exchange-cloe

claimed that the technical qualities and usability of learning objects have been a priority in experimental research whereas only a few initiatives have examined the pedagogical usability of e-learning products (e.g. Del Moral & Cernea, 2005; Hadjerrouit, 2010; García-Quismondo et al., 2008; Nokelainen, 2006; Sofos & Kostas, 2009;).

Two main threads run through the evaluation of learning resources for design purposes. These are manifested and differentiated within the literature as technical and pedagogically-oriented. There is a generalized complaint in the research and academic community that the evaluation of learning objects is mainly approached from a technical standpoint, whereas pedagogical approaches are much less frequent (Hadjerrouit, 2010; Kay & Knaack, 2008; Nokelainen, 2006; Sprock & Gallegos, 2013; Wiley, 2007). Reviewing the studies that evaluate learning resources, it is noted that most of the authors recognize the need to consider both technical and pedagogical aspects in the design as well as the evaluation of learning objects. The technical perspective toward design and evaluation is presented in Section 2.2 whereas more pedagogical approaches are reviewed in Section 2.3.

## 2.2. Technically-oriented Design Perspective

### 2.2.1. Design recommendations and standards

Authors' reflections on the purpose of learning objects in technology-based education suggest that the concept of reusability is responsible, to a large extent, for the particular definition and design of learning objects (Boyle & Cook, 2001; Polsani, 2006; Wiley, Gibbons, & Recker 2000). In fact, some of the most commonly used definitions in the literature include words like "reused" or "reusable": for example, definitions provided by Alberta Learning (2002), IEEE (2002–2005), McGreal (2004), Polsani (2006), and Wiley (2002),

The characteristics that must be satisfied in the design of reusable learning objects have been defined by several authors (e.g. Friesen, 2009; Sanz-Rodriguez et al., 2011; Sicilia, 2004) and are enumerated as follows:

- *Self-contained*: it must be a complete, standalone unit, containing all the information and resources needed by students to complete it.
- *Modular*: it must be capable of being combined with other learning objects.
- *Properly grained*: it must have an adequate size and learning objective.

- *Traceable*: it must be easily identifiable and tracked through an appropriate description of associated metadata.
- *Modifiable*: it should be easy to modify to be re-purposed for a different learning context.
- *Usable*: it must be easy to use, with an intuitive and user-friendly interface.
- *Standardized*: the organization of its parts (metadata, contents, activities, associated resources, etc.) should be compliant with shared specifications.
- *Technological*: it should be platform-independent, include the software – if necessary – required for running and visualizing the learning object's contents.
- *Social and educational*: it should be neutral about a specific subject or domain, pedagogical methods, institutional, cultural, and social aspects. This way the resource may be used in different levels of education and assessment.

From a technical viewpoint, promoting reusability of learning resources across platforms and institutions is grounded upon the adoption of technical standards for content development produced by standardization organizations. These are international bodies that have developed standards for educational purposes, for example (Santos-Hermosa 2012): Instructional Management Systems Learning Global Consortium[3] (IMS), Advanced Distributed Learning[4] (ADL), and the Institute of Electrical and Electronics Engineers Learning Technology Standards Committee[5] (IEEE LTSC). Such organizations promote interoperability between learning systems at the level of communication, user data, and content (i.e. learning objects). With this purpose in mind, and thanks to the efforts of these organizations, there is available to the academic community a variety of specifications that structure and describe all kinds of data associated with e-learning courseware or e-learning users (Table 1 provides some examples).

To facilitate the retrieval, sharing, and reuse of learning materials across different platforms, it is recommended that they should be described according to standard metadata. This task can be considered the most important obstacle that designers and academic practitioners have faced when designing learning materials (Campos et al.,

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[3] http://www.imsglobal.org
[4] http://www.adlnet.org
[5] https://ieee-sa.centraldesktop.com/ltsc/

2008). In this regard, the most commonly used standards are the IEEE Learning Object Metadata (IEEE LOM), the Dublin Core Metadata Initiative (DCMI) and the Canadian Core Learning Resource Metadata (CanCore) (Roy, Sarkar & Ghose, 2010).

**Table 1.** *Popular Learning Specifications and their Purposes*

| Specification | Purpose |
|---|---|
| IMS Content Package[6] (IMS CP) | To organize and describe learning contents |
| IMS Question and Test Interoperability[7] (IMS QTI) | To describe assessment items (i.e. questions, tests or exams) |
| IMS Learner Information Package[8] (IMS LIP) | To describe information associated with a learners' profile |
| Sharable Content Object Reference Model[9] (SCORM developed by ADL) | Technical guidelines for creating structured learning resources allowing their exchange across platforms |
| IEEE Learning Object Metadata[10] (IEEE LOM) | The most extended specification for describing learning resources' characteristics. |

[6] http://www.imsglobal.org/content/packaging/
[7] http://www.imsglobal.org/question/
[8] http://www.imsglobal.org/profiles/
[9] http://www.adlnet.gov/capabilities/scorm.html
[10] http://ltsc.ieee.org/wg12/index.html

### 2.2.1.1. IEEE Learning Object Metadata

IEEE LOM was sanctioned by the IEEE Learning Technologies Standard Committee (IEEE LTSC) to formalize the characteristics of a learning object, including those related to pedagogical aspects. Its current version provides approximately 81 metadata fields distributed in nine categories listed below:

- **General**: fields that gather general information about a learning object such as the title, description, language, coverage, etc.
- **Lifecycle**: fields that inform about the entities that have created or modified the learning object, e.g. author, version, contributor, status, etc.
- **Meta-metadata**: fields that inform about the metadata, e.g. language, contributor, LOM version, etc.
- **Technical**: fields that inform about the technological characteristics and requirements to work with the learning object, e.g. size, format, file type, installation requirements, hardware and software requirements, etc.
- **Educational**: fields that inform about the educational and pedagogical characteristics of the object, e.g. the learning resource type, interactivity type, target users' age range, difficulty, semantic density, etc.
- **Rights**: fields intended to store information about the copyright description and the conditions of use, e.g. cost, licence, restrictions, etc.
- **Relation**: fields that reference the relationship of a learning object with other learning objects, e.g. kind of relationship, target resource, description, etc.
- **Annotation:** fields that gather users' comments on the educational use of the learning object or, provide information about when it was created and by whom. Include fields like entity, description, etc.
- **Classification:** fields that inform about the taxonomic path to localize a learning object in a particular classification system, e.g. source, purpose, taxon path, etc.

### 2.2.1.2. Dublin Core Metadata

Dublin Core Metadata (DCMI)[11] contains metadata developed for describing resources and so enabling more intelligent discovery systems. It is frequently used and

[11] http://dublincore.org/

some authors refer to it because of its simplicity of use (Marzal García-Quismondo, Calzada Prado, & Cuevas Cerveró, 2006). DCMI is formed by two levels, Simple and Qualified, which contains 15 metadata fields for general purposes (Bianco, De Marsico & Temperini 2005), however, it does not provide any elements for describing the pedagogical perspective of a document (Roy et al., 2010).

### 2.2.1.3. CanCore Metadata

The CanCore[12] Metadata Application Profile "is a streamlined and thoroughly explicated version of a sub-set of the LOM metadata elements" (Friesen & Roberts, 2002). It provides a total of 51 elements distributed in eight main categories: *General, Lifecycle, Meta-metadata, Technical, Educational, Rights, Relation* and *Classification*, which are fully compatible with the analogous LOM categories.

DCMI does not provide elements that deal with the educational aspects of resources whereas IEEE LOM and CanCore do. IEEE LOM is, by far, the most widely utilized standard (Ochoa, 2008; Roy et al., 2010) by recognized learning content standardization organizations like Advance Distributed Learning[13] (ADL) or IMS Global Learning Consortium[14]. The Alliance of Remote Instructional Author and Distribution Networks[15] (ARIADNE), the Multimedia Educational Resources for Learning and Online Teaching[16] (MERLOT), the Collaborative Learning Object Exchange[17] (CLOE), the Education Network Australia[18] (EdNA), the National Science Digital Library[19] (NSDL), and the National Science, Mathematics, Engineering, and Technology Education Digital Library[20] (SMETE), are examples of popular LORs that use at least one of these metadata standards (Bianco, de Marsico & Temperini, 2004; Friesen, 2009; Roy et al., 2010).

The creation of the metadata record is an important part of the design of a learning object as it can include technical and pedagogical descriptions that the authors consider

[12] http://cancore.athabascau.ca/en/
[13] http://www.adlnet.org
[14] http://www.imsglobal.org/
[15] http://www.ariadne-eu.org/
[16] http://www.merlot.org/
[17] http://www.cloe.on.ca
[18] http://www.edna.edu.au/
[19] https://nsdl.org/
[20] http://www.smete.org

relevant for repurposing or re-designing the object. However, with the exception of a few evaluation frameworks (Alvino, Forcheri, Ierardi, & Sarti, 2008; Del Moral & Cernea, 2005), it is notable that assessment of whether a learning object is associated with a metadata record is lacking. Why is educational metadata not valued or used to inform the pedagogical design of learning resources?

In the case of the LOM, a significant issue is that instructional and pedagogical guidelines on how educational metadata fields must be interpreted and combined are unavailable. This prevents the correct usage of these metadata and the possibility of performing an effective evaluation of the resource against this standard (Friesen & Roberts, 2002; Marzal García-Quismondo et al., 2006; Campos 2013).

Along with the ambiguous documentation, the values (i.e. vocabularies) accepted by the LOM to feed into metadata are also an issue. The data type accepted may be a primitive type (e.g. a string of characters), a value belonging to a controlled vocabulary (i.e. a list of terms already provided) or a value belonging to other referenced standards. The conflict arises because the interpretation of which values should be applied is tied to a high degree of end-user subjectivity (Agostinho et. al., 2004; Friesen & Roberts, 2002; Marzal García-Quismondo et al., 2006). Also, this value becomes problematic to determine when different metadata fields are mutually dependent (Suthers, Johnson, & Tillinghast, 2001).

Other authors argue that the LOM vocabularies have a limited capacity to allow a meaningful pedagogical description of a learning object (Jonassen & Churchill, 2004; Lukasiak et al., 2004). In this regard, LOM and CanCore admit the usage of other vocabularies, the most widely used being the Digital Library for Earth System Education[21] (DLESE) and the Gateway to Educational Materials (GEM) (Lukasiak et al., 2004).

However, neither of these other vocabularies include a teaching-related vocabulary to help users describe the instructional and learning purposes of the object, covering aspects like, for example, the type of learning, the objective, the learning expectations or the context of use. In contrast with this perspective, it is argued that the aim of the standards, particularly the LOM, is only to specify the semantics of the metadata to describe learning objects and to enable a meaningful interchange of metadata between

[21] http://www.dlese.org/Metadata/

systems (Suthers, Johnson, and Tillinghast 2001). Therefore, metadata describing aspects related to how to use learning objects to support learning are outside their scope.

Marzal García-Quismondo, Calzada Prado, and Cuevas Cerveró (2006) highlight the existence of redundancies of information among the LOM's educational metadata (the *Interactivity type* and *Interactivity level* fields) and also in other categories (e.g the learning object's *Language* in the *General* category and the target user's *Language* in the *Educational* category). The fact that LOM admits the possibility of attributing several metadata records to a single learning object can also result in redundancies of information (Rodriguez González, Conesa Caralt, García Barriocanal, & Sicilia, 2010).

In order to enrich the pedagogical value of metadata records, some authors have proposed new metadata models that include a subset of LOM and incorporate new fields whose purpose is to describe the pedagogical profile of a learning object (e.g. Alharbi, Henskens, & Hannaford, 2012; Alvino et al., 2008; Marzal García-Quismondo et al., 2006). These initiatives coexist alongside other mechanisms use to design and describe learning materials, Educational Modelling Languages (EMLs). These constitute a formal alternative to technical standards that emerge to solve those aspects where standard specifications fail to satisfy (Koper & Manderveld, 2004; Rodriguez-Artacho & Verdejo, 2004) the needs to:

- provide authors of learning contents with a pedagogical authoring layer based on instructional elements;
- describe the learning resource in relation to the target instructional context where it will be used;
- describe emerging pedagogical approaches or new representations of knowledge with instructional vocabularies that are not contemplated in the standards;
- describe learning processes and behaviours.

In order to fulfil these objectives, different EML initiatives have emerged, including: IMS Learning Design[22] (IMS LD) developed by the IMS organization as a standard to describe a learning scenario, all its components and the roles involved; PALO, an initiative to model educational contents (Rodriguez-Artacho & Verdejo, 2004); Tutorial Markup Language (TML) for the description of tutorial systems; Instructional Material Description Language (IMDL) for the representation of contents, assessments, structure,

[22] http://www.imsglobal.org/learningdesign/

metadata, and learner profiles. From these languages and in a great necessity to separate content from presentation styles to satisfy the requirements of collaborative frameworks, have appeared well-known EMLs such as MathML[23] or QML.[24]

Kingston University has used Connexions Markup Language (CNXML). This language is one of the products of the Connexions project developed by Rice University (Henry, Baraniuk, & Kelty, 2003), currently known as the repository with the most learning objects available (Duncan, 2009). The project currently provides a framework for academics to author, share and customized a variety of learning materials, ranging from isolated educational contents (called *modules*) to full courses (called *collections*). All materials created through Connexions[25] are subject to the Creative Commons Licence, which allows authors to modify the copyright as needed.

The main obstacle found is the lack of authoring tools for most of the educational modelling languages. Examples of these tools are LAMS[26] or RELOAD,[27] which allow the creation of materials based on the IMS LD language. These tools are open-source, however, it is necessary to have the resources and knowledge to maintain the software. The project Connexions is one of the few initiatives in the academic community that offers a free and online authoring tool that makes it possible to generate a syntactically valid CNXML-based content.

Generally speaking, compliance with a standard is considered an assurance of the quality of the learning resource. Governmental organizations and non-profit associations encourage educational institutions and teachers to examine learning materials according to a particular standard criterion (Nesbit, Belfer & Vargo, 2002). Thus, for this reason, some of the initiatives reviewed in Section 2.2.2 include as part of their criteria the compliance of the learning object description with IEEE LOM or similar standards (e.g. Del Moral & Cernea, 2005; Vargo et al., 2003). Nevertheless, in the evaluation frameworks reviewed in the following section, the lack of reference to *educational* metadata standards suggests that the pedagogical aspects associated with content resources differ significantly from the pedagogical aspects assessed in these frameworks.

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[23] http://www.w3.org/Math/
[24] https://www.questionmark.com/us/qml/Pages/default.aspx
[25] https://legacy.cnx.org/
[26] http://www.lamsinternational.com/
[27] http://www.reload.ac.uk/ldeditor.html

## 2.2.2. Technical usability of educational software

A particular aspect highly related to effective instructional design is usability. The inherently software-based nature of learning objects implies that they need to satisfy the basic technical usability attributes derived from the principles of software engineering and human–computer interaction (HCI). The guidelines proposed by software usability and HCI experts (e.g., Nielsen (1994), Preece (1997), Schneiderman (1987) and Mandel (1997) as cited in Pressman (2005, pp. 270–271)) provide a solid base for designers and researchers to improve the design of learning objects. The fundamental criteria for good usability of the user interface and underlying software are the following:

- *Easy to learn*: students should find it easy to learn to use the central functions provided by the resource so that they can concentrate on learning the contents which are their main goal (Cooper et al., 2007; Wong, Nguyen, Chang, & Jayaratna, 2003).
- *Efficient*: the functions provided are convenient and allow the student to perform learning tasks quicker.
- *Error-supportive*: in the case of an error response to a wrong usage of the functions, the resource should "teach" the student the correct use so that the error does not happen again.
- *Accessible*: the resource should provide a design able to adapt to all students' needs, especially those with physical disabilities.

It is essential that these usability requirements are considered so that educational technology – either in the form of platforms or contents – is an enabler for learning instead of a barrier (Jeffels, 2011). One of the major challenges of usability in e-learning is to make resources accessible to all learners, especially those with physical or psychological disabilities (Haughey & Muirhead, 2005; Cooper et al., 2007; Jeffels, 2011).

## 2.2.3. Summary of Technical-Oriented Perspective

Developing learning objects according to official standards and specifications is a quality indicator for learning objects. For this reason, educational institutions are encouraged to develop their materials in accordance with them. Standards are criticized for being too technical but pedagogically meaningless, which makes their usage difficult for academic practitioners, but they are also necessary to enable the interoperability and reusability. Several proposals can be identified in the literature that aim to bring academic practice and standard specifications closer together, especially in the area of vocabularies, metadata and languages that incorporate an educational or pedagogical meaning.

The achievement of the structural and contextual requirements to foster reusability have inspired the academic and research community to develop authoring tools and annotation mechanisms which facilitate the creation and description of educational resources in accordance with well-known metadata standards and specifications (e.g. RELOAD, AquRate, etc.).

From a technical perspective, usability of educational software is evaluated according to the principles dictated by the applicable software engineering and HCI guidelines to ensure software quality. In the context of authoring tools and their usability, it is essential that the complexities inherent in technical aspects (e.g. metadata, schema validation, etc.) of standards are carefully addressed in the user interface of these tools so that practitioners do not become discouraged from using them (Campos 2008).

It has been empirically demonstrated that technical usability exerts a direct impact on the pedagogical usability of learning materials (Hadjerrouit, 2010; Nokelainen, 2006) nevertheless, the benefits of a technical approach to design in the context of e-learning are not enough: learning systems and resources may be technically usable but not pedagogically usable and vice versa (Silius et al., 2003; Zaharias 2006). The following section introduces an overview of the implications that pedagogical approaches towards e-learning solutions have for their design process.

## 2.3. Pedagogically-oriented Design Perspective

### 2.3.1. Review of Evaluation Frameworks

Among the variety of evaluation initiatives, this section offers a description of the frameworks more frequently referred to in the literature. Generally speaking, the manner in which these initiatives have evaluated learning resources consists of two key elements: an evaluation instrument and an evaluation method. Nonetheless, other methodological issues impact upon the usefulness of these frameworks to inform the design of learning objects, for example: the fact that the research includes the development of subject-specific learning objects, the amount and type of users participating in the evaluation, the amount and variety of learning objects evaluated, the nature and variety of data gathered, and the validation approach of evaluation constructs. In the following tables (Tables 5 to 11), each framework is reviewed according to these factors, whereas their implications for this research are discussed at the end of this section.

### 2.3.1.1. Learning Object Rating Instrument (LORI) and the Convergent Participation Mode

Nesbit, Belfer, and Vargo (2002) proposed the Convergent Participation Model as a methodological evaluation of learning objects to meet the needs of a wide variety of stakeholders: students, teachers, subject experts, instructional designers and media developers. It is a two-cycle evaluation process based on individual and collaborative reviews of divergent ratings, where participants use the LORI instrument to score the features of a published learning object.

The first version found in the literature refers to LORI 1.3 with ten criteria: *Presentation aesthetics, Presentation design for Learning, Accuracy of Content, Support for Learning Goals, Motivation, Interaction usability, Interactions Feedback and Adaptation, Reusability, Standards Compliance* and *Accessibility*.

This instrument was first used by a group of 12 participants (instructional designers, faculty members, and media developers) who rated the features of eight learning objects published in the MERLOT repository. This initiative served to estimate the reliability of the instrument and also to identify potential improvements in the evaluation process in order to obtain a reliable assessment of a learning object. The findings highlight the importance of a minimum number of evaluators and their prior training in the field of learning objects, so that they need less training to understand the evaluation criteria and to use the instrument (Vargo et al., 2003).

LORI evolved immediately into versions 1.4 and 1.5, where the evaluation criteria were reduced to nine aspects: *Content Quality, Learning Goal Alignment, Feedback and Adaptation, Motivation, Presentation Design, Interaction Usability, Accessibility, Reusability* and *Standard Compliance* (Leacock & Nesbit, 2007). It has become a teaching instrument used for the evaluation of learning objects at Athabasca and Simon Fraser universities in Canada; it is formally used as an evaluation tool by the Southern Regional Education Board, comprised of 16 states in the USA (SREB, 2005, as cited in Leacock & Nesbit (2007)).

Krauss and Ally (2005) used an adapted version of LORI (version 1.4 in Nesbit et al., 2002) in order to evaluate a set of learning objects specifically designed for teaching the subject of Pharmacokinetics at the University of Toronto, Canada. In this study, the authors intended to investigate the basis used by instructional designers when designing learning objects and the challenges faced during the process and, simultaneously, to investigate the issues associated with the evaluation of effectiveness of learning objects. The adapted instrument was composed of eight criteria: *Content Quality, Learning Goal Alignment, Feedback and Adaptation, Motivation, Presentation Design, Interaction Usability, Reusability* and *Value of accompanying instructor guide*. The re-adaptation of this version is due to a general issue already explained in this chapter: the lack of evaluators' familiarity with existing technical standards for the design of learning objects.

The evaluation process performed by Krauss and Ally followed the convergent participation model in combination with the LORI instrument. According to the authors, one of the main benefits of this methodology was to provide designers and teachers with a better comprehension of the process of design of a learning object. It increased awareness of the pedagogical strengths and weaknesses of the design of learning objects, and it also encouraged practitioners to reflect upon their basis for assessing design features (Krauss & Ally, 2005).

### 2.3.1.2. MERLOT and Cochrane's Review Instrument

MERLOT is one of the most frequently referenced LORs in the literature (Ochoa, 2009; Sicilia, 2010). It provides a mature evaluation process based on "scholarly peer review process of peer-reviewed journals" (Hanley (2003), as cited in Cochrane, 2005) for learning objects based on three main aspects (Cochrane, 2005; Haughey & Muirhead, 2005):

- The quality of content, which considers the quality of the learning object's contents about the demonstration of the learning goals and specific aspects, such as correctness, accuracy, referencing, etc.

- Potential effectiveness as a teaching tool, which assesses the learning object's capabilities to support teachers' instructional strategies and students' learning needs.

- Ease of use, which assesses the aspects of software usability of the learning object, such as the layout, the interface, navigation, etc.

Similarly to the LORI process, reviewers are drawn from the discipline for which the material is meant to be used (Haughey & Muirhead 2005). The result of the peer review process is a rating from one to five, with additional comments for each learning object reviewed. The rating scale represents the following (Cochrane, 2005):

1. Materials are not worth using at all.
2. Materials do not meet minimal standards, but there might be some limited value.
3. Materials meet or exceed standards, but there are some significant concerns.
4. Materials are very good overall, but there are a few minor concerns.
5. Materials are excellent all round.

Cochrane used an adapted version of the MERLOT criteria to assess a set of learning objects developed for the subject of Audio Engineering; a discipline common to the Music & Audio Institute of New Zealand and Church Sound Engineers (a group of five church congregations) (Cochrane, 2005). The author focused on three aspects during the evaluation: reusability, interactivity and pedagogy. Cochrane concluded that the main design features of learning objects that impact upon both teachers' instruction and students' learning are: a clear definition of the learning objectives; simulating real-world learning scenarios (activities and equipment); providing high levels of interactivity; and embedding formative assessment into learning objects. About the design process, the author highlights the needs to choose an appropriate multimedia architecture for development; to allow enough time for development and evaluation of learning objects; and to adopt a participant-oriented evaluation method during the design cycle. Apart from these descriptive conclusions extracted from his experience in this study and statistics of ratings obtained from evaluators, Cochrane does not provide empirical validation – statistical reliability, validity, or correlations between criteria dimensions – for either the MERLOT criteria or his evaluation criteria.

Another well-known set of evaluation criteria derived from MERLOT is the one adopted by the Collaborative Learning Object Exchange (CLOE) (McGreal, 2004; Schoner, Buzza, Harrigan, & Strampel, 2005). To evaluate the three aspects mentioned above, the MERLOT criteria use a set of more than 30 individual questions requiring detailed answers, while the CLOE criteria use a smaller set of questions, covering 14 criteria (available in Haughey and Muirhead (2005)). According to the references provided by some authors, CLOE was tested by Howgard-Rose and Harrigan (Kay &

Knaack, 2008; Richards & Nesbit, 2004) however, neither their studies nor their results were found in the literature.

### 2.3.1.3. Haughey and Muirhead's Learning Object Evaluation Instrument (LOEI)

Haughey and Muirhead (2005) presented a comprehensive framework to describe the arguments around the design and usage of learning objects and the corresponding evaluation instrument, LOEI. The evaluation criteria were developed for learning objects to be used in face-to-face lectures in secondary schools belonging to the K-12 sector (including Australia and New Zealand, Canada, the USA, the UK and Europe). Due to this contextual reason, the authors suggest that the context of evaluation and the design process differs from learning objects intended for post-secondary courses (i.e. adult learning in higher education). In spite of this, it makes intuitive sense that learning objects developed for first-year courses in universities can be also evaluated following this criterion.

LOEI was the result of considering four existing evaluation models: CLOE; the Learning Federation Soundness Specification; LORI 1.3 (Vargo et al., 2003), and criteria developed to attend specific concerns of participant schools. The scale allows a reviewer to assess 14 aspects of learning objects, grouped into five categories: Integrity, Usability, Learning, Design, and Values.

The authors provided a good and comprehensive reference for instructional designers where the implications for design in each category are presented. However, their work presents important faults: their research does not include evidence of criteria reliability and validity; it has not been contrasted with additional data such as students' performance outcomes or usability survey results, and I was unable to find any subsequent studies that tested this model.

### 2.3.1.4. Learning Object Evaluation Metric (LOEM) and Multi-component Development and Assessment Models

The LOEM study was performed in research that started in 2005 and evolved until 2011. Considering that the proliferation of research on learning objects started at the beginning of the 2000s, when this research started there were still important gaps concerning the instructional design and evaluation of learning objects, including the following (Kay & Knaack, 2005):

- Research on learning objects and their effectiveness for learning had been only conducted for higher education contexts.
- Technical features in the design were emphasized over pedagogical features.
- Lack of systematic evaluation frameworks that are required to ensure the pedagogical value of learning objects.

The whole of the investigation aimed to address these faults, with which several authors agree (García-Quismondo et al., 2008; Hadjerrouit, 2010; Nokelainen, 2006). Initially, a set of learning objects for the disciplines of Mathematics, Physics, Chemistry, Biology, and Computer Science were implemented following CLOE development principles. This approach was re-adapted for the context of education in secondary schools. The team selected was composed of an expert who trained the team on the CLOE model; pre-service teacher candidates to assist the organization, management and development of learning objects; experienced teachers who were experts in the subject domain; a programmer and multimedia designer and; an expert in Education to guide the evaluation process.

The multi-component development model is represented by the authors' methodological approach. It lasted 13 months and was composed of 15 stages which included: performing a study on the qualities required for learning objects and target students' characteristics, implement several mock prototypes of learning objects, produce electronic versions, conduct formative evaluation of such prototypes' design and determine the form of students' usability test, carry out a pilot testing where volunteer students used the prototypes and provided feedback, include external evaluators for the prototypes developed, carry out the implementation of the final learning objects and perform a final evaluation by the teachers.

The design was intended to meet the requirements agreed by the academic members of the team. Reusability and accessibility were considered the most important technical requirements to achieve. For learning requirements, it was determined that the learning objects developed needed to cover those areas with which students had the most difficulties; to be content-rich in order to be shareable by different grades; to have an interactive and constructive nature; and to reinforce understanding of specific concepts rather than teach them as stand-alone materials (Kay & Knaack, 2005).

Learning objects were evaluated according to their perceived benefit and quality. One of the major strengths of Kay and Knaack's methodology over previous similar initiatives is that evaluation was performed from two different perspectives: students and teachers. The second strength lies in the number of participants in both evaluation groups, which was much greater than in the other initiatives reviewed: 221 students from twelve different high schools aged between 13 and 17 years, and a total of 30 teachers.

Two evaluation instruments were developed and administered. These instruments combined statements to rate each aspect of design using a Likert scale from 1 (Strongly disagree) to 7 (Strongly agree). In addition, the instruments included open-ended questions for the users to describe their own impressions. These are short questionnaires, with six and seven questions for students and teachers respectively. To extract conclusions from perceived the benefit and quality of learning objects, the authors established a coding based on instructional design theories to classify the qualitative responses gathered:

- Perceived benefit: *Timing, Review of Basics/Reinforcements, Interactive/Hands-on/Learner control, Good for visual learners, Computer-based, Fun/Interesting, Learning related, Clarity, Not good at the subject, Compare to other method* and *No reason given.*
- Quality: *Organization/Layout, Learner control over interface, Animation, Graphics, Audio, Clear instructions, Help features, Interactivity, Incorrect content/Errors, Difficulty/Challenge levels, Useful/Informative, Assessment, Theme/Motivation.*

These "codings" represent aspects extracted from students' and teachers' descriptive answers. The results of their analysis revealed that technical requirements of reusability and accessibility were not significant either for teachers or students. They also served, along with a detailed review of the literature on instructional design (Kay, 2007; Kay & Knaack, 2007), to shape the final evaluation criteria, LOEM, published in 2008. As result, LOEM is composed of five main categories with different associated sub-categories:

- *Interactivity*, which comprehends the subcategories *Constructive activity, Control* and *Level of interactivity*
- *Design*, which includes *Layout, Personalization, Quality of graphics* and *Emphasis on key concepts*

- *Engagement*, which refers to aspects associated with the *Level of difficulty, Theme, Aesthetics, Feedback* and *Multimedia*
- *Usability*, which includes the subcategories *Overall ease of use, Clear instructions* and *Navigation*, and
- *Content*, which refers to aspects related to their *Accuracy* and *Quality*.

The LOEM constructs listed above constitute the basis of a new evaluation framework to evaluate the effectiveness of learning objects. Different sets of data gathered from 1113 students and 33 teachers were statistically analysed in order to test the reliability and validity of LOEM constructs. A total of 44 learning objects were evaluated related to different disciplines (e.g. Biology, Canadian History, Chemistry, General Science, Geography, Mathematics and Physics) taught in middle and secondary schools and retrieved from the LORDEC website (Kay & Knaack, 2008). Kay and Knaack collected the following data to carry out their analysis:

- Teachers' evaluation scores for these learning objects using the LOEM instrument composed of 29 items to evaluate the five constructs.
- Teachers' and students' evaluation of the learning, quality, and engagement aspects of learning objects used in the classroom. For this purpose two learning object surveys were developed and administered: LOES-S for students and LOES-T for teachers (Kay & Knaack, 2008). These instruments presented the already mentioned combination of Likert-scale rated items and open-ended questions.
- Students' performance on the learning object's contents, calculated by applying *ad-hoc* pre- and post-test after using the learning object in the classroom.
- Statistics on the usage of learning objects in instructional settings, i.e., percentages of teachers who used the learning object for: reviewing previous knowledge before explaining a new concept; looking at the concept being taught in another way; or introducing or exploring a new concept before the lesson. It was found that learning objects are rarely used to teach a new concept, explore it or extend the concept after the lesson.

These data were used to perform a variety of statistical techniques to assess formally several aspects of LOEM (Kay & Knaack, 2008):

- Cronbach's internal reliability measurements of LOEM constructs were acceptable but not exceptional, especially for the constructs Interactivity and Design. Reviewing the evaluation items for these constructs might improve their reliability. Inter-rater reliability between teachers' evaluation scores was high, however, ranging from 94% to 96%, which reflects the positive effects of providing teachers with training on understanding the LOEM criteria applied to target learning objects.

- Validity of the LOEM constructs was assessed by applying PCA and correlations between them. The authors concluded that only the constructs Interactivity, Design, Engagement, and Usability were consistent with the multi-component design model proposed.

  In contrast, the construct Content did not emerge as a significant factor during the learning object evaluation. This construct covers aspects related to the basic functioning of the learning object (e.g. loading time, audio-visual quality, accuracy and correction of contents, etc.). It showed insignificant correlations with student evaluations, student performance, or teacher evaluations and it did not fit into the factor analysis. The reason may be that learning objects were pre-selected for evaluation and teachers could have filtered out those that had basic problems with contents (Kay & Knaack, 2008).

  Significant correlations were observed between constructs although these not high. This suggests a "conceptual overlap" between the constructs Interactivity, Design, Engagement and Usability (Kay & Knaack, 2008). These "overlaps" between design aspects have also been observed in a study described in the following subsection.

- Correlations between LOEM constructs and students' and teachers' evaluations of learning, quality, and engagement were used to assess the convergent validity of these constructs from these two perspectives. The results obtained showed that students' estimates of learning, quality, and engagement of learning objects correlated highly with the constructs Design, Engagement and Usability, whereas teachers' estimates correlated significantly with the four constructs.
- Finally, correlations between LOEM constructs and students' performance were calculated to assess their predictive validity to evaluate the impact of the learning objects upon the students' learning. The results obtained proved that the four constructs correlated positively and significantly with students' performance.

The tools applied in this study have been quantitatively validated in subsequent studies performed to observe the impact of using learning objects in secondary and middle school sectors, particularly in the disciplines of Mathematics and Science (Kay, 2011a; Kay, 2011b Kay, 2014). These tools have been also used to investigate teachers' perceptions of learning objects used in the classroom (Kay, Knaack, & Petrarca, 2009), and to analyse learning, quality, and engagement of learning objects from students' perspectives (Kay & Knaack, 2009). The main advantage of these studies is that large numbers of students and teachers participated in evaluations of learning objects and used them in classroom contexts. This confirmed the validity of this research, and the effectiveness of the LOEM criteria for evaluation of learning objects and the instruments used for the data gathering.

### 2.3.1.5. Learning Object Attribute Metric (LOAM)

The on-going debate on the reusability of learning objects has been addressed in many research articles. The discussion moves between reusing small and stand-alone "chunks" of contents (Downes, 2001; Polsani, 2006; Sanz-Rodriguez et al., 2011; Sicilia, 2004) towards reusing pedagogical practices (Koper, 2003; Krauss & Ally, 2005; Laurillard & McAndrew, 2003; McAndrew, Weller, & Barret-Baxendale, 2006). The authors of the LOAM study argue that such pedagogical practices are rarely explicit in learning objects; being normally shared in the academic community by using other educational formats (Windle et al., 2007).

The development of LOAM is a collaborative initiative carried out by the University of Nottingham and the University of Cambridge as part of the project "Sharing the LOAD: Learning Objectives, Activities and Designs" funded by JISC (JISC 2006, as cited in Windle et al., 2007). The authors studied the IMS Learning Design Level A[28] specification, which aims to implement pedagogical strategies at the level of class or courses. Level A contains three broad areas to define these strategies: the *environment* in which learning takes place, the *roles* of the students and the tutor, and the *activities* to perform (Windle et al., 2007). The authors analysed these categories and adapted them to the level of learning object. They identified twelve design attributes that potentially impact upon a learning object's pedagogical reusability: *Objective, Integration, Multimedia Richness* and *Context* (extracted from the *environment* category in IMS LD), *Pre-requisites, Support, Feedback* and *Self-Direction* (from the *roles* category), and *Interactivity, Navigation, Assessment* and *Alignment* (from the *activities* category).

[28] http://www.imsglobal.org/learningdesign/ldv1p0/imsld_infov1p0.html

A valuable contribution of this study is the application of Pattern Language techniques (Alexandre, 1977, as cited in Windle et al., 2007). These were used to identify potential conflicts in the design of learning objects at the level of each attribute and recommendations to approach them, and to define comprehensive scoring criteria for each attribute. Scores defined ranged between 1 to 5 and each score is mapped to a specific design approach for an attribute. None of the other studies reviewed in this investigation offers this kind of detail in the instruments used.

The authors validated the evaluation tool in a qualitative and informal manner, i.e. receiving feedback and comments from users with pedagogical expertise and a wide range of stakeholders: developers, teachers, students, and external project evaluators. According to the authors, these were used to redefine the tool; however, quantitative results extracted from analysis of feedback are not reported.

Using LOAM, 101 learning objects, located in two project repositories, were evaluated. The statistical analysis performed and the Spearman's correlations showed the dependencies between these attributes and their influence on design decisions. This study provides clear instructional design guidelines for teachers and developers: an explanation of each attribute, the potential issues for design, and recommendations to approach such issues. Likewise, the evaluation criteria are specific and leave little room for evaluators' subjective opinions. Nonetheless, this initiative also presents the following drawbacks:

- The results obtained, and recommendations for design, are highly tied to the authors' own understanding of each attribute and the meaning given to each score in the scale 1 to 5.
- The authors do not provide the rationale process performed to map the IMS LD Level A categories (i.e. environment, roles and activities) to the level of a learning object.

According to the authors, the learning objects evaluated were originally developed following an agile methodology for developing learning objects proposed by Boyle (Boyle et al., 2006). However, it does not associate development aspects with the pedagogical design attributes defined in their evaluation. LOAM tool is currently available at the website of the University of Nottingham School of Nursing Educational Technology Group (SONET, 2014).

### 2.3.1.6. HEODAR: Reusable Learning Objects Assessment Tool

HEODAR is a tool for evaluating the quality of learning objects considering both educational and technical perspectives. The development of criteria is based on the authors' review of several evaluation assessments and the LORI instrument described above.

To address the evaluation of educational characteristics of learning objects, the authors observe the contents' capability to foster learning and that are related to the curriculum. In this way two dimensions are evaluated:

- *Psycho-pedagogical*, which comprehends design aspects associated with students' characteristics and psychological aspects that influence the learning process. It includes the sub-dimensions of *Motivation and Attention, Professional Competency, Level of Difficulty, Interactivity* and *Creativity*.
- *Teaching*, which evaluates aspects associated with the logical significance of the learning object concerning the curriculum goals. The sub-dimensions established include *Context, Objectives, Learning Time, Contents, Activities* and *Feedback*.

The technical quality of learning objects is observed from the principles dictated by software usability (e.g. Nielsen & Molich, 1990) that were applied to evaluate the design of the interface and navigation of learning objects:

- *Interface design*, which allows the evaluation of the usability of the interface of the learning objects' contents and includes the sub-dimensions *Text, Images, Animations, Multimedia, Audio* and *Video*.
- *Navigation design*, which evaluates aspects associated with the organization of contents within the learning object. It includes the sub-dimensions *Home Page* and *Navigation.*

The ultimate purpose of HEODAR is to help the process of managing learning objects in a learning management system (LMS). For this reason, it is a tool designed to be integrated into these systems and extend their functionality.

According to the authors, HEODAR presents the potential to facilitate teachers in the evaluation of learning objects existing in a system by assigning a numeric value to the aspects associated with each sub-dimension. These values are unified and incorporated into the metadata record associated with the learning object. The final value represents the evaluation of learning objects associated with the number of teachers who evaluated it, which enriches the quality of the evaluation process itself (Morales et. al. 2009).

HEODAR is currently integrated with Moodle.[29] The tool has been tested in individual experiments and sample visualizations of evaluation results have been provided (Rincón Valadez, Martínez Lazcano, & Curiel Anaya, 2012).

Automatizing the evaluation process implies a great saving of time. One may ask, however, how this final value impacts upon the overall management of learning objects in the platform. I have not found results that help to answer this question. HEODAR does represent a comprehensive framework for teachers and instructional designers to evaluate learning objects, but the reliability and validity of the criteria dimensions have not been statistically investigated.

### 2.3.1.7 MECOA: Quality Evaluation Model for Learning Objects

This model is the result of a collaborative investigation between several Latin American and Spanish institutions with the purpose of developing methodologies and tools for assessing the quality of learning objects, supporting their construction and usage in Learning Object Management Systems (LOMS) (Eguigure & Zapata, 2011). MECOA is designed to evaluate the quality of learning objects from a pedagogical perspective, identifying evaluation criteria based on five dimensions:

- *Content*

A dimension composed of seven features associated with the contents of the learning object: *Information about objective, Typology, Mass media balance, Learning objective, Information quality, Timeliness of information* and *References.*

- *Representation*

A dimension composed of three features which relate to what the learning object and its elements represent: *Articulation components, Iconicity* and *Form.*

- *Competence*

A dimension composed of four criteria that relate to the pedagogical competence achieved with the learning object and how it has been achieved: *Level of achievement, Results, Cognitive process* and *Development of competence on pedagogical.*

- *Self-management*

A dimension that evaluates the capability of a learning object to arouse feelings of satisfaction in a learning object: *Security* and *Initiative.*

[29] https://moodle.org/?lang=en

- *Signification*

A dimension that evaluates aspects in the learning resource of how knowledge is organized and transferred and whether this is done in a way that is motivational for the student, progressive, or adapted to the student's needs: *Motivation, Recognizable conceptual structure, Generalization* and *Cognitive challenge.*

- *Creativity*

A dimension that evaluates aspects in the learning object's design that allows the learner to recognize his or her own interests and promote control over individuals' learning processes: *Self-knowledge* and *Choice among alternatives on solving problems.*

The MECOA evaluation instrument is implemented as part of AGORA (Help for Managing Reusable Learning Objects, in Spanish), a proposed management system whose ultimate purpose is to facilitate teachers in the construction and reuse of learning objects (Eguigure & Zapata, 2011). As with HEODAR, the reliability and validity of MECOA have not been statistically measured.

## 2.3.2. Pedagogical usability of educational software

In his proposal of an evaluation framework to assess the educational usability of learning systems and materials, Petri Nokelainen explains very clearly what is *pedagogical usability* (Nokelainen, 2006). This notion is founded upon the concepts of *usability* and *utility* defined by Nielsen and Molich (1990), one of the most referenced and well-known authors in the field of software engineering. Nielsen affirmed that both usability and utility are quality attributes that can be used to evaluate the overall usefulness of a software product. *Usability*, assesses "how easy user interfaces are to use", while *utility* refers to their functionality, i.e. "does it do what users need?"[30]

Applying these two concepts to learning systems and learning objects, Nokelainen considers pedagogical usability as a sub-concept of utility (see Figure 1), which can be defined as the capability of a system or materials contained in it to make it possible for students and teachers to achieve their goals (Nokelainen, 2006).

[30] http://www.nngroup.com/articles/usability-101-introduction-to-usability/

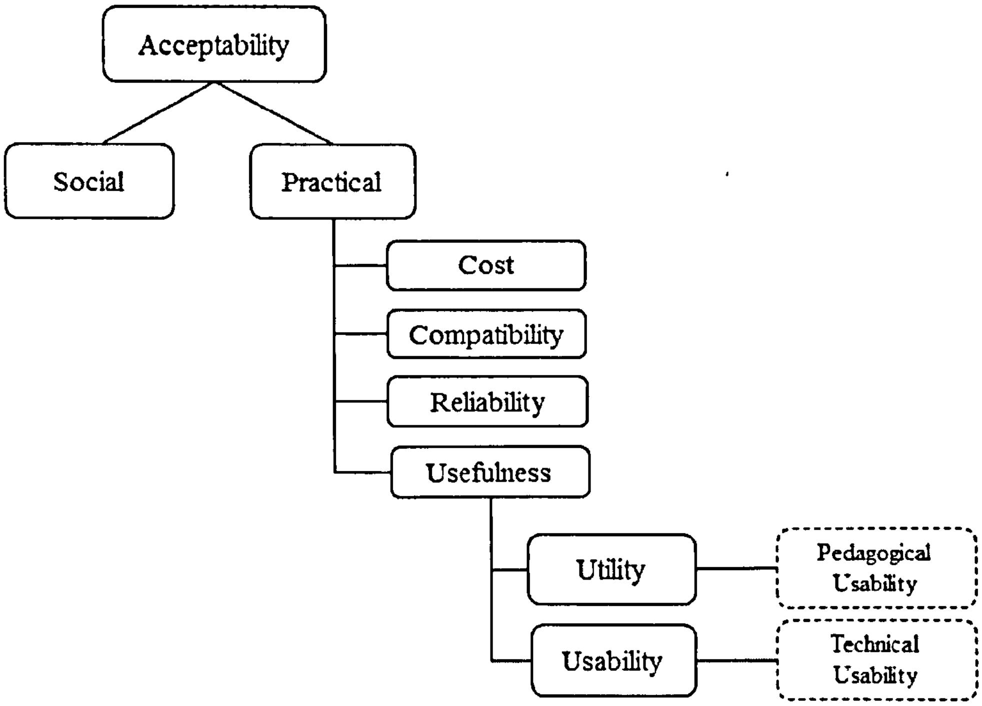



**Figure 1.** Conceptual Mapping of Usability
Adapted from Nielsen (1990, 198) by Nokelainen (extracted from Nokelainen 2006).

Other references in the literature point out that the *pedagogical usability* of e-learning systems and materials relies on two factors:

- their capability to support students' learning processes (Hadjerrouit, 2010; Melis, Weber, & Andrès, 2003; Nokelainen, 2006); and
- their capability to be adaptable and applicable to different educational situations in accordance with the selected learning objectives (Cooper et al., 2007; Silius et al., 2003).

Regardless of the perspective, evaluation frameworks for pedagogical usability of educational software are designed to consider the needs of the final user, and this is what makes criteria differ from reviewed evaluation frameworks.

Several authors have investigated, and proposed frameworks for pedagogical usability of learning systems and learning objects, however, in this context, Nokelainen's work stands out for several reasons:

- Nokelainen developed his criteria on the grounds of a review of existing well-known evaluation frameworks for usability of educational software (e.g. Reeves, 1994; Quinn, 1996; Albion, 1999; Squire & Preece 1996, 1999), identifying the lack of consideration of the cultural background of the student as an important factor for usability;

- In addition to this review, Nokelainen developed his criteria on the grounds of the learning theories of behaviourism, cognitivism, constructivism, and principles of instruction;
- The criteria dimensions are developed to assess both the technical and pedagogical usability of learning environments as well as the pedagogical usability of learning objects delivered;
- The criteria were tested with real users and validated in two different and consecutive cycles that allowed for modifications in the evaluation tools. The results of these evaluations confirmed all aspects (56 dimensions) defined in the criteria.

Some proposals of evaluation frameworks to assess the pedagogical usability of educational software have been based on Nokelainen's work (e.g. García-Quismondo et al., 2008; Hadjerrouit, 2010; Ogunbase 2014). More recent frameworks incorporate affective states that impact upon learning and upon students' perceptions of usability of the software (e.g. Hadjerrouit, 2012; Pinto & Gomez, 2011; Zaharias, 2009).

Nokelainen proposes to evaluate the pedagogical usability of learning objects using ten broad dimensions. These dimensions refer to design aspects where the differences among learners and their individual learning needs, interests, and styles should be considered. The dimensions are listed as follows (Nokelainen, 2006): *Learner Control, Learning Activity, Cooperative and Collaborative Learning, Goal Orientation, Applicability, Added Value, Motivation, Valuation of Previous Knowledge, Flexibility* and *Feedback*.

With the exception of Hadjerrouit research (Hadjerrouit, 2012), pedagogical usability evaluations do not incorporate the analysis of students' behaviour in their methodologies. This prevents obtaining empirical data that would inform whether the learning object helped teachers and students to achieve their goals (Nokelainen, 2006).

## 2.3.3. Discussion and Implications of Previous Studies

The studies reviewed in Section 2.3.1 constitute a small but representative set of the methodologies and instruments of the evaluation initiatives of learning objects. This section highlights the implications arising from these frameworks that impact upon the methodology required to answer the research questions considered by this thesis.

The first main aspect that stands out in these studies is the approach taken for the evaluation methodology. The factors that characterize these methodologies might offer a broad field of discussion due to their influence on how these methodologies are useful to inform the design of learning objects. These factors are identified and described as follows:

1. The stage of the learning object's life cycle where evaluation takes place is a significant differentiating aspect. The methodologies reviewed can be classified as formative or summative, depending on whether the evaluation of learning objects took place during their development or usage phase (formative) or afterwards (summative). Parallel to being formative or summative, these methodologies might also include the development of learning objects.

Only three of the studies reviewed – Cochrane, Krauss and Ally, and Kay and Knaack – performed evaluation processes during the development of learning objects. These authors, regardless of their research purposes, offer valuable conclusions intended to support the instructional design of learning objects. In contrast, other studies, like, for example, Haughey and Muirhead or Krauss and Ally, offer valuable information on the actual use of learning objects within their instructional context, exposing the conflicts and issues that emerge and designers and teachers might consider during design. Contributions from development experiences as well as the context of use can help to inform the design of learning objects. Nonetheless, it is difficult to find studies that include and describe both of them in detail, except Kay and Knaack's research (2.3.1.4).

As a consequence, methodologies that include development of learning objects and their formative evaluation seem to be more effective in informing pedagogical aspects of design. Since each stage of the development is enriched with the feedback received from the previous stage, design aspects that impact upon teaching and learning can be foreseen and improved during the development of the resource. At the same time, teachers become involved in the construction process of a single resource. This impacts upon the design of the instructional context (i.e. the lesson) which forms part of the teaching strategy.

2. The amount and variety of participants in the evaluation learning objects is an important factor. These participants might include a wide range instructional designers, practitioners with pedagogical expertise, teachers, and students.

Of these studies, only LOAM (subsection 2.3.1.5) included all these categories of participants. LORI (2.3.1.1), MERLOT and CLOE (2.3.1.2), LOEI (2.3.1.3), HEODAR (2.3.1.6) and MECOA (2.3.1.7) mainly included teachers and experts in the field and in pedagogy. Krauss and Ally (2.3.1.1), Cochrane (2.3.1.2) and LOEM (2.3.1.4) respectively also included a small number of students. Curiously, the studies incorporating students in the evaluation extract meaningful evaluations of the design of the target learning objects and can make recommendations to support a pedagogically effective design. This suggests that students' role in the evaluation of learning objects is vital to inform pedagogical aspects of design. Teachers' role is also crucial since the construction of a single learning object involves thinking of the pedagogical design of the target instructional context (i.e. the lesson) and the overall teaching strategy.

The number of participants is also critical since, from a statistical point of view, the bigger the sample of individuals testing an evaluation instrument, the better it is to obtain credible evidence of reliability and validity on both the instrument and the criteria.

3. The number and variety of disciplines of the learning objects evaluated is another important factor that influences the validity and applicability of evaluation criteria to different subjects. In this sense, Kay and Knaack's methodology (2.3.1.4) during the evolution of their research gives rise to the study with reported results obtained from the largest amounts of learning objects and numbers of participants in evaluations performed.

4. The common fact that characterizes these studies is the lack of behavioural data in these methodologies. Empirical results provided are all based upon users' scores on learning objects' design criteria. Whereas this is an appropriate method for gathering users' perceptions of the learning object, it leaves much room for user's subjectivity (Krauss & Ally, 2005), without behavioural data to inform the design of a learning object.

The second main aspect that contributes directly to this investigation is the set of criteria defined in these frameworks and the corresponding evaluation instruments. Most authors argue that their respective evaluation criteria have been constructed on the grounds of learning theories, principles of instruction, standard specifications, and best practices shared across the global academic community, however, it the general lack of proper definitions of the design attributes evaluated is surprising. The only exception in the studies reviewed is LOAM (2.3.1.5). LOAM has been of great assistance when investigating pedagogical attributes of learning objects due to the following:

1. It has been specifically developed to assess and support the pedagogical design of learning objects.

The higher level elements of a learning design – i.e. IMS Learning Design – were adapted to the level of learning objects on the grounds of the pedagogical experience of tutors and researchers, rather than in the technological aspects of the specification, pre-established instructional design principles, or learning theories. This "ground-up" focus on the teacher adds unique value to LOAM since teachers import aspects of the learning design from their successful applications in other learning contexts, like, for example, face-to-face workshops and classrooms. Through their participation on the development and evaluation of these criteria, it has been possible to express and analyse the pedagogical or didactic aspects that emerge in a learning design. Such aspects were adapted to the level of a learning object.

2. Each pedagogical design attribute is well defined and addresses arising conflicts.

LOAM proposes a core set of pedagogical attributes (analysed individually in Section 7 of this chapter) whose definition is focused on an aspect of a learning object, providing the designer or teacher with a comprehensive rationale of design conflicts and recommended ways to approach them. Although the purpose of this criteria and rationale is to promote the reusability of pedagogical practices among teachers, it is the only framework that provides such support oriented to inform the pedagogical design of learning objects.

3. Meaningful evaluation scores.

Each attribute is scored on a Likert scale from 1 to 5. Each value in the scale is assigned a meaning comprehensive enough for evaluators to assess learning objects with a common understanding of the attribute and the score, which leaves little room for subjectivity during design evaluation.

4. Relationships between design aspects.

LOAM the only study that provides statistical correlations between pedagogical attributes and defines and translates such correlations into what they imply when making decisions about the design approach to each aspect involved in the relationship.

The main benefit of reviewing these initiatives is to reveal the wide spectrum of aspects that are associated with the pedagogical design of learning objects. Constructing and visualizing this spectrum is necessary to identify those aspects that can be considered as pedagogical or didactic. The following section offers a classification of attributes evaluated according to different dimensions identified in the studies enumerated in Table 2. LOAM pedagogical design attributes have been used as guidance to confirm their existence in other criteria.

## 2.4. Design Dimensions of Learning Objects

There are similarities and differences between criteria dimensions that classify the properties of learning objects according to each of the evaluation frameworks (see Sections 2.3.1 and 2.3.2) and concerning the amount and definition of properties covered in each dimension. Despite a general lack of detailed definitions of design dimensions and properties in the literature, it is possible at least to identify the characteristics most frequently evaluated in previous initiatives.

A set of typological categories has been defined according to the review of the evaluation frameworks:

I. Contents: refers to all attributes related to the characteristics that value the quality of the information provided in a learning resource.

The aspects addressed include the quality of the information (such as accuracy, veracity, and clarity) and its educational impact (level of difficulty, a balanced presentation of ideas, its relevance concerning the subject or the learning objectives, etc.)

II. Design: refers to those attributes that evaluate the user interface of a learning resource.

The aspects include the interface's aesthetic and the layout of its elements; the mechanisms offered to navigate through contents; accessibility for users with disabilities or mobile devices; capability to be reused in other learning contexts (i.e. other courses, learning units, systems or learners), and the extent to which the resource can be customized according to individual teaching needs.

III. Learning-Teaching: refers to the strictly pedagogical attributes of a learning resource.

These attributes help to evaluate those aspects of a learning object that impact upon the learning process and, therefore, help a practitioner to consider the usage of such object as part of his or her teaching strategy.

The aspects of design evaluated include: the alignment of the learning object's contents and activities with regard to learning goals (objective / alignment); the level of control and independence awarded to learners concerning their own learning of a topic (learner control / autonomy); the manner in which knowledge is transmitted or integrated within the resource (organization / integration) and its connection to prior and future learning (pre-requisite / core knowledge); the level of support (support) and mechanisms (e.g. multimedia, scaffolding, etc.) provided by the resource to improve learning achievements.

IV. Usability: refers to those characteristics that make a learning object more functional and practical for learning.

It covers general aspects such as the ease of use, the predictability of what the interface's elements mean or do, or additional features that might facilitate and assist learning with the object.

V. Technical: attributes contained in this category evaluate those properties of a resource related to its level of interoperability with other learning tools (platforms, repositories, authoring), its capability to be used effectively without any tool or the need of additional software plugins for its functionality.

These definitions have been further analysed to extract specifically named attributes, summarized in Tables 3.1, 3.2 and 3.3, and grouped according to the main categories. These will form the basis for producing an empirical evaluation that is required to address the research questions. For the purposes of Tables 3.1–3.3 below, the studies examined have been allocated numbers as follows:

**Table 2.** *Bibliographical References for Evaluation Frameworks*

| | Evaluation Framework | Main Bibliographic Reference |
|---|---|---|
| 1 | Pedagogically Sound basis for Learning Objects reuse | Boyle & Cook, 2001 |
| 2 | LORI 1.3 | Vargo, Nesbit, Belfer & Archambault (2003) |
| 3 | LORI 1.5 | Nesbit, Belfer & Leacock (2007) |
| 4 | CLOE | extracted from Haughey & Muirhead (2005) |
| 5 | LOEI | Haughey & Muirhead (2005) |
| 6 | MERLOT (adapted evaluation instrument) | Cochrane (2005) |
| 7 | LORI (adapted evaluation instrument) | Krauss & Ally (2005) |
| 8 | Learning Object Evaluation Criteria | Del Moral & Cernea (2005) |
| 9 | LOEM | Kay & Knaack (2005), Kay & Knaack (2008) |
| 10 | UMES Online Course Learning Object Evaluation Rubric | Buzzetto-More & Pinhey (2006) |
| 11 | Pedagogical usability criteria for digital learning materials | Nokelainen (2006) |
| 12 | LOAM | Windle, Wharrad, Leeder & Morales (2008) |
| 13 | MIMETA | García-Quismondo, Prado & Osti (2006) |
| 14 | HEODAR | Morales, Gómez & García (2008) |
| 15 | Pedagogically-Oriented Evaluation Criteria for Educational Web Resources | Sofos & Kostas (2009) |
| 16 | Conceptual framework for the evaluation of web-based learning resources | Hadjerrouit (2010) |
| 17 | MECOA | Eguigure, Zapata,Menendez & Prieto (2011) |
| 18 | Evaluation criteria for Learning Objects | Turel & Gurol, 2011 |

**Table 3.1.** *Classification of Attributes for Evaluation of Learning Objects: Dimensions: Content and Design*

| Dimensions | Study number | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| **Contents** | | | | | | | | | | | | | | | | | | |
| Educational significance | | √ | | | | | | √ | | | | | | | | | | |
| Relevance | | √ | | | | | | | | | | | | | √ | | | |
| Accuracy | | √ | √ | √ | √ | √ | √ | √ | √ | | | | √ | √ | √ | | √ | |
| Level of detail | | √ | √ | | | | √ | √ | | | | | √ | √ | √ | | | |
| Veracity | | √ | √ | | | | √ | | | | | | | √ | √ | | | |
| Balance | | | √ | | | | √ | | | | | | | √ | | | | |
| Difficulty | | | | | | | | √ | √ | | | | | | | | | √ |
| Clarity/Understandability | | | | √ | | √ | | √ | | | | | | | | √ | | |
| References | | | | √ | | | | √ | | | | | | | | | √ | |
| **Design** | | | | | | | | | | | | | | | | | | |
| Aesthetics | | √ | | | | √ | | √ | | √ | | | √ | √ | √ | | √ | |
| Multimedia quality | | | | | | √ | | √ | | | | √ | | √ | √ | | | |
| Accessibility | | | | | | | | | | | | | | | | | | |
| Navigation | | | | | | | | √ | | √ | | √ | √ | √ | | | | |
| Accessibility | | √ | √ | √ | √ | | | √ | | | | | √ | | | | | |
| Reusability (context) | | √ | √ | | √ | | √ | √ | | √ | | | | | | | | |
| Reusability (learners) | | | √ | | | | | | | | | | | | | | | |
| Customization | | | | | | √ | | √ | | | | | | √ | | | | |
| Layout | | | | | | | | | | | | | | √ | √ | | | |

**Table 3.2.** *Classification of Attributes for Evaluation of Learning Objects: Dimension: Learning and Teaching*

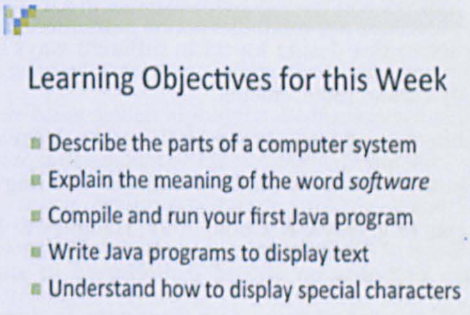
| Dimensions | Study number | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| **Learning and Teaching** | | | | | | | | | | | | | | | | | | |
| Objective/ Alignment | √ | √ | √ | √ | √ | √ | √ | √ | | √ | √ | √ | √ | | √ | √ | √ | |
| Organization/ Integration | | √ | | | √ | √ | √ | √ | | √ | √ | √ | √ | | | √ | √ | |
| Subject context | √ | | | | | √ | | | | | | √ | | | | | | |
| Pre-requisite / Core knowledge | | | | √ | √ | √ | | √ | √ | √ | √ | √ | | | | √ | | |
| Support | √ | | | | | | | | | √ | | √ | | | | | √ | √ |
| Feedback | √ | √ | √ | √ | √ | √ | √ | √ | | √ | √ | √ | | √ | | | | |
| Learner control/Autonomy | | | | | | | | | √ | | √ | √ | | √ | | √ | √ | √ |
| Interactivity | | | | | | | √ | √ | √ | √ | √ | √ | √ | √ | | √ | | √ |
| Assessment | √ | | | | | √ | | √ | √ | √ | √ | √ | | | | | √ | √ |
| Motivation | | √ | √ | | | | √ | √ | √ | | √ | | | | | √ | √ | √ |
| Engagement | | √ | √ | √ | √ | √ | √ | √ | | | | | √ | √ | √ | | | √ |
| Scaffold (media) | √ | √ | √ | | √ | √ | | | | | √ | | | | | | | √ |
| Enhancement (media) | | √ | √ | √ | √ | | √ | √ | | | | | | | | | | |
| Flexibility /Adaptability | | √ | √ | | | | √ | √ | | | √ | | √ | | | √ | | |
| Efficiency | | | | | | √ | | | | | | | | | | | | |
| Constructive/Collaborative learning | | √ | √ | | | | | | | | √ | | √ | √ | √ | √ | | √ |
| Multimedia | | | | | | | | | √ | | | √ | √ | √ | √ | √ | √ | √ |
| Retention | | | | | | | | | | | | | | | | | | √ |

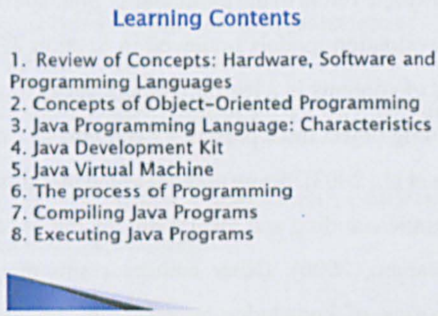
**Table 3.3.** *Classification of Attributes for Evaluation of Learning Objects: Dimensions: Usability, Technical and Other Attributes*

| Dimensions | Study number | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| **Usability** | | | | | | | | | | | | | | | | | | |
| Ease of use | | | | √ | √ | √ | | | | | | | √ | √ | | | | |
| Ease of navigation | | √ | √ | √ | √ | | √ | | | | | | √ | | √ | | √ | |
| Predictability of the user interface | | √ | √ | | | | √ | √ | | | | | | | | | | |
| Help features | | √ | √ | | √ | | √ | √ | √ | | | | | | √ | | | |
| Target learners | | √ | | √ | √ | √ | | | | | | | | | √ | | | |
| Contextual assistance | | | | | √ | | √ | | √ | | | | √ | | | | | |
| Clear instructions | | | | √ | √ | √ | √ | | √ | | | | √ | √ | | | √ | |
| **Technical** | | | | | | | | | | | | | | | | | | |
| Standards compliance | | √ | √ | | | | | | | | | | | | | | | |
| Metadata | | | | | | | | √ | | | | | | | | | | |
| Content packaging | | | | | | | | √ | | | | | | | | | | |
| Keywords | | | | | | | | | | | | | | | | | | |
| Ontologies classification | | | | | | | | √ | | | | | | | | | | |
| Requirements | | | | √ | | | | | | | | | √ | | √ | | | √ |
| Stand-alone | | | | √ | √ | | | | | | | √ | | | | | | |
| **Other values** | | | | | | | | | | | | | | | | | | |
| Cultural sensitivity | | | | | √ | | | | | | | | | | | | | |
| Credit to creators | | | | √ | | | | | | | | √ | | | √ | | | |

Explicative example for the attribute *Objective*:

Different understandings about this attribute give rise to different approaches in design. In this research, the attribute *Objective* is defined as what a student should be able to know or demonstrate after working with a learning resource. Accordingly the design of a learning resource is directly related to the manner in which learning objectives are written. The examples showed in Figure 2 below belong to two different slide presentations. These are a common type of e-learning resource, here used to teach first-year Programming subjects at Kingston University and AUCh respectively.




(Example 1) (Example 2)

**Figure 2.** Comparative Examples of the Pedagogical Attribute *Objective* in the Design of a Slide Presentation Learning Resource

According to the understanding of the attribute *Objective*, the examples above help to identify good and bad design practices concerning this attribute:

- The resource should inform the student of the intended learning outcome (as in Example 1) instead of enumerating the concepts that are explained in it (as in Example 2).
- It is good practice for a resource to focus on a single learning objective and cover it completely or as much as possible, instead of focusing on several learning objectives. Instead, both slide presentations in the figure above present contents that cover a set of learning objectives defined for the whole lesson. A large amount of new terms or new information usually overloads learners' working memory, and it also reduces the possibility of this slide presentation being reused in another programming module or lesson.

A different scenario for the design of this attribute occurs when a set of learning objectives need to be covered by the same resource or when they are related to the same concept. In this case, it would be good that the resource expresses this relationship explicitly and make the potential user aware of it.

## 2.5.2. Integration

This attribute refers to the particular organization of contents and activity items existing in a learning object. Authors of evaluation models reviewed in Section 2.3 describe this design aspect in different ways so that the organization of contents in a learning object needs to satisfy certain requirements.

A learning object must present its contents in a meaningful and logical manner (Buzzetto-More & Pinhey, 2006; Vargo et al., 2003). Some authors argue that this organization should scaffold students' learning and allow an efficient understanding and mental processing of concepts (e.g. Boyle & Cook, 2001; Haughey & Muirhead, 2005; Nokelainen, 2006). Other authors claim that such organization should demonstrate to students the conceptualization of knowledge by providing hierarchical conceptual maps (e.g. Eguigure & Zapata, 2011; García-Quismondo et al., 2008; Haughey & Muirhead, 2005), progressively reinforce concepts (e.g. Cochrane, 2005; Kay & Knaack, 2005) and demonstrate relationships among them (e.g. Cochrane, 2005; García-Quismondo et al., 2008; Krauss & Ally, 2005). Del Moral and Cernea propose that such organization is based on five elements: an overview, theoretical explanation of topics, activities, a summary and assessment (Del Moral & Cernea, 2005). This structure is reminiscent of a learning unit structure; articulating the learning object's components in this way might be useful to integrate the learning object into a learning unit (Morales Morgado, Gómez Aguilar, García Peñalvo, & Therón Sánchez. 2009).

The organization of different types of contents within a learning object is associated with the integration of media elements (e.g. videos, audio, animations, simulations, etc.). This is based on existing evidence on the positive impact of multimedia on learning (see attribute *Multimedia Richness* below). In this way, a balanced, seamless, and appropriate **integration** of these elements within the object implies that the overall learning value of "the whole is greater than the sum of its parts" (Windle et al., 2007). LOAM recommends organizing contents in such a way that the learning object's "form follows function" (Windle et al., 2007). In this sense, the HEODAR criteria suggest that a learning object should demonstrate through the organization of its contents one or several learning strategies depending on its learning purpose (problem-solving, case studies, etc.) (Morales Morgado et al., 2009).

Teachers not habituated to integrating different types of information in the same learning material might tend to separate textual theoretical explanations from audio-visual materials that show practical application of the concepts, simulations and activities for practice and assessment, etc. Different materials complement each other within the learning unit to facilitate the achievement of learning objectives. It is usual for the instructor to communicate to students how these materials are organized, the sequence of access, and with what purpose, whereas students typically follow instructions. Nokelainen's empirical research on pedagogical usability argues that the organization of learning resources must be flexible and consider learners' individual differences, reward the student with the freedom to navigate freely through learning materials, identify appropriate learning resources, and even participate in the integration between them (Nokelainen, 2006). This seems to be consistent with three of Hadjerrouit's criteria (Hadjerrouit, 2010):

- *Differentiation,* which highlights the need to develop learning objects whose organization of contents can be adapted according to differences between students;
- *Autonomy,* which highlights the importance of providing the knowledge in such a way that the student is more independent of the teacher's instruction; and
- *Variation,* which recognizes students' capabilities to work with a combination of different learning resources adapted to their learning styles, needs, and ways of learning.

Explicative example for the attribute *Integration*:

*Integration* is defined in this research as the manner in which different types of contents are integrated into the learning resource so that the overall form aligns with its function within the whole learning design, and scaffolds and enhances learning.

The strategy adopted to integrate different contents (i.e. theory, examples, or activities) is usually chosen by the lecturer who transmits knowledge in accordance with his or her own understanding of the topic (Haughey & Muirhead, 2005). For instance, an inductive strategy to organize knowledge introduces explanations that require students to reflect on and comprehend the scenario. In contrast, a deductive strategy presents a problem-solving scenario that encourages the student to learn from the practice and deduce or conclude the theory. These two approaches are related to the manner in which individuals tend to learn and, whereas induction corresponds to the natural way to teach, deduction corresponds to the natural human way to learn (Felder & Silverman, 1988).

## 2.5.3. Context

This attribute refers to the instructional context in which the learning object is going to be used. It is defined as "the degree of contextualization of materials or how specific to a discrete group of learners" (LOAM Tool Attribute Scoring Criteria, p.2). Examined criteria refer to one or both of these aspects, however, the aspect evaluated is the learning object's potential for reusability.

The aspects evaluated with the LORI vary depending on the version: LORI 1.3 (Vargo et al., 2003) assesses the potential of the learning object to be transported between different courses without requiring any modification (Krauss & Ally, 2005). The last version, LORI 1.5, focuses on evaluating the potential of the learning object to be "used in varying learning contexts with learners from different backgrounds" (Leacock & Nesbit, 2007, p.45).

Cochrane evaluates whether the object can be reused in different courses due to several content characteristics such as the demonstration of a core concept, the contents are clear, concise, accurate, and well summarized, and relevancy to a specific course. He concludes that although these characteristics in design are relevant for reusability, the role of the educator to embed a learning object in a bigger learning context is crucial (Cochrane, 2005).

The other aspect evaluated by *Context* is that the learning object's design allows it to be used by a broad range of learners (Buzzetto-More & Pinhey, 2006; Leacock & Nesbit, 2007; Windle et al., 2007). It requires consideration of students' learning needs, levels, cognitive variety (Leacock & Nesbit, 2007), and learning pace (García-Quismondo et al., 2008). At least, it is important that the learning object includes information about the target group of learners for which it is intended (e.g. their academic level, age or background) (CLOE, as cited in Haughey & Muirhead (2005)), and possibly in its associated metadata record.

Leacock and Nesbit (2007) argue that a learning object can be effective for a broad range of learners but recognize that no single learning object is effective for all learners in all contexts. None of the evaluation instruments can affirm or predict such a thing. In order to inform the instructional context in this aspect, it is necessary to analyse students' behavioural data (Kay & Knaack, 2008; Nokelainen, 2006). Students' characteristics are crucial information in instructional design, especially in learner-centred design approaches (Zaharias, 2006). Therefore, students' characteristics constitute another factor determining the context where a learning object is used: their learning needs, their backgrounds, the behaviour in different scenarios that comprise the teaching strategy, their learning styles, their behaviour within the learning environment, and the materials, activities and assessments delivered.

Reusability at the level of learning contents was achieved to a certain extent thanks to standards (Boyle, 2003), however, achieving reusability at the level of instructional context, that is, learning scenarios and learners, is still a major challenge in the area of learning objects. The aspects considered by different authors lead one to think that the challenge is due to the diversity of learning scenarios and learners, two factors that occur simultaneously.

This research agrees that learning objects do not have a value or utility outside instructional contexts (Cochrane, 2005; Haughey & Muirhead, 2005; Krauss & Ally, 2005) as this value lies in their application to classroom settings or learning environments where the teacher might not be present (Haughey & Muirhead, 2005). Achieving reusability implies that the design of a learning object has to be flexible enough for it to be combined with other resources in the instructional context (Del Moral & Cernea, 2005; Haughey & Muirhead, 2005; Windle et al., 2007). Examining the instructional context is crucial for design since it determines the learning object's size (a property commonly referred to as its *granularity*) and its combination with others (Polsani, 2006; Sicilia, 2003; Wiley, Gibbons, & Recker, 2000; Wiley & Waters, 2005). The debate around the combination and granularity of learning objects to be reusable continues and currently no consensus has been reached. The general recommendation is to design learning objects as small "chunks" of content, as disaggregated from each other as possible, to facilitate their repurposing, however, this creates a tension with the instructional context of use which is also influenced by the instructor's teaching style (Haughey & Muirhead, 2005).

During the design process of a learning object, it is not possible to predict the variety of learning scenarios that will use it. Therefore, reusing a learning object might require modification of the scenario (i.e. the target instructional context) to allow the integration of the new element or modification of the design of the object. In either case, the human factor is required since modifying educational contexts or content chunks requires pedagogical expertise (Cochrane, 2005; Haughey & Muirhead, 2005; Wiley, 2007). In this situation, it has been proposed that reusability should be aimed at the level of pedagogical practices (Krauss & Ally, 2005) or learning designs (Windle et al., 2007) instead of learning objects.

Explicative example for the attribute *Context*:

In this research, *Context* is defined as the degree of contextualization of the resource concerning the learning unit topic or how specific it is to learners' level of knowledge.

In the case of computer programming subjects, it is common to develop resources that refer to topics that are outside the context of the resource's learning unit. The following example illustrates the meaning of this attribute:

In the case studies presented in this thesis, the strategies to capture a user input in a Java program are one of the first lessons. In one of this strategies, the programming code requires the learner to use the class Scanner. In the case of the course INFO055, this is the concept of class and specific Java classes (like the Scanner class). In INFO023, these concepts are explained in a second-year course. Some concepts and elements of the programming code taught to students are out of context about both the learning unit and students' current knowledge. Figure 3 shows a resource that illustrates this example:

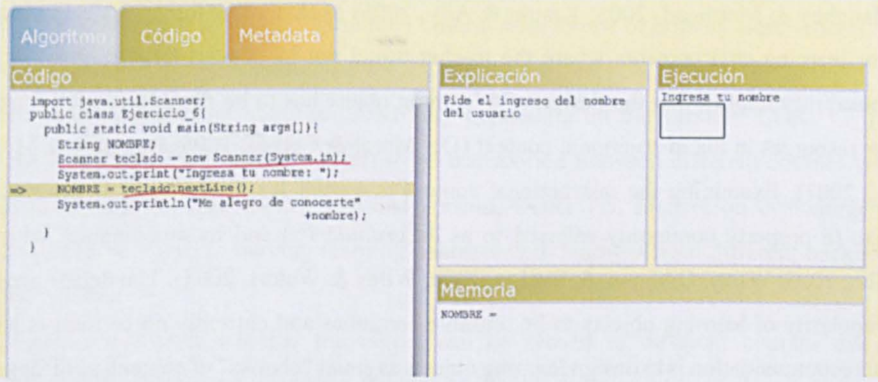



**Figure 3.** Example of Attribute *Context*

The Scanner object used in the code (named "*teclado*") or the Scanner class is not explained, nor referenced in any of the other tabs. The resource does not include references to other resources within the same lesson or in other lessons that explain the concept.

It would be ideal to design the resources in a learning unit in such a way that it is not necessary for students to deal with concepts that have not been explained at that point or in previous lessons. When this is not possible (e.g. the example above) an option is to enrich the context of the resource by including extra resources in the same lesson. It is like creating a "family" of small resources that the student can relate to each other. In this example, an additional resource was incorporated to explain the Scanner class and how it is used. This modification improves the attribute *Context* of the learning unit.

Another option is to extend the attribute *Context* of the resource by including explanations or references about the "missing" concepts (e.g. the class Scanner, the terms *class* and *object*). This kind of modification needs to be approached very carefully since it contradicts the rule of designing according to a single learning objective or concept. Nonetheless, it is common practice to incorporate new concepts when the aim is to use a learning resource to link different learning units, when it is intended to encourage advanced students to undertake more complex activities, to dig deeper into specific knowledge, or when the aim is to inform students about how to move forward with the knowledge acquired. In these scenarios, the design approach for the resource's context can be enriched directions to external content resources or activities, conceptual maps that help students to acquire a mental model of the knowledge, interactive help menus, etc.

## 2.5.4. Multimedia Richness

This attribute refers to the amount and appropriateness of multimedia elements embedded in the learning object for the purpose of facilitating learning. The usage of multimedia content (e.g. texts, diagrams, audio, video, and animations) in instructional design is based on the theory and principles of multimedia learning (Leacock & Nesbit, 2007). The main proposition is that "Multimedia messages designed in the light of how the human mind works are more likely to lead to a meaningful learning than those which are not" (Mayer, 2002).

Static media elements do not always allow the visualization of existing relationships between concepts (Krauss & Ally 2005). In this case, the development of interactive multimedia elements is needed to transmit a specific degree of knowledge, skill, or association of concepts. These usually require the development of interactive multimedia contents in learning objects (Cochrane, 2005; Krauss & Ally, 2005).

These features, especially interactive multimedia, make learning objects powerful tools to enhance traditional teaching methods in such subjects (Cochrane, 2005) and can present students with learning scenarios not easily replicated in face-to-face lectures (Haughey & Muirhead, 2005). Incorporating interactive multimedia elements in learning objects leads to a positive impact on students' learning processes, engagement, motivation, and fundamental affective states such as boredom or attention (Cochrane, 2005; Fetaji & Fetaji, 2007; Garcia-Quismondo et al., 2008; Graf, Liu, Chen, & Yang 2009; Haughey & Muirhead, 2005; Kay & Knaack, 2005, 2008, 2011; Krauss & Ally 2005; Windle et al., 2007; Zaharias, 2009).

Developing learning objects with interactive multimedia elements can be challenging. Firstly, the development is time-consuming and costly because, in the best-case scenarios, development teams require staff with specific technical knowledge (programmers, media designers), instructional designers, experts in pedagogy, teachers and students (Alharbi et al., 2011; Windle et al., 2007). It is a non trivial process that requires the time and joint efforts of these people (Gadanidis, Sedig, & Liang, 2004; Kanuka, 2006). Secondly, once it is published, it is very difficult to modify the resource for reuse as this requires more developers and appropriate software tools (Wiley, 2002).

As a result of including in the methodology the development process of interactive multimedia learning objects, Cochrane recommends choosing with great care the multimedia architecture for implementation, since it needs to meet specific requirements of the discipline or subject to be learnt. The platform used by Cochrane was QuickTime[31] (Apple Computers, 2004), characterized for providing programming tools that allow one to track students' interactions with elements in the interface. Although the development team did not use them to obtain these data, in the context of this investigation I believe that data extracted from these interactions constitutes an excellent monitoring of students' learning processes, which is valuable for design.

[31] http://www.apple.com/quicktime/what-is/

Explicative example for the attribute *Multimedia Richness*:

The attribute is defined as the extent to which the various media types (audio, video, graphics, images, etc.) embedded in the resource or the learning unit facilitate learning and the achievement of objectives. An example of multimedia elements that can be used for this purpose is shown in Figure 4 below.

In this example, the discipline of Audio-Engineering requires students to handle and master the usage of certain controls in electronic devices. The resource shown provides a simulation of such controls. It constitutes an excellent example of the design of an interactive resource that present a high level of multimedia richness.

**Figure 4**. Example of Attribute *Multimedia Richness*.
Source: Cochrane (2005).

In the case of learning programming concepts, a good example of a rich multimedia design was developed by London Metropolitan University and published in the Codewitz[32] material bank. This example was used to explain the concept of *array* in Java. The images below correspond to a resource: an animation and the sequence of verbal and visual information provided to the learner when interacting with the "Show" button.

[32] http://www.codewitz.com/demoobjects.php

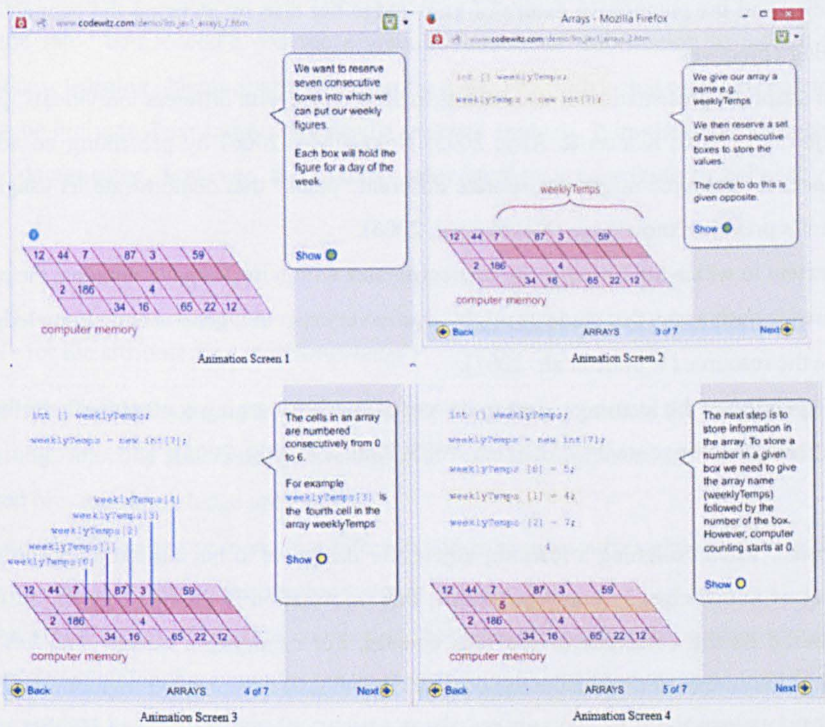



**Figure 5.** Example of Attribute *Multimedia Richness*. Sequence of screen in an Animation

## 2.5.5. Previous Knowledge

This attribute refers to the level of cognitive knowledge or skills that a student must already possess to understand new concepts presented in a learning object or to perform an activity (Windle et al., 2007).

The criteria reviewed evaluate this attribute by observing the following characteristics in a learning object:

- It provides a clear identification of important previous concepts or ideas (CLOE), observing the degree of detail with which pre-requisites are reviewed and explained within the resource (Buzzetto-More & Pinhey, 2006; Del Moral & Cernea, 2005; Kay & Knaack, 2005; Nokelainen, 2006). In this way, students are informed of what they need to know already to continue successfully with their learning and extend their knowledge.
- It presents pre-requisite knowledge in connection to previous and future learning (Eguigure & Zapata, 2011; Garcia-Quismondo et al., 2008; Haughey & Muirhead, 2005). This approach would provide students with a more meaningful scenario, not only by making them conscious of the relevance of earlier

concepts and the cumulative nature of knowledge but also by showing the connection existing among learning objectives.

- It can adapt the presentation of its contents in accordance with different individuals' previous knowledge (Hadjerrouit, 2010; Krauss & Ally, 2005; Nokelainen, 2006) by presenting an adaptive design. For instance, the resource might incorporate different "paths" that demonstrate its usage depending on the student's previous knowledge (Nokelainen, 2006).
- The extent to which the learning object incorporates within its design or contents the previous knowledge required in such a way that students might require very specific, general or no knowledge about the subject to use the resource (Windle et al., 2007).
- The capability of the learning object to be reused in other learning contexts without the need to make any modifications to its contents (Cochrane, 2005; Krauss & Ally, 2005).

It is usual, when designing a learning object, for designers to have information on the target learners' expected level of knowledge. In many occasions, this information is provided by the institution's academic programme based on the outcomes of previous courses. For example, a student who has passed the course "Programming I" is supposed to have the basic knowledge to start the course "Programming II". In this scenario, the design of the learning object may be based on the learning objectives aimed for that new course and the teaching style adopted. However, it is logical to expect a difference in the level of knowledge among students who passed with an "A" grade from those who passed with "C" or "D" grades. As a consequence, the same learning object would have a different impact on students' progress in the new course.

Learning objects should "respect" individual differences in previous knowledge which should be considered during the design process (Hadjerrouit, 2010; Nokelainen, 2006). An approach to identifying different levels of knowledge existing in a cohort is to perform a diagnostic test at the beginning of the course, so the teaching strategy and face-to-face sessions can be better adapted. In the investigation on evaluating the effectiveness of learning objects, this kind of test has been conducted as a pre-diagnostic mechanism whose results were contrasted with the results of a post-diagnostic test. In this way, it was possible to obtain insights into the resource's impact on academic performance.

Obtaining and incorporating this information during the course to produce better adapted learning objects is difficult or, in the case of interactive multimedia materials, unviable. Including a review of the important prior concepts required to understand the new ones could be an alternative that also diminishes individual differences in the level of knowledge but still be informative to the learner. Nokelainen proposes a design strategy whereby different paths might be incorporated into the learning object to "demonstrate the usage of the learning material depending on the previous knowledge of the learner" (Nokelainen, 2006, p. 185). In contrast, in this research it is argued that empirical research on students' behaviour with learning objects and activities conducted in different academic years in the same course could provide a valuable source of information to inform the *Previous Knowledge* design of new learning objects or improve existing ones. The truth is that each new cohort is different, and there will always be individual exceptions that need a separate analysis. It implies a slow process that needs to be systematically documented, however, the findings generated may contribute to enhance design on an empirical basis.

Explicative example for the attribute *Previous Knowledge*:

This attribute is defined as the extent to which a learner is required to possess the pre-requisite knowledge to achieve the learning objective successfully. Examples of how to incorporate in the design of a learning resource the required previous knowledge are:

- To include a separate section or menu that refers to contents or resources already seen in that lesson or in previous lessons, and refer to this section when it is necessary.
- To allow the visualization of existing connections between knowledge the student already possesses and new knowledge which, for example, can be done by incorporating conceptual maps in the resource.
- To show the student how to use this "previous knowledge" to achieve the learning objective desired. For example, Figure 6 shows a resource designed for novice students which explains the implementation of the code required to solve a problem.

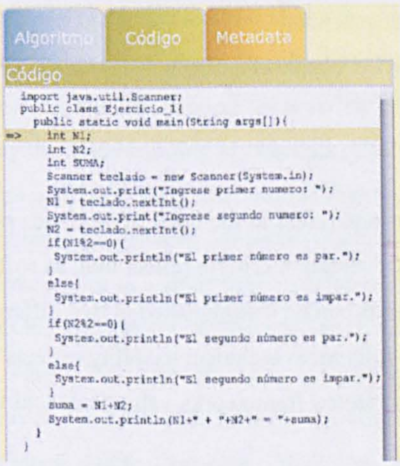



**Figure 6.** Example of Attribute *Previous Knowledge*

In Computer Science degrees, first-year students are introduced to programming languages and coding by learning to write pseudo-code and design flow charts; whereas the next step is learning to implement the actual code in a specific programming language. The attribute Previous Knowledge in the design of this resource is well approached since the initial tab "Algoritmo" shows students how pseudo-code and flow charts help to develop the required code (Figure 7).

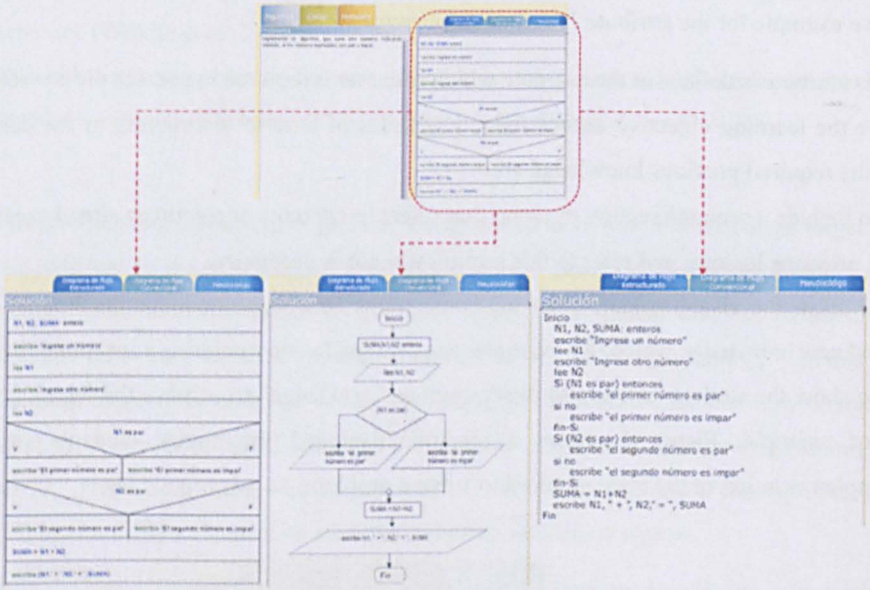



**Figure 7**. Example of Attribute *Previous Knowledge* with Unfolded Tabs

## 2.5.6. Support

Regarding design, this attribute refers to the level of guidance provided to the student within the learning object (Windle et al., 2007). The evaluation criteria reflect that, as software products of instructional design, the support provided in learning objects can be distinguished at two different levels: technical and pedagogical. The technical aspect of this attribute references technical usability aspects reviewed in Section 2.2.2 of this chapter. Authors of more pedagogically oriented frameworks value technical usability and assess the following aspects in each dimension:

- *Easy to learn*

  The learning object must provide clear instructions for its usage (Cochrane, 2005; CLOE; Haughey & Muirhead, 2005; Krauss & Ally, 2005; Leacock & Nesbit, 2007; Kay & Knaack, 2008; Eguigure &

Zapata, 2011) and it must present a consistent layout and structure across sections (Leacock & Nesbit, 2007; Garcia-Quismondo et al., 2008; Hadjerrouit, 2010).

- *Efficient*

  Associated aspects concern the ease of navigation through contents (Krauss & Ally, 2005; Leacock & Nesbit, 2007; Garcia-Quismondo et al., 2008; Kay & Knaack, 2008; Hadjerrouit, 2010; Eguigure & Zapata 2011) or the time of response to the learner's interactions or delay in loading web content (Leacock & Nesbit, 2007; García-Quismondo et al., 2008).

- *Error-supportive*

  In the context of educational software it is important that any error of the student is related to the learning goal and not to the resource's interface. Apart from providing a consistent and intuitive interface design, the learning object should provide help and instruction features that allow the learner to grasp the directions quickly and return to the content or activity (Haughey & Muirhead 2005; Krauss & Ally 2005; Leacock & Nesbit, 2007; Garcia-Quismondo et al., 2008). Ideally, such help and directions can be adapted to individual needs (Windle et al., 2007).

- *Accessible*

  Among the set of evaluation criteria reviewed in this research, this attribute is only specifically evaluated in Haughey and Muirhead's model (2005), LORI 1.5 (Leacock & Nesbit, 2007) and ALFIN (García-Quismondo et al., 2008).

Other characteristics are evaluated in the design of learning objects to provide another kind of support (which could be referred as *pedagogical support*) intended to aid both the teaching and learning processes.

Design features of learning resources that are considered to help the instructor in teaching are related to learning objectives and contents. These features include: support for a variety of learning objectives (Cochrane, 2005); increase and reinforce progressively the understanding of concepts (Cochrane, 2005; García-Quismondo et al., 2008); include a variety of assessment activities (Buzzetto-More & Pinhey, 2006; Cochrane, 2005; García-Quismondo et al., 2008); demonstrate relationships between concepts (Cochrane, 2005; Krauss & Ally, 2005); efficiency in the sense that a learner can learn a lot in a short time (Cochrane, 2005; García-Quismondo et al., 2008); include academic references (CLOE; Del Moral & Cernea, 2005; García-Quismondo et al., 2008; Haughey & Muirhead, 2005; Leacock & Nesbit, 2007); not requiring the instructor's intervention to be used in combination with other resources (Haughey & Muirhead, 2005); accurate, error-free, and balanced presentation of contents (CLOE; Buzzetto-More & Pinhey, 2006; Cochrane, 2005; Del Moral & Cernea, 2005; García-Quismondo et al., 2008; Haughey & Muirhead, 2005; Krauss & Ally, 2005; Leacock & Nesbit, 2007; Vargo et al., 2003); provide a suitable level of detail and difficulty in contents (García-Quismondo et al., 2008); and include contextual assistance (García-Quismondo et al., 2008; Haughey & Muirhead, 2005; Morales Morgado et al., 2009).

The design features mentioned above are also intended to support students' learning processes. However additional features in this aspect are also evaluated in the design of learning objects:

- Adaptability of contents to students' levels and learning needs (Del Moral & Cernea, 2005; Eguigure & Zapata, 2011; Krauss & Ally, 2005; Leacock & Nesbit, 2007; Vargo et al., 2003; Windle et al., 2007).

One of the main objectives in providing adaptive learning systems and learning objects is to reproduce the high levels of achievement that are obtained with one-to-one tutoring (Akbulut & Cardak, 2012; Brusilovsky, Karagiannidis, & Sampson, 2004). Adaptive mechanisms are implemented by making use of a wide variety of sources such as an individual's performance history, measures of aptitude, preferences or affective states (Leacock & Nesbit, 2007). The result is an adaptive learning design that varies in the number and format of explanatory contents, and the type, amount, and difficulty of exercises and assessments.

In turn, adaptive learning objects are rarely available for reuse outside the research for which they were developed (Leacock & Nesbit, 2007). The reason may be that achieving high levels of adaptability implies considering learning needs that are too specific and too dependent on the learning situation (Nokelainen, 2006; Zaharias 2006, 2009). The amount of literature demonstrates that much more research has been conducted on implementing adaptive learning systems than learning objects, which confirms that it seems easier to incorporate adaptive mechanisms to platforms than to learning materials.

Adaptability is also associated with the level of control provided to learners over their own learning processes. It refers to the existence of choices that enable the student to select the level of instructional support obtained or to select among different learning activities to satisfy diverse learning interests (e.g. self-knowledge, cognitive challenges) (Buzzetto-More & Pinhey, 2006; Eguigure & Zapata, 2011; Kay & Knaack, 2008; Leacock & Nesbit, 2007; Morales Morgado et al., 2009) (see attribute *Self-direction* below).

- Feedback

The feedback provided to the learner constitutes one of the main forms of supporting learning. It is considered by itself as a separate attribute that is explained in the next section.

- Usage of multimedia

As it was described in the attribute *Multimedia Richness*, multimedia elements in learning objects are considered important to support, improve, enhance, and motivate learning.

- Include different learning strategies (Eguigure & Zapata, 2011; García-Quismondo et al., 2008; Morales Morgado et al., 2009).

Depending on each learning scenario and the approach adopted in the teaching strategy, different learning strategies are proposed to students. Learning strategies are developed by behaviourist and constructivist instructional methods. A well-known example of behaviourist learning strategies is so-called "drill-and-practice" learning methods, which "account for the bulk of instructional software now in actual classroom use" (Koschmann, 1996, p. 7). In contrast, strategies like problem-solving learning (Jonassen, 2000), experiential learning (Kolb & Kolb, 2005), discovery learning (Shulman & Keisler, 1966, as cited in Kichnner, Sweller & Clark 2006) or inquiry learning (Bateman, 1990, as cited in Kichnner, Sweller & Clark 2006) steam from constructivist approaches. These learning strategies present advantages and disadvantages and their application depends to a great extent on the learner's academic level (Clark et al., 2010; Kichnner, Sweller & Clark 2006). Behaviourist strategies imply a controlled and structured learning process, which makes software implementation easier. However, constructivist strategies entail a fierce challenge for instructional designers (Jonassen, 2010; Merrill, 2002; Karagiorgi & Symeou, 2005).

Explicative example for the attribute *Support*:

This attribute refers to the level of support provided to the learner by the content author within the learning resource, e.g. in the form of help menus, glossaries, navigational support, on screen advice, etc.

*Support* in design includes everything that helps prevent confusion in the user's mind. Confusion is a common affective state in first-year students learning how to program: students need to understand multiple programming concepts, learn the "computer-thinking" to implement algorithms, and simultaneously understand the usage of programming environments.

Figure 8 shows an example where the student is provided with dynamic explanations while executing the code using the navigational buttons provided. At the same time, an animation appears, colouring the parts of the flow chart that correspond to the line of code executing at that moment.

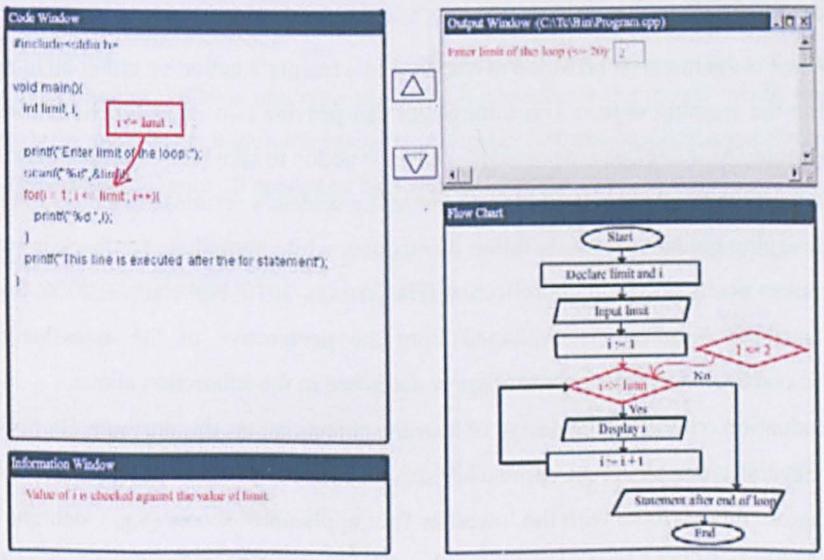



**Figure 8**. Example 1 of attribute *Support.From Bodrow & Bodrow (2006)*

Another form of providing support is shown in the resource below (Figure 9) where the interface is divided into two parts, the code and the explanation of the code. The explanation part supports the acquisition of knowledge of concepts during the session with the learning resource. The button "More" shows detailed explanations about the specific line of code.

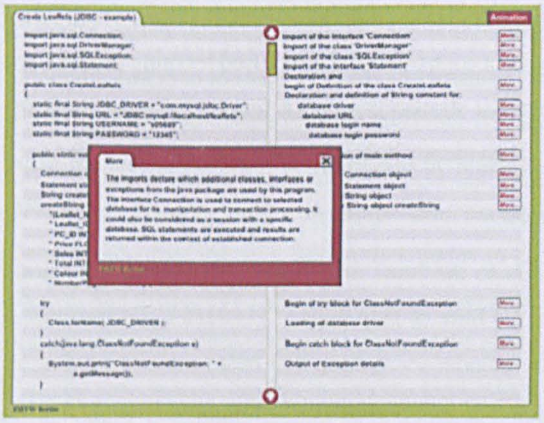


**Figure 9**. Example 2 of Attribute *Support*
From Bodrow & Bodrow (2006)

## 2.5.7. Feedback

*Feedback* is the message provided in response to a learner's action on either an interactive or assessment element within the learning object. These messages can provide two main functionalities: inform the student which is – or *should be* if choices are provided – the next action to take (called *feedforward* by Bjorkman (1978), as cited in Sadler (2010)) or provide an assessment of the student's response to a task. *Feedforward* is supposed to be an encouraging guidance towards future ineractions, while immediate feedback is supposed to correct the student's mistakes gently and promote reflection (Hadjerrouit, 2010; Nokelainen, 2006; Sadler, 2010).

The attribute *Feedback* is explained from the perspective of the assessment functionality since *feedforward* is considered as the attribute *Support* described in the subsection above.

All evaluation criteria for the design of learning objects assess this attribute. By reviewing the evaluation instruments, several types of design approaches can be identified. When no feedback is provided, evaluation instruments assess this attribute with the lowest or "not applicable" scores (e.g. Cochrane's adapted version of MERLOT criteria, or LOAM instrument). Usually, at least one of the following types of feedback is provided: messages with basic information like "correct/wrong" or quantitative marks; messages with short explanations of the mark obtained (e.g. "The correct answer is..."), explanations tailored to the learner's response (e.g. "You answered [...] however, that response [...]"), or explanations that include additional advice for a particular learner and improve the learning object's adaptability (Windle et al., 2007). Only LOAM specifies a different score for these types, whereas the other instruments leave the score to the evaluator's opinion.

General recommendations are suggested when implementing the attribute *Feedback* (Sadler, 2010):

- To praise students on the strengths of their work;
- To inform them about deficiencies, where they occurred, and their nature;
- To tell them what would have improved their response; and
- To point to what could be done next time they complete a similar activity.

Evaluation criteria only contemplate whether feedback is provided, however, whether the feedback satisfies these qualities is not evaluated in any of them, except Nokelainen's e-Valuator system and instrument.

Any learning activity without feedback "is completely unproductive for the learner" (Laurilliard, 1993, as cited in Cummins, 2008) which makes it a fundamental pedagogical attribute. However if the learner does not clearly understand feedback information, then it will have little or no impact (Cummnis, 2008; Sadler, 2010). From the perspective adopted in this investigation, what it is important is what the student makes of feedback. Therefore, analysing the interactions performed after receiving different types of feedback may inform about the utility of the information provided, and the impact on the learning process and on the usage of other resources in the learning unit.

Explicative example for the attribute *Feedback*:

This attribute is defined as the level and type of feedback provided to the learner while working with the interactive elements or assessments within the resource. As mentioned above, there are different levels of feedback. The resource shown in Figure 10 presents a basic level:

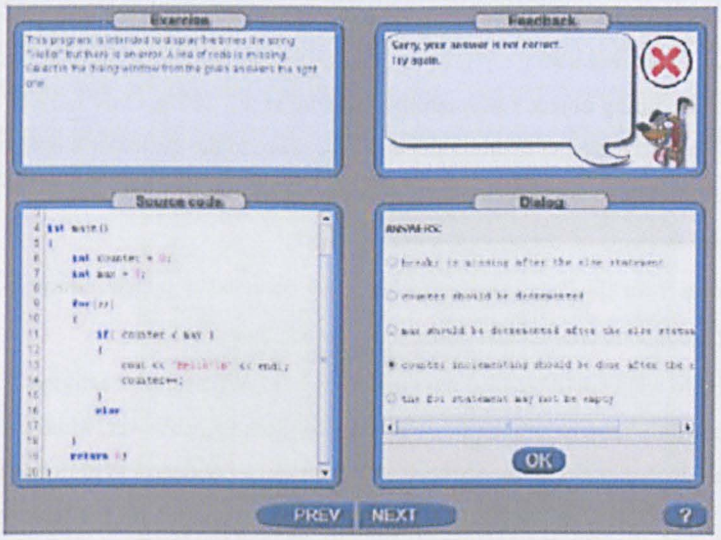



**Figure 10**. Example 1 of Attribute *Feedback*.
Basic feedback shown after a wrong answer (extracted from Bodrow & Bodrow, 2006)

Before a student selects an answer in the dialogue section, the corresponding feedback text is the basic message "correct!" or "incorrect".

More thorough feedback is provided in the following resource where, when the student selects the wrong line of code it shows a brief explanation (Figure 11) and when the right line of code is chosen the feedback is motivating and explains why it is correct (Figure 12):

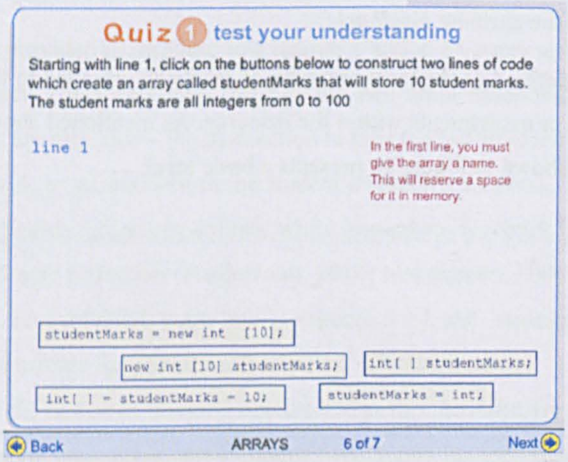



**Figure 11.** Example 2 of Attribute *Feedback*. Message shown after a Wrong Answer.

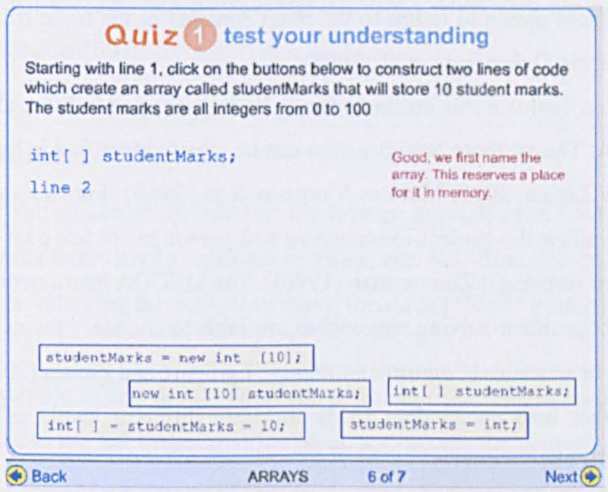



**Figure 12.** Example 3 of Attribute *Feedback*. Message shown after a Correct Answer.

## 2.5.8. Self-direction

This design attribute refers to the level of control afforded to the learner when interacting with the resource. As previously mentioned, this attribute is closely related to the term *learner control*, which implies freedom to select the sequence of contents visited, activities to complete, the representation of the contents, the pace, etc. The LORI tool values this attribute as a manner of enriching the learning object's potential for adaptability (Leacock & Nesbit, 2007; Vargo et al., 2003).

From the design perspective, this attribute involves providing choices. At the level of learning environments or learning units, choices can be provided through open access and interaction with different content resources, activities, and assessments; at the level of a learning object, it involves open navigation, optional interactivity, optional sections, etc. The LOAM instrument allows one to evaluate the learning object from this perspective, considering the existence and amount of choices provided in the selection of tasks, completion or navigation. Thus, this is due to the conception that choices should enhance learning objectives, which are attained more through activity items and less by content elements (Buzzetto-More & Pinhey, 2006; Windle et al., 2007).

From a cognitive perspective, García-Quismondo and colleagues evaluate the capability of the resource to personalize interactive items (*Personalised interactivity*), proposing the completion of multiple tasks simultaneously and giving access to multiple contents depending on the increasing attention (*Flexibility*).

Similarly to LOAM, this criterion also values the existence of clear and consistent navigational options within the object as well as access points to return to the main contents in the topic from any section of the learning object (*Navigation*) (García-Quismondo et al., 2008).

Other models that evaluate this attribute due to its impact upon individuals' cognitive development are HEODAR and MECOA. The attribute *Self-direction* can be clearly identified in both instruments as the attribute *Creativity* (Eguigure & Zapata, 2011; Morales Morgado et al., 2009). For design, it implies including activity items and contents that allow the student to recognize and pursue his or her own learning interests (this is also known as "self-regulated learning": Zimmerman (1990)). The MECOA instrument also evaluates in the resource the existence of different problem-solving approaches available to choose,[33] the existence of options to select the level of difficulty faced in activities (*Cognitive challenge*: Eguigure and Zapata (2011)), and whether the resource includes components that lead the student to demonstrate different levels of initiative (*Self-management*: Eguigure and Zapata (2011)).

The LOEM framework evaluates the level of learner control in the dimension of *Interactivity*. The level of learner control in this context is considered as the possibility to select the display of contents and information provided as well as to manipulate them. This level of control is particularly significant in learning objects for disciplines such as Maths (e.g. Gadanidis et al., 2004), Geometry (e.g. Sedig, 2001), Audio Engineering (e.g. Cochrane, 2005), Pharmacokinetics (e.g. Krauss & Ally, 2005) or Computer Programming (e.g. Cooper, 2010).

The level of learners' control over their own learning process is still a current topic of debate in the academic and research community. Constructivist approaches to learning support providing students with high levels of control, however, this presents certain dangers that need to be controlled, such as disorientation, distraction, and cognitive overload (Kirschner, Sweller & Clark 2006; Scheiter & Gerets, 2007). In this matter, instructional designers are recommended to consider the principles of Cognitive Load Theory (CLT). CLT assumes the existence of a limited *working memory* connected to a *long-term memory* (Baddeley, 1986, as cited in Kirschner, 2002). At any particular time, humans operate with their working memory, which normally allows the individual to hold about seven information items simultaneously, from which only two or three might be actually being processed rather than on hold (Miller, 1956, as cited in Kirschner (2002) and Nokelainen (2006)). The long-term memory acts as a repository for more permanent knowledge and skills not used all the time but which the individual needs to know and remember (Kirschner, 2002). Because of this limitation, the design of instruction should be adequate to the learner's working memory capacity for an effective learning process, otherwise learning might be diminished and inefficient (Kirschner, 2002, 2010; Leacock & Nesbit, 2007; Mayer & Moreno, 2003; Nokelainen, 2006). There is evidence that suggests that high levels of learner control are suitable for learners who present an adequate prior knowledge on the subject, better self-regulatory learning

[33] It should be noticed that this design option could also be considered as the *Support* attribute already described.

skills, and positive cognitive skills and attitudes towards learning (Mayer & Moreno, 2003; Scheiter & Gerets, 2007). Other authors suggest that students can make better decisions when they are informed about different choices provided (Leacock & Nesbit, 2007).

Explicative example for the attribute *Self-direction*:

This refers to level of self-direction afforded to the learner through open navigation across different sections of the resource, optional interactivity, optional sections, etc. Self-direction can be limited to a linear navigation through the resource, allowing the student to move forwards ("Next" button) or backwards ("Back" button).

Figure 13 shows an example of this design approach of the attribute *Self-direction*. In contrast, Figure 14 provides an additional menu to the left that allows the student to access the content he/she is interested in.

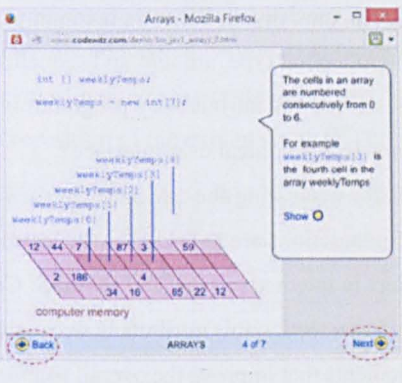



**Figure 13.** Example 1 of Attribute *Self-direction*: Design Approach with Buttons "Back" and "Next".

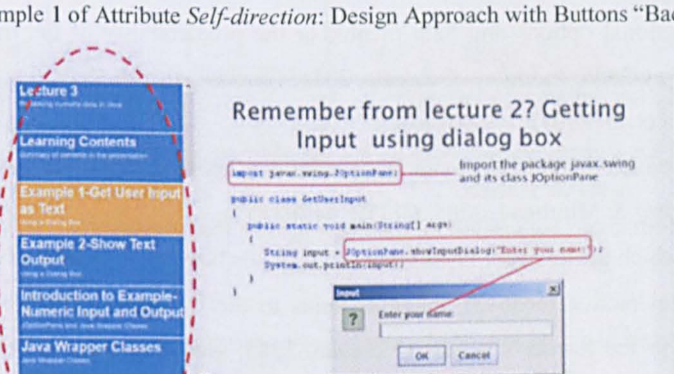



**Figure 14.** Example 2 of Attribute *Self-direction*: Design Approach that Includes a Direct-Access Menu.

## 2.5.9. Interactivity

Interactivity is one of the most valuable and appreciated design features in learning objects. It is the main difference between learning objects and traditional teaching materials such as textbooks. It maintains students engagement in what they are learning by attracting their attention (Littlejohn, 2007).

LOAM defines this attribute as the extent to which the learner can engage actively with the learning object. This instrument, however, only evaluates the percentage of the elements in the learning resource that allow interaction. The authors highlight an existing issue about when to provide didactic interactivity or more complex and constructivist interactivity. They recommend providing "simple, engaging interactions spread across the object and aligned with the learning objective" (LOAM Tool Attribute Scoring Criteria, p. 1), but in the design process some questions arise that require empirical research to be answered, like, for example: How to associate an interaction or a group of interactions to a learning objective? If different learning objectives are usually described through different verbs (e.g. as specified in Bloom's taxonomy), what kind of interaction or group of interactions is appropriate to which verb? What type, amount and sequence of interactions are required to align with a learning objective typically described for introductory programming courses? Is it possible to represent these interactions with interactive items in a graphical user interface?

Similarly to Windle's approach for evaluating the attribute *Interactivity*, other initiatives merely evaluate the extent to which different types of interactions are provided in the learning object without specifying the type or the aspect in which a learning object is interactive (e.g. Del Moral & Cernea, 2005; Morales Morgado et al., 2009). According to other evaluation frameworks, this attribute is associated with the following design aspects:

- The existence of interactive elements that improve the overall usability of the learning object, for example, the existance of navigational options and help menus, or the predictability of the interface and ease of use (Buzzetto-More & Pinhey 2006; Eguigure & Zapata, 2011; García-Quismondo et al., 2008; Leacock & Nesbit, 2007; MERLOT; Vargo et. al. 2003).

- The extent to which interactive items align with the learning objective or simulate real scenarios (Cochrane, 2005; Haughey & Muirhead, 2005; CLOE; MERLOT).

- The manner in which the interface or its contents responds before an interaction on the user's behalf. The resource can provide interactive feedback, adapt contents to the learner's profile, or change the display of information according to the learner's needs (Cochrane, 2005; García-Quismondo et al., 2008; Haughey & Muirhead 2005; Kay & Knaack 2008; Leacock & Nesbit, 2007; Vargo, 2002).

- The extent to which the learner can control the pace, processing, and sequencing of information or create an outcome with the resource (Cochrane, 2005; Eguigure & Zapata, 2011; García-Quismondo et al., 2008; Kay & Knaack, 2008; Krauss & Ally, 2005).

- The extent to which the learning object provides social or collaborative interaction between learners and the teacher (Buzzetto-More & Pinhey, 2006; Garcia Quismondo et al., 2008; Sofos & Kostas, 2009);

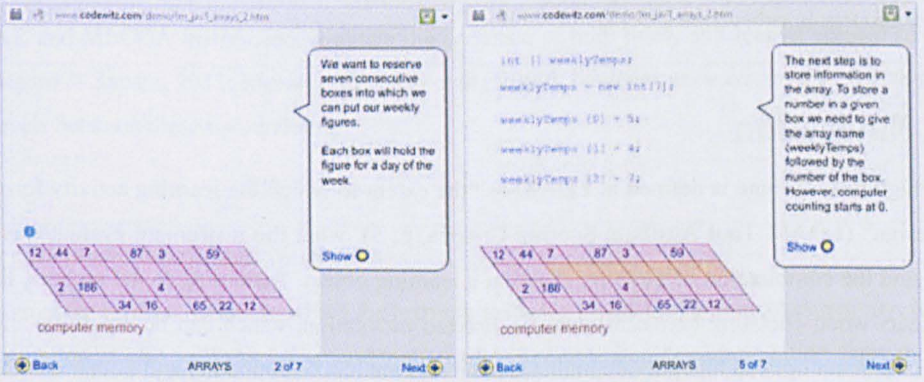
Other aspects that evaluate the quality of interactivity are: the extent to which the learning object motivates learners, is visually attractive, and emulates realistic environments (Cochrane, 2005).

Explicative example for the attribute *Interactivity*:

In this research, *Interactivity* refers to the extent to which a learner can engage with the resource in such a way that it motivates and facilitates the learning process.

The resource developed by London Metropolitan University (previously referenced to illustrate the *Multimedia richness* and *Self-direction* attributes) constitutes a good example to show when and how to provide interactivity for novice learners in first-year Programming courses.

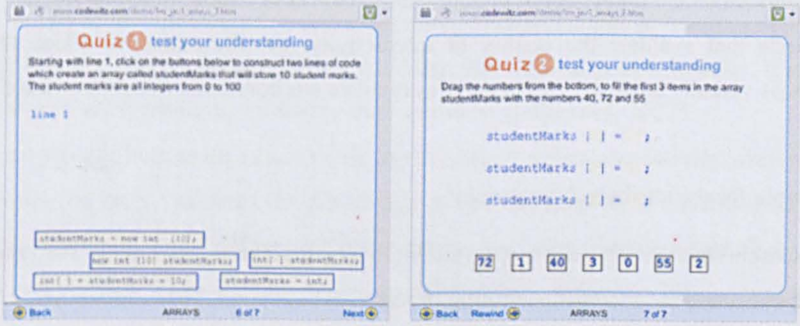
At the beginning of the resource, the concept of "array" is explained by showing an animation and brief verbal explanations. Although the level of interactivity provided at this point is limited, it is appropriate since the student can control the pace and repetition of the explanations (Figure 15).




Animation start screen — Animation end screen

**Figure 15.** Example of Attribute *Interactivity*. Design Approach for Student to Control the Pace and Repetition of Explanations.

The second part of the resource proposes two exercises. In Figure 16 it can be noticed that the level and purpose ofinteractive items have changed. In the first exercise, the student is provided with a set of lines of code and asked to order them as it should be done in a real program (Exercise 1 in the figure). Second, the learner is asked a question to check whether the concept has been understood (Exercise 2 in the figure).




Exercise 1 Exercise 2

**Figure 16.** Example 2 of Attribute *Interactivity*. Design Approach for Interactive Assessment.

In this example the type of interactions proposed in exercises can be considered an excellent design approach. It allows the student to focus on learning the concept of "array" and how to build a program, without dealing with the complexities of programming environments or compilation messages (Boyle, 2006). In other words, the type of interaction keeps the learner focused on learning the main topic. This type of interaction also aligns very closely with the course learning objective of solving a problem by creating a Java algorithm (see attribute *Alignment* in subsection 2.5.12).

## 2.5.10. Navigation

Although this attribute is defined in LOAM as "the extent to which the learning activity forms part of the learning design" (LOAM Tool Attribute Scoring Criteria, p. 5), what the instrument evaluates is the types of navigation and the combination of them provided in a learning object. According to the authors, the conflict in design appears when choosing between linear or directed navigation, which can be repetitive and tedious, or more open non-linear options that provide multiple pathways but can be confusing and disorienting to the learner, especially those who are not familiar with the topic. The recommendation is to make activities meaningful, mix linear and non-linear sequences, and allow the learner to choose. In the evaluation frameworks reviewed there can be found approaches that follow at least one of three alternatives:

- Linear or didactic

Haughey and Muirhead (2005) propose linear navigational approaches in such a way that the learning object's contents are structured to scaffold student learning. Buzzetto-More and Pinhey (2006) propose a navigation that is clear, logically organized and meaningful.

- Learner control (open navigation)

Cochrane (2005) proposes to implement a pedagogical navigation within the learning object in such a way that it is orientated "for students' investigation rather than linear".

- Combination

Krauss and Ally (2005) propose a combination of navigation mechanisms. First, following the behaviourist learning theory, the resource's contents are organized in ordered tabs. Secondly, a network of related contents was presented to provide students with multiple pathways. A set of learning strategies were also included in such a way that students received direct instructions when using a specific strategy.

Del Moral and Cernea (2005) assess whether the learning object provides a combination of two main navigation mechanisms: (1) a comprehensive navigation system that allows access to any section of the resource from any section; and (2) a navigation mechanism based on a linear conceptual design of the subject in such a way that it follows the formula "overview-theory topics-activities-summary-assessment". Sofos and Kostas (2009) evaluate seven types of navigational options that range from "No navigation" to "Smart Navigation", however, they do not provide design examples for each category.

Other authors value the presence of different navigational options to ensure usability and, at the same time, the organization and navigation through contents in such a way that it is conceptually meaningful (e.g. showing relationships between concepts, hierarchical relationships, key concepts, etc.) (García-Quismondo et al., 2008). The HEODAR and MECOA instruments evaluate the presence of both linear and learner control navigational aspects (Eguigure & Zapata, 2011; Morales Morgado et al., 2009), however, they do not distinguish a range of navigation levels between these two extremes.

Explicative example for the attribute *Navigation*:

This attribute refers to extent to which the learning resource, whether it is content or activity, forms part of the learning design. An example of a combination of both linear and open navigation through different sections (e.g. with "Next" and "Back" buttons) in a resource can be seen in Figure 17 (also used to illustrate the attribute *Self-direction* subsection 2.5.8).

This kind of combination can be also implemented through menus, glossaries of concepts, or conceptual maps included in the resource. In this case, however, to prevent the learner from "getting lost" it is a good practice to provide a mechanism that helps to track the sequence of concepts or sections that have been visited (in web design, this is known as "breadcrumbs"). Likewise, it is usually recommended make any section of the resource available from any section.

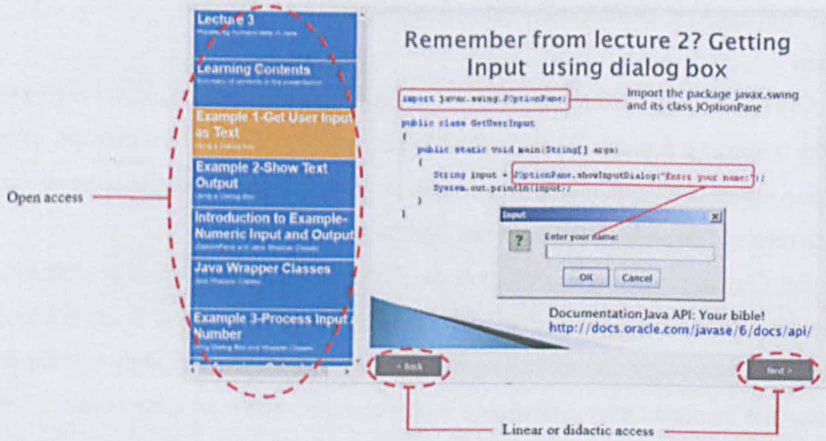



**Figure 17**. Example of Attribute Navigation. Design Approach of a Combination of Linear and Open Navigation Mechanisms.

## 2.5.11. Assessment

The LOAM instrument defines this attribute as "the extent to and ease of which the learner can perform an effective self-assessment" (LOAM Tool Attribute Scoring Criteria, p. 6). The aspect evaluated is the amount of self-assessment questions in a learning object and how many of them address the learning objective. The authors argue that self-assessment is for the learner's benefit, enabling them to can test how well they have understood the material. Therefore the recommendation is to define the assessment clearly, so the student is conscious of what he or she is supposed to practise or test and pose the same level of difficulty as the other materials.

Design implications for the remaining evaluation frameworks agree with this understanding, varying little in their approaches. The learning object should include assessment items with formative and summative feedback to reinforce knowledge (e.g. CLOE; Cochrane, 2005; Del Moral & Cernea, 2006; Haughey & Muirhead, 2005; Kay & Knaack 2005, 2008). Other studies consider that, above all, assessment items need to be designed in such a way that they align with the learning objective for which the object is designed (Buzzetto-More & Pinhey, 2006; Del Moral & Cernea, 2005; Leacock & Nesbit, 2007; Richards & Nesbit, 2004; Vargo et al., 2003). In the LOAM instrument this property is a separate attribute called *Alignment* (subsection 2.5.12.).

The MECOA framework evaluates this property as the competition indicator of the learning object (Eguigure & Zapata, 2011). Regarding design, this framework suggests that the following aspects need to be taken into account: the alignment between the competences provided by the object with the learning objective;

the kind of element within the object facilitating the achievement of such competence; the type of competence acquired, and the activities that mediate such achievement.

It is worth noting that none of the evaluation criteria make recommendations about using a concrete type of assessment interaction (or a sequence of them) depending on the learning objective to be achieved.

Explicative example for the attribute *Assessment*:

This attribute is defined as the extent to which and ease with which the learner can perform an effective self-assessment.

When including assessment items in a learning object, these must align with the concepts or learning objective for which the resource is designed. An example of assessment items is presented in Figure 18 (also used to illustrate the attribute *Interactivity*, subsection 2.5.9).

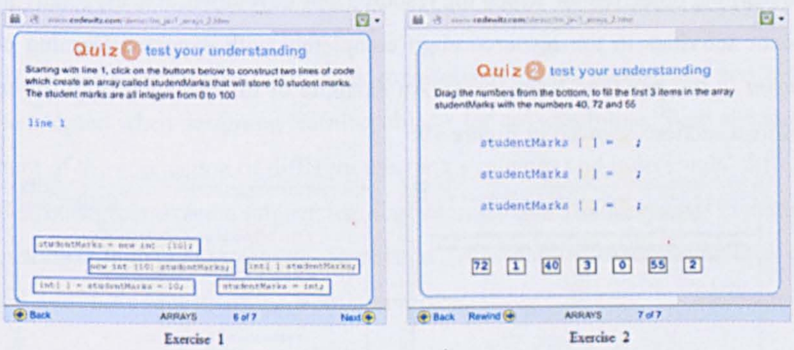



**Figure 18.** Example of the Attribute *Assessment*.
Sequence of Assessment Items in a Learning Object for Java Programming Subjects.

In this example, self-assessment exercises are mainly focused on the contents of the resource (focused on explaining the concept of arrays in Java). The drawback of this kind of assessment is that it is brief (composed only of two short exercises) and lacks more variety of questions. For example, it could have included questions to interpret a piece of code, more exercises to build an algorithm, or a final test with no supportive feedback that would provide the student with a formative score.

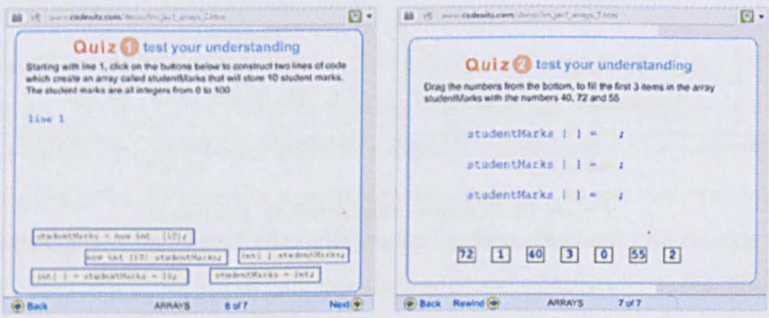
## 2.5.12. Alignment

LOAM defines this attribute as "the extent to which the assessment elements measure attainment of the learning objective" (LOAM Tool Attribute Scoring Criteria, p. 6). As has been mentioned, *Alignment* can be easily confused with the *Assessment* attribute; however, whereas the latter measures the amount of assessment items existing in the object that address the learning objective, *Alignment* measures the percentage of the learning objective that is addressed in assessment elements. LOAM authors recommend that the self-assessment elements and the learning objective must be completely aligned so that learners are confident that they have attained the learning objective.

Other authors apply this property to content elements contained within the learning object (CLOE; MERLOT; Sofos & Kostas, 2009), which may impact upon the level of interactivity provided by the object. For example, from a design perspective, Cochrane (2005) argues that it is important that all the object's contents help simulate realistic learning scenarios, supporting a variety of learning objectives.

Explicative example for the attribute *Alignment*:

The attribute *Alignment* is defined as the extent to which assessment items in the resource measure attainment of the learning objective for which the resource was developed. It is especially important to ensure that self-assessment activities in the resource align completely with expected learning objectives (see the attribute *Assessment* in the previous subsection). An example of this pedagogical attribute is shown in the interactive assessment sections showed in Figure 19:




Exercise 1 Exercise 2

**Figure 19.** Example of Attribute *Alignment*.
Inclusion of Intearctive Assessment Items that align with Learning Objectives.

The self-assessment items presented in the figure are closely aligned with the learning objectives defined for the programming topic and the course. This design approach is particularly good since it manages to align with a set of learning objectives such as: comprehend the concept, build algorithms, develop logical thinking, and become familiar with the syntax of the Java programming language.

### 2.5.13. Implications of pedagogical attributes

The first main consequence of analysing pedagogical attributes according to the different meanings identified in the evaluation frameworks' criteria is that it forces practitioners to reflect upon their practice and evaluate, thus at least in their own minds, the design of the authored materials at the level of these attributes. The resources used in case studies presented in this thesis have important faults in the attributes described above. For example, content materials are separate resources from activity resources, therefore content materials lack assessment items. This lack affects the assessment of attributes like *Objective*, *Assessment* and *Alignment*.

The second consequence is to appreciate the "connection" or "overlap" existing between certain attributes, such as the attributes *Objective, Integration, Context* or *Previous Knowledge*. These attributes relate the learning resource directly to the instructional context where it is used. Since students interact with a learning resource and partner resources in its context, it seems that analysing students' behaviour may help to assess these attributes (Campos et. al., 2012).

The analysis of these pedagogical attributes manifests multiple approaches and alternatives in each attribute that can be adopted when designing learning objects for any discipline. Such alternatives emerge from the acknowledgement of the application of different teaching strategies and individuals' differences concerning learning needs, styles, background on the subject, learning interests, and affective states that impact upon learning or motivational factors. All these factors are associated with learning behaviour since different previous initiatives have used it to study aspects of the learning process.

## 2.6. Learning Behaviour and Pedagogical Design of Learning Objects

### 2.6.1. Learning Styles and Learning Behaviour

The main hypothesis of this thesis attempts to establish whether learning behaviour can be used to inform the pedagogical design of e-learning resources based on the set of attributes proposed in the previous sections of this chapter. In this context, consideration needs to be taken of individual factors that affect individual's learning behaviour and how they may be used to improve the design and development of e-learning solutions.

Learning styles constitute a key factor that influences an individual's learning process; their potential to inform the design of learning resources is considered in this thesis. Nevertheless, concerning the identification of the learning styles of participants in this research, there are some constraining factors that require review. As with the learning platform that was chosen to deliver the learning objects to the participants, the practitioner-led approach provides a key constraint. The main case studies that form the basis for this research are Computer Programming courses delivered at the Institute of Informatics of the UACh in Valdivia, Chile. In this Institute the learning styles of students are routinely assessed in a range of courses.

Particularly in the subjects of Computer Programming, the Institute of Informatics participated actively in the IGUAL project.[34] Among the objectives of this project was the implementation and validation of innovative and contextualized solutions that help students to acquire new programming knowledge and skills, and provide adaptive support based on students' profiles, which considered their cultural background, their "Felder–Silverman" learning styles, and their learning needs. The platform, Aprende Tutoring System,[35] was used during 2013 in pilot courses delivered at five universities in Latin America. Aprende was used to deliver learning objects that were classified and delivered on the grounds of students' learning styles. Both the platform and learning objects were evaluated with very positive results regarding the adaptation and improvement of students' academic performance (Campos et al., 2013).

With the purpose of continuing the investigation of the influence of learning styles, we developed the "detector of learning styles" (DEA) system (De la Maza, Álvarez-González, Campos, & Vásquez, 2014). This tool provides students with questionnaires and shows the results obtained for three different learning style models: the Felder–Silverman Index of Learning Styles (Felder & Silverman, 1988), the Herrmann Brain Dominance Instrument (Herrmann, 1991) and the Structure of Observed Learning Outcome taxonomy (SOLO) (Biggs, 1979). Future work in this project includes integrating the DEA system into a bigger learning environment able to dynamically recommend learning contents and activities to a student based on his or her learning style.

In both the IGUAL and DEA initiatives, students' learning styles are ascertained by administering the corresponding learning style questionnaire whose results are associated with students' profiles. In contrast, students' learning behaviour is the data source that has been applied to detect learning styles automatically in learning platforms and improve their adaptability to individuals (Graf et. al. 2009; Khan, Graf, Weippl, & Tjoa, 2009; Moridis & Economides, 2008; Moridis & Economides, 2009).

These findings are valuable contributions to the development of ALSs. They have not yet been applied to the development of learning resources, however, there are a few proposals in the literature that suggest to resort to learning style theories when developing learning objects. This approach would strength the pedagogical design of resources and would improve the academic performance of those students with a strong preference for a particular learning style (Arias, Moreno & Ovalle, 2009; Felder & Silverman, 1988; McLoughlin, 1999; Ossadon

[34] http://www.igualproject.org/
[35] http://aprende.igualproject.org/

& Castillo, 2006; Sprock & Gallegos, 2013). In spite of this, there is at present no evidence that instruction should be designed and planned on the basis of a learning style model. The work presented in this thesis is intended to shed light on this topic.

Accordingly, a study of the actual influence that a learning style preference exerts upon students' behaviour with different resources online delivered is called for. The practitioner-led approach introduced in Chapter 1 determines this aspect of the work presented by conditioning the selection and administration of a learning style model suitable for the purposes of this investigation. Among the three models available in DEA at UACh, the Felder–Silverman Learning Style Model (FSLSM) has been widely investigated in e-learning contexts for two main reasons: first, it describes learning styles in four separate dimensions, and in using these dimensions, FSLSM includes styles of previous well-known models like Kolb or Mayer-Briggs (Graf, 2007); second, it is one of the models most often used in technology-enhanced learning, especially in adaptive hypermedia systems (Graf, 2007; Kuljis & Liu, 2005).

### 2.6.2. The Instructional Context of E-Learning Resources and Students' Learning Behaviour

The hypothesis established in this thesis proposes to apply information obtained from the analysis of learning behaviour to inform the design of learning resources according to the group of attributes described above. As the analysis of such attributes suggests, in some of them the design of a learning object is connected to the design of its intended context of use, which supports the arguments of Haughey and Muirhead (2005) or Krauss and Ally (2005).

Haughey and Muirhead (2005) provide well-documented literature and experience on the instructional use of learning objects in the K-12 sector and developed a comprehensive model for their evaluation. The authors affirm that "learning objects do not have a value or utility outside instructional contexts. Their value is in the application to classrooms settings or to online environments where teachers may or may not be present." (p. 2). Krauss and Ally (2005) conducted the development and evaluation of interactive learning objects for a complex learning discipline in higher education. They conclude that designing for reusability implies de-contextualizing the learning object, which means "stripping it of its inherent value" (p. 16).

The instructional context or contextualization of a learning object is the scenario in which the object is being used, and it can include a wide range of parameters that should be considered in the design of learning objects (Wiley, 2007). Wiley defined instructional context as a "spatial or temporal juxtaposition of learning objects" and established a relationship between the internal context of a learning object (i.e. its internal design) and the instructional context where it needs to fit in (e.g. a learning unit or lesson composed of other learning objects) (Wiley et. al. 2004, p.1). Wiley's study used this relationship to inform the instructional design of learning objects.

In contrast to this approach, in a previous work my proposal was to inform the design of resources on the grounds of their usage and impact upon learning. In order to achieve this, I created a theoretical data model to represent students' interactions with resources belonging to a learning unit (Campos et. al., 2012). Whereas that proposal suggests the analysis of learning paths generated by students, i.e. the sequences of interactions with contents and activities, the present work proposes the extraction of a set of learning metrics from students' behaviour and analyses such metrics to observe links between different resources delivered within a learning platform. In this way conclusions about their pedagogical design can be drawn on the grounds of students' behaviour. Previous investigations of behavioural patterns to detect learning styles and affective states automatically (Campos et. al., 2012) have helped to define an initial set of learning metrics that will be extracted from students' interactions and analysed for this research.

**Table 4.** *Learning Behaviour Indicators* (source Campos et. al., 2012)

| **Common Learning Features** | **Indicators** |
|---|---|
| Content objects, outlines and examples | number and time of visits |
| Formative and Summative Assessment-Test | number of answered questions, time until submitting the test, number of revisions, performance on specific types of questions, answering the same question wrong twice, time on reviewing the results |
| Exercises | number of performed exercises, time until submitting the exercises, performance on questions about interpreting solutions/developing new solutions, number of performed revisions, time for reviewing the results |
| Navigation | number of learning objects skipped, number of visits to course overview page, time spent on the overview page of a topic |

## 2.7. Delivering Learning Objects

Regarding the usage of an e-learning solution that conforms to the usability requirements for the delivery of e-learning objects required by this study, there are some constraints that require reviewing. In particular, the practitioner-led approach that was introduced in Chapter 1 provides a fundamental constraint. This approach conforms to the practices adopted by the wider group of practitioners operating in the learning environment in which the research is being undertaken, in this respect this environment was defined by the operating requirements of the Kingston University undergraduate programme. The original undergraduate module that was used as a proof of concept for investigating the research questions posed in this thesis was CO1040: Object-Oriented Programming in Java. The LMS officially used at Kingston University is the Blackboard Learning Management System which is used on an institution-wide basis. Operational constraints and mission-critical guidelines dictate that the custom software developments required to undertake this study meant that it was not feasible to use and modify this platform directly. In addition, the proprietary and closed nature of the Blackboard development environment was a further issue that caused problems in using it for this study. However, the existence of a second learning environment, Kingston University Online Learning Environment (KUOLE), which was developed in-house and is used in tandem with the Blackboard system offered the possibility of adopting this system as a research vehicle.

The module CO1040, which became the initial proof of concept that would form the basis for this research, combined the usage of two environments: the university's official LMS, Blackboard, and the in-house LMS, KUOLE. Whereas Blackboard was used to enable communication between the teacher and the students, provide students with access to different learning materials, monitor the completion of the assignments, and perform official assessment tests, KUOLE was used to deliver learning activities during practical workshops and monitor students' performance closely during the course. A more detailed description of the implementation of the KUOLE platform and its usage in this research is provided in the Chapter 3 of this thesis where the adaptations needed to allow it to address the pedagogical requirements discussed later are described. The platform was developed in 2008 by the Faculty of Computer and Information Systems and Mathematics (CISM-SEC) at Kingston University as a custom e-learning solution for the specific needs of a postgraduate (master's degree) course in Network Security. This course was offered as both face-to-face and distance learning programmes; in the latter, students attended to an intense schedule of face-to-face lectures during one week and performed most their work out of the classroom. A learning system was required to support this course (and similar courses) with a Blended Learning solution so as not to disadvantage distance learners in comparison with face-to-face learners on the same programme.

The main objective of this platform was to provide these students with a learning tool that could be used to access module learning materials and perform activities proposed for this course. KUOLE was designed to be a flexible, cross-platform tool able to deliver course materials and activities, maintaining a consistent interface regardless of the content. The standard chosen to implement KUOLE materials was CNXML (see above, section 2.2.1).

In the same manner that module contents were organized, structured, and linked through XML files, students' interactions with such contents were also stored in XML files, and each student had one file that contained information about the basic session details of the student's access to contents and activities. This approach could be extended to other student interactions and was appropriate to address the requirements of the research.

## 2.8. Summary of Chapter 2

In order to meet the research objectives established in Chapter 1, this chapter has introduced the reader to the existing empirical research on the design and evaluation of learning objects. Two main approaches have been presented: the technical approach guided by the concept and achievement of reusability and the pedagogical approach which advocates other aspects of design related to didactic capabilities of learning objects.

Firstly, with the aim of identifying such aspects, the main evaluation frameworks for learning objects have been selected for review of their evaluation criteria and their evaluation methodologies. As an expected outcome of this review, a wide variety of design aspects were identified, and a classification system was proposed so that pedagogical aspects could be distinguished. As an unexpected outcome, the review of evaluation methodologies and criteria allowed me to identify a set of methodological characteristics which constitutes a comprehensive set of criteria to select and characterize evaluation frameworks for further classification and usage as a tool to guide the instructional design process. These criteria include: incorporating the development of learning object or objects to be evaluated; perform formative or summative evaluation cycles; include varied and numerous potential consumers in the evaluation stages; the amount and variety of learning objects evaluated; the measures of reliability and validity of evaluation instruments; and the identified and measured relationships between different criteria.

Among the frameworks reviewed, the Learning Object Attribute Metric (LOAM in subsection 2.3.1.5) presents validated criteria, evaluation instruments and scale defined specifically for assessing pedagogical design. For this reason, it has been used for guidance in the identification of a common core set of twelve pedagogical design aspects from among a wide spectrum of criteria found in the studies reviewed. These attributes are: *Objective, Integration, Context, Multimedia Richness, Previous Knowledge, Support, Feedback, Self-direction, Interactivity, Navigation, Assessment* and *Alignment*. Since the design is traditionally evaluated through its usability, these attributes have been also used as the basis to construct a custom evaluation instrument to collect students' perceptions of the pedagogical usability of e-learning resources provided. This instrument is explained in Chapter 3, and a sample of it can be found in Appendix 10 at the end of this thesis.

Secondly, as learning behaviour is proposed as an empirical base to inform the pedagogical design of learning resources, the review extended to how learning behaviour has been traditionally used to inform pedagogical features in educational software. In the context of this research, special emphasis needs to be put on investigating the influence of learning styles upon students' behaviour in e-learning systems. The literature on this aspect is extensive concerning the models and methods used to obtain detect students learning styles. However, the practitioner-led approach adopted in this research favours the selection of the FSLSM, and uses its mechanisms for collecting and administering results. The analysis of pedagogical design attributes suggests that certain aspects of the design of the instructional context influences the design of its learning materials and activities. This coincides with other authors' conclusions about the design of learning objects. A theoretical proposal I previously presented, which is based on a similar hypothesis, was found useful for this work in the identification of the set of learning metrics required. These metrics will help to analyse behaviour and extract conclusions on improvements in pedagogical design of learning resources, and to analyse the actual correlation between behaviour and learning styles so that pedagogical design is informed accordingly.

Finally, analysis of students' behaviour required a platform that would allow delivery of e-learning resources and capture of students' interactions with them. Within the contextual circumstances in which this research took place, two delivery systems for Computer Programming courses are available at UACh: KUOLE and IGUAL. Since it is necessary to collect data on students' behaviour with developed resources and activities, KUOLE is the most appropriate platform, however, modifications to it are necessary so that it delivers learning resources in other formats different than CNXML. Likewise, it was necessary to capture interactions that occur within a learning object, therefore, mechanisms were needed to allow capture and storage of interactions with CNMXL content elements. Additionally, a data model I proposed to model students' learning paths might serve as guidance to design and implement a database connected to the KUOLE platform, responsible for storing students' interactions with the platform and e-learning resources. This model and the interactions stored are detailed in Chapter 3.

# CHAPTER 3

# Investigating the Viability of Learning Metrics to Inform the Pedagogical Design of e-Learning Resources

This chapter presents the methodology applied to inform the design of learning resources for Computer Programming subjects by exploring students' behaviour with such resources. The chapter presents the analysis procedure and results obtained for materials and students of two separate programming courses, INFO055 and INFO023, taught at the Austral University of Chile (UACh). The outline of this chapter is as follows:

First, the research questions addressed in this chapter and the methodology applied to answer them are presented in Sections 3.1 and 3.2 respectively. In 3.2, the reader will find a detailed explanation of the stages followed, the type and nature of data required, instruments applied for data gathering, and the research methods selected.

Section 3.3 presents a detailed explanation of the instruments used for the gathering of data required for this analysis. The origin and nature of these instruments are varied: custom software tools that have been created for this investigation; the set of learning measurements obtained for analysis; pre-existing questionnaires for collecting learning styles; and a customized survey. Each instrument is individually explained in respective subsections. Likewise, to facilitate understanding of the results presented in the following chapter, the statistical research methods selected are explained separately in Section 3.4.

The chapter concludes with a description of the case studies used for this thesis, which are presented in Section 3.5. It aims to provide the reader with the characteristics of these courses regarding their objectives, the group of students in each cohort, an overview of their teaching and assessment methods respectively adopted, and their participation in this study.

## 3.1. Research Questions

The experimental research presented in this thesis aims to explore the usability of data extracted from behaviour for two purposes: first, to inform the pedagogical attributes of the design of a resource, and second, to analyse the influence of learning styles upon students' behaviour. As a consequence, the methodology presented in this chapter is designed to answer two specific questions:

❖ *Can the design characteristics of e-learning resources be informed through the analysis of students' behaviour?*

❖ *Does a student's learning style explain his or her behaviour with learning materials and activities, or is it the discipline, in this case Computer Programming, that determines such interactions and behaviour?*

In order to avoid confusion, the reader should notice that these are specific questions that will be answered using the results obtained from the data analysis performed (Chapter 4). It is envisaged that the conclusions obtained help respond the main research questions of the thesis that were set out in Chapter 1.

## 3.2. Research Methodology

The methodological approach adopted in this investigation is based on two case studies, coded as INFO055 and INFO023 respectively. The stages summarized in this section describe the process of data gathering and data analysis that have been applied in these cases. The results individually obtained for each course will be contrasted to answer the research questions stated above. The steps considered for this methodology are described as follows:

### 3.2.1. Selection of Lessons and Materials for Analysis of Behaviour

Despite the fact that INFO055 and INFO023 are both introductory Java programming courses for novice students, they differ in learning objectives, contents, and activities. Whereas INFO055 teaches the concepts of the object-oriented programming paradigm to students, INFO023 focuses on teaching algorithms and logical thinking, using Java as a programming language for the course (in UACh, object-oriented programming subjects are usually taught in second-year courses). For example, INFO055 includes lessons centred on the design of classes, objects, and inheritance; INFO023 includes lessons on implementing recursive programs, handling and processing text files, and handling Java exceptions. Regarding the learning resources used, major differences in the materials have also been observed: INFO055 students have been provided with materials typically used in the CO1040 module at Kingston University, whereas INFO023 students have been provided with both traditional and new materials developed at UACh.

These differences explain the selection of a set of five lessons for analysis in this research. The lessons include the knowledge related to basic programming concepts: the concept of variables; different data types and arithmetic operators in Java; implementation of basic interactive programs to capture and process users' input; programming flow and control structures; and implementation of methods.

## 3.2.2. Data Gathering

Two different sets of data were collected for this investigation: (1) data related to students, including the learning metrics that are associated with their behaviour, formative and summative performance; and (2) data on students' learning styles that are associated with a specific learning style model.

### 3.2.2.1 Students' behavioural and performance data

Students' behavioural data (also referred to in this investigation as *learning metrics*) is a data set composed of quantitative information extracted from students' interactions with the content and the activity resources provided in each lesson of the course. These interactions are qualitative records collected during the course and stored in KUOLE's database.

In order to observe behavioural trends and discover possible relationships between interactions with different types of resources and activities, it is necessary to obtain and analyse a set of metrics that measure students' interactions with the courseware delivered through KUOLE. The nature of data required for this investigation and the data gathering process is explained as follows.

In order to obtain quantitative learning metrics from qualitative interactions, customized software was implemented to retrieve students' session records from the database, generate metrics for each lesson and finally store these metrics in Microsoft Excel files. A description of the KUOLE platform, the database and learning metrics collected is provided in Section 4 of this chapter. Students' performance is a set of quantitative data composed of two measures: the formative grades obtained during the course and the final grade obtained at the end of the course. These data were collected from the respective module leaders of each course. The results of analysis of both behavioural and performance data is provided in Chapter 4. Such results were integrated and used in subsequent stages of analysis.

#### 3.2.2.2. Students' learning styles data

The model selected to classify students' learning styles in this investigation is known as the Felder–Silverman Index of Learning Styles. There are two advantages to the use of this model: the availability of the Index of Learning Styles (ILS) questionnaire and, most importantly, it allows an individual's learning style to be classified quantitatively, facilitating its integration with other quantitative data used in this investigation.

The ILS questionnaire was translated into Spanish and administered to students in both courses through the DEA system developed at UACh. This mechanism made it possible to store students' learning styles and provided their results in Microsoft Excel files, which facilitates subsequent analysis and classification tasks.

Brief descriptions of the FSLSM and of the DEA system, and an exemplary visualization of the ILS questionnaire results, are provided in Section 4 of this chapter, whereas the exploratory analysis of students' learning styles for both courses is presented in Chapter 4.

#### 3.2.2.3. Students' usability perception data

To collect students' perceptions of the usability of both content and activity resources, a specific questionnaire was administered to students at the end of their respective courses. As explained in Section 4 below, this is a customized questionnaire designed to obtain students' perceptions of the pedagogical usability of learning materials delivered in these courses.

The quantitative results obtained from this questionnaire and its subsections are presented in Chapter 4 of this thesis. The results of usability perception, in particular, were used along with the respective behavioural data to analyse the impact of the design of different resources and activities upon the learning of programming subjects.

### 3.2.3 Analysis of Students' Behaviour

The methodological approach adopted in this investigation is based on the belief that, by identifying behavioural trends and variations in interactions with different learning resources, it is possible to focus on their pedagogical design characteristics to observe potential improvements.

The first statistical method used for this exploration is Principal Component Analysis (PCA). PCA is a statistical technique normally applied in studies where large sets of variables make the analysis and interpretation of results difficult. Generally speaking, its purpose is to reduce a set of independent variables by grouping together those with similar characteristics and thus produce a smaller set of variables called components or factors. These components are linear combinations of these variables, capable of explaining the observed variance in the original data. A variety of studies have applied PCA with different aims in the area of e-learning. For example, it has been used to explore the factors that influence students' satisfaction with web-based learning (e.g. Kim & Moore, 2005); the factors that influence the pedagogical usability of e-learning systems (e.g. Zaharias & Poulymenakou, 2009); and to identify students' performance indicators in computer programming courses (Hunter, Livingstone, Neve, & Alsop, 2013). PCA was applied in this investigation with the following objectives:

i. Observe the relevance and impact of each type of resource in the learning process.
ii. Discover hidden relationships between interactions with different learning resources revealed by this process.

The second research method applied aims to identify differences in students' learning metrics concerning their learning styles. With this purpose, two sources of quantitative data were used for this analysis: students' learning metrics, and the data collected on students' learning styles.

A wide variety of statistical methods exists to study variations in a set of variables. The selection of a specific method must be guided by a set of statistical assumptions that the data must previously satisfy to obtain reliable results. Generally speaking, in the analysis of variance, such assumptions are based on the concepts of normality – i.e. data must show a normal distribution in each group – and homogeneity – i.e. data must show homogenous variances in each group (Jaume & Català, 2001). A set of initial Kolmogorov–Shapiro tests was applied to the set of learning metrics to observe whether the condition of normality was satisfied. The results obtained from these tests indicated that our data were not normally distributed; therefore, a non-parametric method for analysis of variance was required (Chan & Walmsley, 1997).

The statistical method adopted in this investigation is the Kruskal–Wallis H Test. This method is a non-parametric test well known as an alternative to the one-way ANOVA method when data do not meet statistical requisites (McDonald, 2014). The method has been used to determine whether there are statistically significant differences in the medians and distribution of each learning metric (dependent variables) between students groups existing in each learning style dimension (independent variables). To enable this analysis, students in INFO055 and INFO023 were classified into different groups according to each learning style dimension. Since both samples of students were small, some groups had no students and therefore no analysis of variance could be made.

Detailed explanations of both PCA and the Kruskal–Wallis H Test methods, how they were performed and the results obtained for both courses are presented in Section 3.4 below.

## 3.3. Instruments for Data Collection

### 3.3.1. Kingston University Online Learning Environment

KUOLE is the instrument used in this investigation for collecting students' interactions with learning resources in each learning unit. Originally, the delivered module contents were organized, structured, and linked through XML files and similarly students' interactions with the contents were also stored in XML files, in such a way that each student had one file per module containing all his or her interactions with contents and activities. For this investigation, interactions were to be collected from both the platform features and from within the resources. However, collecting and analysing these interections required to modify the mechanism for storing data captured from KUOLE and the resources delivered.

Concerning the adaptations required to gather interactions with learning resources, KUOLE used the standard Connexions Markup Language (CNXML) which presented an additional obstacle when developing new resources for UACh courses, in particular, making the contents interactive. XSLT sheets were the mechanism used to convert dynamically any XML-structured document into HTML. Since an official XSLT style sheet was developed for rendering contents with institutional colours and format, it was also used to make interactive certain CNXML tags. For example, with the tag "solution", through the development of the corresponding code script that could be dynamically embedded in or referenced from the XSLT file, it was possible to show or hide the solution text or code of a programming problem proposed to students.

Due to the inconvenience of the authoring process, the fast growth of students' files, the teaching usage planned for KUOLE, and its envisaged purposes of research to inform the teaching practice, two key modifications were performed to the backend of the system:

1. Both mechanisms based on XML files to store module structure of contents and students' interactions with learning materials and activities were replaced by a relational database developed in SQL.
2. The mechanism of rendering CNXML contents was extended, enabling the environment to deliver content materials and activities in different formats: PDF documents, slide presentations, interactive videos and materials, HTML pages, etc.

Despite the addition of new CNXML-based materials it was still necessary to deal with the official authoring, schema validation, and style tasks. These modifications gave KUOLE the usability necessary to be used in the UACh courses presented as case studies in this investigation.

Regarding the changes at the platform level, it was necessary to implement a database that facilitates the query and analysis of data belonging to students' behaviour and descriptive data belonging to learning materials delivered. Originally, KUOLE was a basic learning environment designed to collect students' interactions with learning materials and their responses to learning activities completed in each learning unit of the course. The diagram presented in Figure 20 shows the structure and relationships of the tables that form the database for this purpose.

Each course (**Course** table) delivered in KUOLE is composed of a group of learning units sequenced according to the teaching plan (**CourseTopic** table) which in turn are composed of a set of learning resources (**LearningResource** table). Such resources are the content objects and activities ordered according to the sequence planned by the teacher.

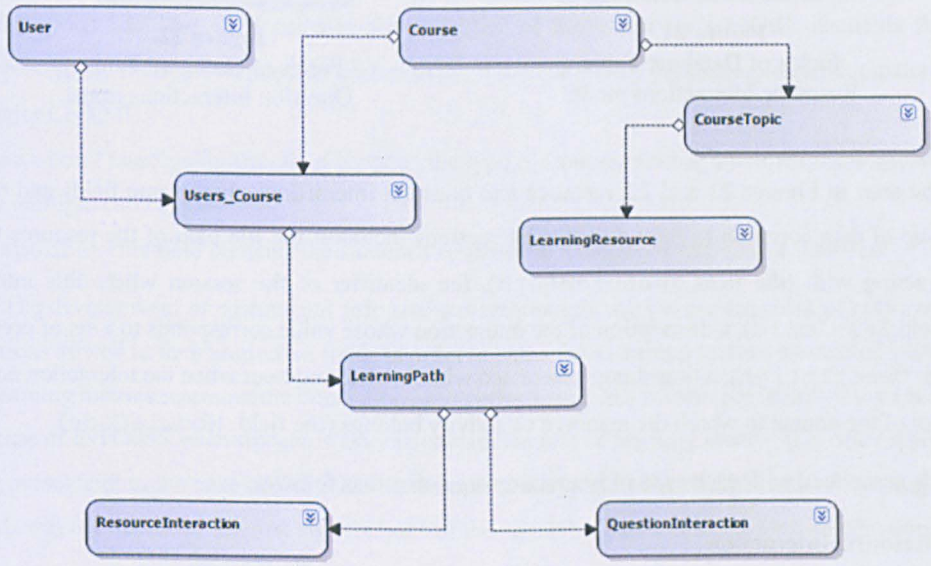



**Figure 20**. Model of the KUOLE Database

Students registered on the course are assigned the corresponding login details to access the platform (**User** table) and associated with the corresponding course (**Users_Course** table). In a session (**LearningPath** table) a student may access different learning units and interact with the respective content materials (**ResourceInteraction** table) and perform learning activities (**QuestionInteraction** table). Since these interactions constitute a key source of information for this investigation, the fields representing each interaction type are explained as follows:

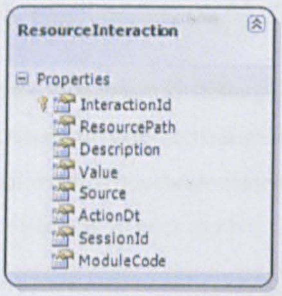



**Figure 21.**
Fields of Database Table
Resource Interactions model

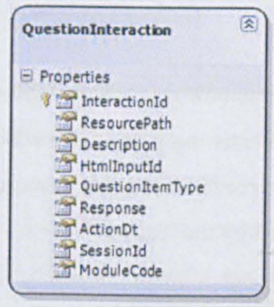



**Figure 22.**
Fields of Database Table:
Question Interactions model

As can be seen in Figures 21 and 22, resource and question interactions share some fields and differ in others. The group of data common to both types of interactions includes: the file path of the resource that the student is interacting with (the field `ResourcePath`), the identifier of the session where this interaction occurred (the field `SessionId`), a description of the interaction whose value corresponds to a set of predefined values (the field `Description`), a timestamp associated with the date and hour when the interaction occurred, and the identifier of the course to which the resource or activity belongs (the field `ModuleCode`).

The fields associated with each type of interaction are defined as follows:

- In the table **ResourceInteraction**
  - o `Description`: the purpose of this field is to indicate the beginning or ending of access to a resource. Possible values assigned to this field include: "visit resource", "select resource tab" and "close resource tab".
  - o `Value`: indicates the title of the content object or activity that has been accessed.
  - o `Source`: indicates the element in the KUOLE user interface through which a resource has been accessed. It can refer to either the "tree" that represents the hierarchical organization of resources in the learning unit or the open tab of a resource that is being used.
- In the table **QuestionInteraction**:
  - o Description: the purpose of this field is to distinguish the kind of activity that has been attempted. Among the different types of activities that can be implemented with CNXML, the types used in INFO055 and INFO023 courses are:

- Activities whose response is a piece of text (for answering a question) or code (for providing the solution to a programming exercise or task). In the case of INFO023, most of the programming exercises are presented to students with the option of accessing the teacher's response or retrieving their responses. Possible values established for this field include: "text response", "student solution request", "teacher solution request".
- Activities whose response corresponds to the selection of a single or multiple options (used in quizzes). Quizzes provided to students in these courses often include the option to request a hint to help the student think of the correct response to a question. Possible values associated with this field include: "selected response", "unselected response" and "hint request".

o `HtmlInputId`: This field contains the identifier of those activity's HTML elements that contain or represent the student's response to such activity. It is a mandatory parameter in learning materials developed under CNXML.

o `QuestionItemType`: This field contains the type of exercise (either a text response question or a single or multiple choice question)

o `Response`: This field contains the student's response to a proposed exercise or question.

The development of customized software was required to analyse the sequence of resource and question interactions as well as their respective fields in order to extract the learning metrics associated with each learning unit. Learning metrics represent the interactions and performance of a student per lesson in the course. Therefore, in the case of INFO055, each student is associated with ten sets of learning metrics (i.e. one set per learning unit in the course) and, in the case of INFO023, each student is associated with eight sets of learning metrics (since KUOLE was only used for the first eight lessons of the course). Table 5 lists the metrics contained in each set.

Table 5. *Learning Metrics Variables*

| INFO055 | INFO023 |
|---|---|
| Total Sessions | Total Sessions |
| Lesson Time | Lesson Time |
| Slides Visits | Slides Visits |
| Slides Time | Slides Time |
| Video Visits | Video Visits |
| Video Time | Video Time |
| Donwloads Visits | Interactive Examples Visits |
| Downloads Time | Interactive Examples Time |
| Instructions Visits | Interactive Materials Visits |
| Instructions Time | Interactive Materials Time |
| Quiz Visits | Quiz Visits |
| Questions Answered | Questions Answered |
| Hint Requests | Hint Requests |
| Questions Skipped | Questions Skipped |
| Quiz Time | Quiz Time |
| Exercises Visits | Exercises Visits |
| Exercises Answered | Exercises Answered |
| Exercises Skipped | Exercises Skipped |
| Exercises Time | Exercises Time |
| Tasks Visits | Student Solution Requests |
| Tasks Answered | Student Solution Time |
| Tasks skipped | Teacher Solution Requests |
| Tasks Time | Teacher Solution Time |
| Formative Performance | Formative Performance |

## 3.3.2. Felder–Silverman Index of Learning Styles Questionnaire

With the aim of providing academic practitioners with a tool that allows them to discover students' learning styles in order to plan their teaching strategies and resources, the DEA system (De la Maza et al., 2014) was developed at the Institute of Informatics at UACh. The DEA system includes the questionnaires and results of three different learning style models: the Felder–Silverman Index of Learning Styles (ILS) derived from the FSLSM (Felder & Silverman, 1988); the Herrmann Brain Dominance Instrument (Herrmann, 1991); and the SOLO taxonomy (Biggs, 1979). The DEA provides a visualization mechanism for teachers to select a model and observe the learning style of a particular student.

The FSLSM, the model selected for this research, interprets students' learning in four dimensions (Felder & Silverman, 1988):

- *The Active–Reflective dimension informs about the manner in which a learner processes new information.*

Active learners like to try things out, they learn better when they are engaged in an activity or a discussion. In contrast, reflective learners prefer to reflect on things, they tend to learn better through introspection.

- *The Sensing–Intuitive dimension informs about the type of information a learner preferentially perceives.*

Sensing learners are guided better by external information that they can see, hear or physically sense; intuitive learners are better guided by internal information like possibilities, insights, or hunches.

- *The Visual–Verbal dimension indicates the sensory channel through which a learner perceives external information most effectively.*

Visual learners tend to remember best the data they have seen, for example, in the form of pictures, diagrams, figures, animations, graphs, and demonstrations; verbal learners remember information best in the form of words that they can hear, read, or say.

- *The Sequential–Global dimension informs about the manner in which a learner understands information.*

Sequential learners progress towards understanding in a continuous, ordered, and step-by-step sequence, whereas global learners learn in big leaps, in such a way that at the beginning they seem not to comprehend anything but "suddenly" they put everything together and get the "big picture".

The questionnaire containes 44 single choice questions. It allows a range of these dimensions in an interval that goes from [±11, ±11] and distinguishes three categories within each dimension: a strong preference is located in an interval [±11, ±9], a moderate preference is located in the interval [±7, ±5], and a balanced preference in the interval [+3, -3].

| | Fuerte | | Moderado | | Equilibrado | | | | Moderado | | Fuerte | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 11 | 9 | 7 | 5 | 3 | 1 | 1 | 3 | 5 | 7 | 9 | 11 | |
| ACTIVO | | X | | | | | | | | | | | REFLEXIVO |
| SENSITIVO | | | | | | | X | | | | | | INTUITIVO |
| VISUAL | X | | | | | | | | | | | | VERBAL |
| SECUENCIAL | | | | | | | | | | X | | | GLOBAL |

**Figure 23.** DEA Visualization of a Student's Score on the Felder–Silverman Index of Learning Style

Figure 23 shows an example of how the DEA system allows us to visualize the results of a student who has completed the ILS questionnaire. Additionally, the system delivers on request a Microsoft Excel file with the learning styles results for all the students in a cohort. The results of this questionnaire can be interpreted as a vector composed of four odd integer coordinates. Additionally, the DEA offers the teacher a brief explanation of how to interpret these coordinates. In the example above, the information is presented as follows:

Student *X* Learning Style = [9, -1, 11,-7] which indicates,

- *Student X has a STRONG preference for the ACTIVE style with a value of 9. Active students learn new information better by doing something with it, for example, by practising, discussing, or applying it to some scenario.*
- *Student X has a BALANCED preference for the INTUITIVE style with a value of 1. Intuitive students tend to be good theorists and innovators. They understand abstract concepts and Maths quickly.*
- *Student X has a STRONG preference for the VISUAL style with a value of 11. Visual students prefer new information in the form of diagrams, figures, and graphics. They tend to remember better what they see.*
- *Student X has a MODERATE preference for the GLOBAL style with a value of 7. Global students learn in big leaps, visualizing the whole. It is difficult for them to explain their methodologies and results.*

This system was used to administer and collect the results for the ILS questionnaire[36] from students in INFO055 and INFO023 respectively. Cohort reports offered by the DEA system are Microsoft Excel documents that contain the list of students in the cohort and their corresponding learning styles vectors with no descriptive information.

[36] The questionnaire is available at http://www.engr.ncsu.edu/learningstyles/ilsweb.html. A sample of this questionnaire can be found in Appendix 9 at the end of this thesis.

### 3.3.3. Pedagogical Usability Survey

During INFO055 and INFO023 it was not possible to perform a direct evaluation of the design of the resources on the students' behalf. Instead, a psychometric survey was administered to them at the end of their respective courses. Students were asked to evaluate their courseware through a psychometric questionnaire[37] based on 12 affirmations. Each statement was designed to measure the student's perception of the resources' pedagogical usability, tackling the core pedagogical design attributes explained in Chapter 2.

In this questionnaire, students were asked to state their degree of agreement with each affirmation using a 1–5 Likert scale. The questionnaire was administered to students of INFO055 and INFO023 at the end of their respective courses.

## 3.4. Research Methods

### 3.4.1. Principal Components Analysis with PROMAX Rotation

The software used to perform this analysis was SPSS. To perform a PCA analysis upon a set of variables, first it is necessary to test the sampling adequacy of the data. The statistic used to test such adequacy is the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO). To perform a valid factor analysis, it is necessary that the KMO provides a value close to 1.0 and over .5. For INFO055 and INFO023 learning metrics this test shows an adequacy of .718 and .646 respectively, which are acceptable to carry on with the PCA (Beaumont, 2012).

Next, there are two aspects that need to be determined when applying PCA (and similar exploratory factor analysis techniques): (1) the number of components to extract and (2) the rotation. The number of components is a key decision to make since it impacts directly on the results obtained. SPSS offers two options: extracting all those components whose eigenvalue is greater than 1.0 or extracting the number of components specified by the researcher. Following conventional wisdom in the application of PCA, we chose the former (Costello, 2009).

The rotation type will not affect the final results. It is simply applied to clarify the structure "component-variables" and aids the interpretation of results (Costello, 2009). SPSS allows one to select between orthogonal and oblique rotations. Orthogonal rotations show uncorrelated components whereas oblique rotations show the correlation between components. The choice of one or other rotation depends on whether there is a good theoretical reason to think that components should be correlated (Kootstra, 2004). Nevertheless, where components are uncorrelated both rotations will produce nearly identical results, and conventional wisdom

[37] A sample of the Usability survey has been translated into English and can be found in Appendix 10 of this thesis.

suggests applying an orthogonal rotation to facilitate the interpretation of results (Abdi, 2003; Brown, 2009; Costello, 2009). In this investigation, it was expected that students' interactions with different types of learning resources would be correlated to each other, so an oblique rotation was chosen.

Among the different types of oblique rotation offered by SPSS, we selected a *PROMAX* rotation. The main results obtained from this analysis include: a *factor pattern matrix*, containing the coefficients for the linear combination of the behavioural variables; a *factor structure matrix*, which represents the correlations between the variables and the factors; and a *factor correlation matrix*, which shows the correlations between factors. For this investigation, only the factor structure and factor correlation matrices are shown and interpreted.

To facilitate explanations of obtained components, the following notation will be used to refer to a group of variables related to the same learning resource:

- The term *Tasks* is used to refer to the learning metrics obtained from students' interactions with programming tasks provided in the course: Tasks_Visits, Tasks_Answered, Tasks_Skipped, and Tasks_Time.
- The term *Exercises* is used to refer to the group of learning metrics obtained from students' interactions with programming exercises provided in the course: Exercises_Visits, Exercises_Answered, Exercises_Skipped, and Exercises_Time.
- The term *Quizzes* is used to refer to the group of metrics obtained from students' interactions with comprehension quizzes provided in the course: Quiz_Visits, Questions_Answered, Hint_Requests, Questions_Skipped, and Quiz_Time.
- The term *Slides* is used to refer to the group of learning metrics obtained from students' interactions with slide content resources provided in the course: Slides_Visits, Slides_Time
- The term *Instructions* is used to refer to the group of learning metrics obtained from students' interactions with "instruction" content resources provided in the course: Instructions_Visits, Instructions_Time.
- The term *Downloads* is used to refer to the group of learning metrics obtained from students' interactions with downloadable worked examples provided in the course: Downloads_Visits, Downloads_Time.
- The term *Videos* is used to refer to the metrics obtained from student interactions with video materials provided in the course: Video_Visits, Video_Time.
- The term *Performances* is used to refer to students' formative and summative marks gained during and at the end of the course respectively: Formative, Summative.

- The terms *Interactive Examples* and *Interactive Materials* are used to refer to the group of metrics associated with student interactions with these resources: Interactive_Examples_Visits, Interactive_Examples_Time, Interactive_Materials_Visits and Interactive_Materials_Time respectively.

## 3.4.2. Kruskal–Wallis Hypothesis Test

As has been previously explained in the subsection 3.2.3, the Kruskal–Wallis Hypothesis Test (or, K–W H-Test) is applied in this investigation with the purpose of confirming whether specific learning styles are responsible for existing variations in students' behavioural metrics. Therefore, the dependent variables selected to perform this analysis correspond to those learning metrics that represent students' interactions with content resources and activities. This research aims to prove the hypothesis that different learning styles influence the behavioural metrics. The null hypothesis would affirm the opposite.

To facilitate the understanding of the Kruskal–Wallis procedure and the interpretation of results in the subsection below, Figure 24 shows a flow chart of the steps to follow when performing this statistical method.

*i. Hypothesis Test*

The first results returned by the SPSS allow one to identify for which particular variables the null hypothesis might be rejected. It is based on the calculation of an approximated p-value that increases with the sample size. The significance level determined for this analysis is .05, which implies that the association between the dependent variable and the independent variable is statistically significant at a 95% of confidence (Rubio & Berlanga, 2012).

Those variables whose p-value is above .05 in the hypothesis test are an indication that students' behaviour is similar across groups; and therefore the null hypothesis cannot be rejected. In these cases, groups' behaviour is not further analysed. On the other hand, those variables whose p-value is below .05 in the hypothesis test are an indication that students' behaviour is not similar across groups; therefore the null hypothesis is rejected. In these cases, it is necessary to analyse the groups' behaviour to identify specific differences among them concerning their learning preference.

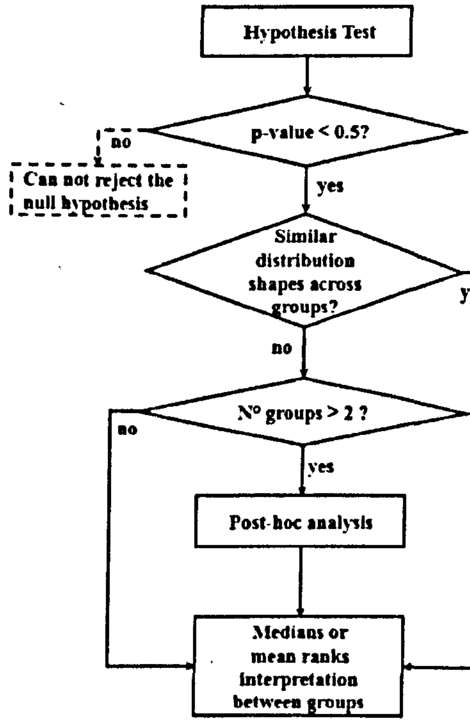



Figure 24. Workflow of Kruskal-Wallis Hypothesis Test

*ii. Distribution visualization across groups*

Many non-parametric tests (such as Kruskal–Wallis or Mann–Whitney tests) are not concerned with the actual values of dependent variables. Instead, they focus on their relative values, i.e. *mean ranks*. For this reason, these tests are frequently defined as "mean-rank based non-parametric tests". The use of mean ranks in the Kruskal–Wallis H test is relevant for two reasons: first, mean ranks provide an indication of how the values of dependent variables are different between categories, and second, the mean rank is linked to stochastic homogeneity, so the differences in original values' variances are solved.

To determine whether there is a statistically significant difference in the medians of the groups associated with an independent variable, the shapes of the distributions in each group must be similar to each other. If shapes are dissimilar among them, then it is not possible to make inferences about the group's medians, so the differences between groups will be based on *mean ranks*. The results obtained from this analysis are revealed by this criterion. A boxplot diagram shows the distribution shape of the variable for each group associated with a learning style dimension (independent variable).

The significance across groups obtained in the hypothesis test does not allow one to observe statistical significances between groups with regard to a particular behavioural metric (dependent variable). Therefore, post-hoc analysis will be required to identify such differences.

*iii. Statistically significant differences between groups*

Post-hoc analyses were performed in this research with two aims: first, to compare each group's behaviour with the others; and second, to determine whether variations in behaviour between groups of students are statistically significant.

Post-hoc analyses are especially necessary when there are more than two groups to compare in order to observe which of these comparisons are significant and which are not. These analyses consist of performing pair-wise comparisons to observe the differences between each group combination. In SPSS, the procedure to perform pairwise comparisons in a Kruskal–Wallis analysis uses Dunn's procedure with a Bonferroni correction for multiple comparisons[38] in this way: new significance levels are calculated and adjusted in accordance with the level of significance initially established (in this case, .05) and the number of comparisons to perform. For example, if there are four groups of students, six pairwise comparisons will be required to observe differences among groups (combination without repetition). The adjusted significance value would be .05 divided by six, resulting in a p-value = .0083. The adjusted significance level used for interpretations is then recalculated with respect to the original.

The number of dependent variables analysed in these samples (21 variables) originated a tremendous amount of visualizations and statistical tables that initially retain the null hypothesis. For this reason, the results explained in the following subsection only report those metrics that rejected the null hypothesis in the first test, showing a K–W statistical significance below .05.

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[38] "SPSS Statistics generates the pairwise comparison results according to the procedure described by Dunn (1964). This particular procedure uses the whole data set when making each pairwise comparison in a manner similar/analogous to post hoc tests following a one-way ANOVA. It is also possible to run multiple Mann-Whitney U tests – one for each pairwise comparison – with a correction for multiple comparisons (e.g., Bonferroni), but these tests will only use the data from the two groups being compared. As such, there is no guarantee that the results of these two methods will agree. Unfortunately, there is disagreement on which method should be used for pairwise comparisons (although the Dunn (1964) procedure can be justified) and if the results of the two methods disagree substantially then replication studies with large samples might be warranted (Sheskin, 2011)." (*Statistics.laerd.com. Kruskal-Wallis H test in SPSS statistics – interpreting and reporting post-hoc tests [online].*)

## 3.5. Case Studies INFO055 and INFO023

Two different courses were chosen for the case studies presented in this research. The common characteristic of both courses is that they are introductory courses to the subject of programming in Java language:

- INFO055 was offered at the Institute of Informatics at UACh as an optional course available for all students of a degree in Engineering. In this university, this course was the first course taught in the English language.

- INFO023 is offered at the Institute of Informatics at UACh as part of the core programme for first-year students in the Computer Engineering degree.

Table 6 below summarizes the characteristics of these courses regarding the period when the course took place, the data gathered, and the number of students in each course.

**Table 6.** *UACh Case Studies*

| Course | Number of students | Course Duration | Data Gathering Period |
|---|---|---|---|
| INFO055 (UACh) | 11 | September 2012–December 2012 | September 2012–December 2012 |
| INFO023 (UACh) | 18 | March 2013–July 2013 | March 2013–May 2013 |

The rest of this section describes the traditional teaching strategy adopted in these courses. It explains the combination of theoretical and practical lectures offered during each course, the usage of institutional LMSs, and the incorporation of the KUOLE platform into the teaching plan. Likewise, it details the assessment methods applied in each participating course.

### 3.5.1. Teaching strategies

The INFO055 course originated as a consequence of academic collaboration agreements between UACh and Kingston University. INFO055 was a pilot course with a two-fold objective: (1) to apply a blended learning approach in programming subjects for novice students who have never used e-learning platforms or learning objects during their education; and (2) it was seen as an opportunity to reinforce the Chilean students' level of English, so this course was taught in this language.

The teaching strategy applied in INFO055 was inspired by the teaching method applied in an equivalent level module offered at Kingston University, "Introduction to Object Oriented Programming in Java" (coded as

CO1040). It combines a series of weekly face-to-face lectures and practical workshops. The concepts delivered are practised through a set of programming activities proposed in the corresponding weekly workshop. Likewise, problem-solving sessions are provided on request to allow students to obtain help with understanding the material, to encourage them to think through the programming assignments in a structured way before attempting to write the code, or to solve problems in attempted programming activities.

In contrast with CO1040 which used two e-learning platforms for the course, KUOLE is the only learning environment used in INFO055 in either face-to-face lectures or practical workshops. As explained in more detail in Section 6, the platform was only designed to deliver course learning activities developed in CNXML language, so it had to be modified and extended to enable the delivery of different kinds of learning materials as well.

Another significant circumstance in INFO055 is the background of the students. The course was offered as an optional course for all learners studying at the Faculty of Engineering – composed of different institutes or schools such as Informatics, Naval Architecture, Acoustic, Construction, etc. – regardless their academic year or background. In the final cohort, a total of three students belonged to Engineering programmes other than Computer Science.

INFO023, the second case study, is part of the core programme of studies for Computer Science undergraduate students at the Institute of Informatics. These are first-year students in their second semester of the year. The students already possessed basic knowledge of programming concepts and a similar level of experience in Python. A small number of the students (n=18) who had never used e-learning solutions to support their learning tasks. The course makes use of SIVEDUC, a platform for administrative purposes, developed at university level and applied to enable communication between the teacher and students and download documents with learning materials and activities for the course.

INFO023 applies a teaching strategy based on one face-to-face lecture and two practical workshops per week, where students attend to complete proposed programming exercises for each learning unit. The KUOLE platform is presented to students as an environment where they can access a wide variety of learning resources and keep a record of their work at practical sessions by submitting their responses to different learning activities. The module leader encourages students to use the platform but they are not forced to use it inside or outside the classroom or workshop. It is expected that this circumstance hinders the empirical results obtained in this study, so its influence is considered in the discussion offered at the end of the chapter.

### 3.5.2 Assessment methods

In INFO055, the assessment of learning objectives is performed by the completion of programming assignments proposed during the course and a final in-class test. Such tests are composed of questions about programming concepts and code comprehension. A maximum of 40% of the final grade corresponds to the performance on the completion of the course's learning activities (i.e. quizzes, exercises and programming assignments) and the other 60% corresponds to the mark obtained in the final test.

In contrast, assessment method in INFO023 combines the marks obtained in formative and summative in-class tests. These tests are programming problems and students are allowed to access and refer to all the learning materials and exercises in case they need it. In total there are four formative exams and three summative ones; the weight assigned to the performance in each test is detailed as follows:

- The average of the marks obtained in the four formative tests comprises 25% of the final grade.
- The mark obtained in each one of the three summative tests contributes another 25% each with respect to the final grade.

The assessment method is relevant for data gathering in this study. Since the module leader of INFO055 takes into account the performance in lesson activities in the final grade, it is expected that students, even though they are not forced to use KUOLE, will use the platform to demonstrate their work during the course. The assessment method in INFO023 does not consider such performance which poses an obstacle for gathering data from INFO023 students. Students are not forced to submit any of their solutions to programming activities, but they are strongly recommended to submit their work since it will be useful for them as a resource to refer to during practical workshops, and formative and summative tests.

## 3.6 Summary of Chapter 3

The methodology presented in this chapter conforms to the typical practitioner-led research scenario where data collected, instruments applied for their collection, and analysis methods constitute the core of this methodology. The specific circumstances of the courses from which these data were collected were not under complete experimental control and required pragmatic solutions that might affect the results. Examples are: the fact that none of the students on either of the courses had ever used an e-learning platform or a learning object as additional tools for learning; the course is optional; and the varied backgrounds of students on an optional course that is not part of their core programme studies, etc.

The statistical methods described will be applied to the data collected from the case studies separately and the results obtained will be presented in the following chapter.

# Chapter 4

# Analysis of Results

This chapter presents the results obtained from running statistical methods explained in the previous chapter, i.e. PCA and the Kruskal–Wallis H Test and basic statistics calculated to observe students' perceptions of the usability of materials and activities proposed during their corresponding programming course. These results are presented and discussed in this chapter as follows:

First, the results presented in Section 4.1 correspond to the PCA method. Since the method was run for each case study individually, the results for INFO055 are presented in subsection 4.1.1 and INFO023 in subsection 4.1.2.

Second, and according to the methodology adopted in Chapter 3, Section 4.2 presents two different groups of results. First, an initial exploration of existing learning style groups was performed in both courses and the results are presented in subsection 4.2.1. Second, the application of the Kruskal–Wallis procedure to verify the relationship between students' learning styles and their actual behaviour with resources and activities are presented in subsections 4.2.2 and 4.2.3 for INFO055 and INFO023 case studies respectively.

The third group of results corresponds to the analysis of usability survey administered to students, which is explained in Section 4.3. This section also includes the reliability coefficient of the instrument designed to gather students' responses.

The interpretation of individual results is offered in the subsections mentioned and they are discussed in Section 4.4. The chapter concludes with the problems and limitations caused by the methodology adopted and uncontrolled external factors.

## 4.1. Learning Metrics and Performance Relationships

The learning metrics showed a KMO adequacy of .718 for INFO055 and .646 for INFO023, which are acceptable to carry on with the PCA method (Beaumont, 2012).

To facilitate explanations of the components obtained, the following notation will be used to refer to a group of variables related to the same learning resource:

- The term *Tasks* is used to refer to the learning metrics obtained from students' interactions with programming tasks provided in the course: `Tasks_Visits`, `Tasks_Answered`, `Tasks_skipped`, and `Tasks_Time`.

- The term *Exercises* is used to refer to the group of learning metrics obtained from students' interactions with programming exercises provided in the course: `Exercises_Visits`, `Exercises_Answered`, `Exercises_Skipped`, and `Exercises_Time`.

- The term *Quizzes* is used to refer to the group of metrics obtained from students' interactions with comprehension quizzes provided in the course: `Quiz_Visits`, `Questions_Answered`, `Hint_Requests`, `Questions_Skipped`, and `Quiz_Time`.

- The term *Slides* is used to refer to the group of learning metrics obtained from students' interactions with slide content resources provided in the course: `Slides_Visits`, `Slides_Time`

- The term *Instructions* is used to refer to the group of learning metrics obtained from students' interactions with "instruction" content resources provided in the course: `Instructions_Visits`, `Instructions_Time`.

- The term *Downloads* is used to refer to the group of learning metrics obtained from students' interactions with downloadable worked examples provided in the course: `Downloads_Visits`, `Downloads_Time`.

- The term *Videos* is used to refer to the metrics obtained from student interactions with video materials provided in the course: `Video_Visits`, `Video_Time`.

- The term *Performances* is used to refer to students' formative and summative marks gained during and at the end of the course respectively: `Formative`, `Summative`.

- The terms *Interactive Examples* and *Interactive Materials* are used to refer to the group of metrics associated with student interactions with these resources: `Interactive_Examples_Visits`, `Interactive_Examples_Time`, `Interactive_Materials_Visits` and `Interactive_Materials_Time` respectively.

### 4.1.1. Results for INFO055

The rotated matrix (Table 7) shows that 23 learning metrics have been simplified into six components. It can be noticed that metrics associated with learning activities (highlighted in orange) and academic performances (highlighted in green) are clearly separated from metrics associated with content materials (highlighted in blue). This result suggests a generalized disconnection between the usage of content resources and the completion of learning activities; it also shows that interactions with learning activities have exerted a bigger impact on academic performance than content materials provided during the course. To obtain more specific information the analysis and interpretation of the loadings in each component is described as follows:

**Component 1: Programming Activities and Performances**

The highest loadings in this component correspond to the variables Tasks, Exercises and Performances. Active behavioural metrics (i.e. visiting, answering and spending time) with programming activities correlate positively with academic performance, whereas passive metrics (i.e. skipping activities) correlate negatively.

Loadings for Quizzes are lower in this component but also correlate positively with the completion of Tasks and Exercises, as well as with Performances. This suggests that performing comprehension assessment of programming concepts available in a lesson impacts to a minor degree on the overall course performance. Also, it indicates that interacting with lesson activities, in particular with programming activities, improves students' course performance whereas not interacting worsens it. This interpretation makes intuitive sense with the conventional wisdom that programming is learnt by practice (Neve, Hunter, Livingstone, & Orwell, 2012).

Loadings for Content resources in this component are missing (values under 0.3 are not shown in the table), implying that these resources have not influenced the completion of programming activities or academic performances.

**Component 2: Quizzes**

The highest loadings in this component correspond to learning metrics related to comprehension activities. In this component both Exercises and Tasks present positive correlations with the completion of Quizzes. Similarly to component 1, this suggests that the completion of programming activities encourages the completion of quizzes.

Regarding content resources, most of them do now show relevant correlations except Slides. Visits and time spent with slide-based materials correlate positively in this component. Thus, students used these materials as a main support to complete exercises and quizzes in the lesson.

**Table 7.** *PCA55 Factor Structure Matrix*

| | Component | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Tasks_Skipped | -.893 | | | | | |
| Exercises_Answered | .888 | .500 | | | | |
| Formative | .871 | | | | | |
| Tasks_Answered | .869 | | | | | |
| Exercises_Skipped | -.866 | -.394 | | -.322 | | |
| Exercises_Time | .797 | .468 | | | | |
| Summative | .726 | .488 | | .303 | .303 | |
| Tasks_Time | .653 | | | | | .351 |
| Questions_Skipped | -.651 | -.507 | | -.310 | -.351 | .315 |
| Quiz_Visits | .453 | .921 | | | | |
| Questions_Answered | .541 | .866 | | | | |
| Quiz_Time | .550 | .750 | | | | |
| Hint_Requests | | .737 | | | | |
| Downloads_Time | | | .893 | | .349 | |
| Donwloads_Visits | | | .826 | | | |
| Video_Visits | | | .792 | | .499 | |
| Slides_Time | | | .688 | -.343 | .522 | |
| Video_Time | | | | .823 | | |
| Exercises_Visits | .677 | .381 | | .695 | | |
| Instructions_Time | | | | | .737 | |
| Instructions_Visits | | | | | .730 | |
| Tasks_Visits | .516 | .437 | | | | .748 |
| Slides_Visits | | .454 | .510 | | .561 | .615 |

**Component 3: Content Materials**

The highest loadings in this component correspond to the Downloads, Videos and Slides content resources. It is worth noting that metrics with these resources correlate positively in this component. Thus, in lessons where all these materials are provided, students have made use of all of them, indicating a coherent connexion between their respective contents. The only resource which does not present relevant loadings with these is Instructions. Loadings of learning activities and performances are also missing, which suggests that, in general, interactions between learning activities and content resources are not related to each other.

**Component 4: Video-Exercises**

The time spent with video materials represents the highest loading in this component. Except the total visits to exercises, other metrics related to content resources and activities do not show significant loadings and, therefore, no significant correlations with the time in video materials. This result indicates that students spent time watching available videos in the lesson while working on proposed exercises. Thus, video resources provided students with a good support when completing programming activities.

**Component 5: Instructions**

The highest loadings in this component correspond to Instructions. Slides, Videos and Downloads present lower and positive correlations with Instructions. This may suggest that students reading Instruction materials in a lesson also resort to Slides, more than resorting to Videos or Downloads available.

Since Instruction materials are designed to present the student with learning objectives intended to be achieved during programming activities, it is surprising that associated behavioural metrics with exercises and tasks do not show loadings in this component.

**Component 6: Tasks-Slides**

In this last component visits to programming tasks, visits slide materials and skipping quiz activities correlate positively in this component. This result may imply that instead of investing the time in performing self-assessment, students rather invest their time in actually programming and resort to slide materials if any support is needed.

The factor correlation matrix (Table 8) presents the correlations between components.

**Table 8.** *PCA55 Component Correlation Matrix*[a]

| Component | Prog. Activities. and Performance | Quizzes | Content Materials | Video - Exercises | Instructions | Tasks - Slides |
|---|---|---|---|---|---|---|
| Prog. Activities. and Performance | 1.000 | .346 | -.178 | .200 | .060 | .057 |
| Quizzes | .346 | 1.000 | .034 | .083 | .271 | .215 |
| Content Materials | -.178 | .034 | 1.000 | -.044 | .434 | .148 |
| Video-Exercises | .200 | .083 | -.044 | 1.000 | .035 | -.170 |
| Instructions | .060 | .271 | .434 | .035 | 1.000 | .046 |
| Tasks-Slides | .057 | .215 | .148 | -.170 | .046 | 1.000 |

One of the highest correlations occurs between the factor Programming Activities and Performances and the factor Quizzes (.346). This result suggests that performing exercises and tasks in lessons slightly encourages the students to perform self-assessment tasks in the lesson and vice versa. However, this correlation is very low.

With respect to other components, even lower correlations are found with those representing content materials, Content Materials (-.178) and Instructions (.06). These results seem to indicate that interacting with programming activities has not implied the interaction with associated content resources in the lesson; on the contrary: Programming Activities and Performances correlating negatively with Content Materials means that more interactions with slide materials, worked examples of code, and videos imply fewer interactions with programming activities and therefore worse academic performance. Although this correlation is very low, it is not desirable at all. On the other hand, Instruction materials are designed to be resorted to when students complete programming activities as they provide information about learning objectives. Therefore, a correlation of .06 suggests that students did not perceive these materials as important when attempting exercises and tasks in lessons.

The second highest correlation occurs between Content Materials and Instructions (.434). This result suggests that when accessing content materials in a lesson, students tend to visit all the resources available. However, the content of Instruction materials is not explicitly associated with the contents of the other materials, which may explain this low correlation.

### 4.1.2. INFO023 Results

Table 9 shows that six components that form the rotated matrix obtained for this course. At first sight, it gains our attention that students' academic performances are clearly separated from their learning metrics, being associated with the last component of the solution. Also, it can be noticed that variables corresponding to learning activities and content materials are, in comparison with INFO055, more spread and mixed across components.

**Component 1: Programming Activities**

The highest loadings in this component correspond to interactions with programming exercises. The metrics associated with students' requests for the solution to exercises are positively correlated with the metrics of visits, answers, and time spent with exercises. These results suggest that, when visiting exercises, students have either submitted their solution to the exercise or reviewed solutions previously submitted. Similarly to PCA55, Quizzes present positive correlations, indicating that the completion of comprehension activities has an effect upon the completion of exercises.

With respect to content materials, only the time spent with Interactive Examples shows a significant positive correlation. Thus, students who first interact with these materials feel motivated or prepared to attempt exercises.

**Component 2: Quizzes – Interactive Examples**

The highest loadings in this component correspond to interactions with Quizzes and Interactive Examples. They are all positively correlated which may suggest that performing comprehension activities as well as interacting with programming visualization-based examples impact on each other.

The number of skipped exercises in this component correlates negatively with these loadings (-.520). Thus, students who complete Quizzes and try Interactive Examples tend to skip exercises to a minor degree.

**Component 3: Videos - Slides**

Visits and time spent with Videos and Slide materials show the highest loadings in this component. These variables correlate positively within this component, which implies that in lessons providing these materials (in this case lesson 6) students have interacted with videos as much as they did with slide materials. Skipped questions correlate negatively (-.320) – students interacting with these materials tend to skip self-assessment tasks to a minor degree.

**Component 4: Teacher Solution**

The highest loadings in this component refer to particular metrics extracted from students' interactions with Exercises in each lesson. The time spent with exercises, requests for the teacher's solution, and the time spent reviewing this solution correlate positively within this component.

The presence of the variables `Exercises_Visits` and `Exercises_Time` and the lack of `Exercises_Answered` variable in this component should be noted. Thus, students accessing exercises frequently did so to access the teacher's solution while performing the exercise and afterwards the answer was not submitted. It is possible that the students access teacher's solution to reuse the code when they face new related exercises.

**Component 5: Interactive Materials**

The highest loadings in this component correspond to Interactive Materials presenting positive correlations, in contrast to Interactive Examples and skipped questions, which correlate negatively with the component. This result suggests that students who interact with Interactive Materials tend to skip comprehension activities to a minor degree, whereas they also tend to interact less with interactive examples.

**Component 6: Academic Performance**

As indicated at the beginning of this analysis, the highest loadings in this component correspond to students' academic performances. None of the metrics associated with learning activities or content resources present significant correlations in this component. This manifests that such grades are not related to the usage of the KUOLE platform or the learning resources provided.

**Table 9.** *PCA23 Factor Structure Matrix[a]*

| | Component | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| **Exercises_Visits** | .903 | | | .409 | | |
| **StudentSolution_Requests** | .875 | .474 | | | | |
| **Exercises_Answered** | .824 | .391 | | | | |
| **StudentSolution_Time** | .784 | .336 | | | | |
| **Exercises_Time** | .771 | | | .717 | | |
| **Questions_Answered** | .509 | .869 | | | | |
| **Quiz_Visits** | .417 | .865 | | | .332 | |
| **Quiz_Time** | | .827 | .371 | | | |
| **InteractiveExamples_Time** | .564 | .696 | | | -.479 | |
| **Hint_Requests** | | .679 | | | | |
| **InteractiveExamples_Visits** | .458 | .609 | | | -.493 | |
| **Exercises_Skipped** | | -.520 | | | | |
| **Video_Visits** | | | .924 | | | |
| **Slides_Visits** | | | .885 | | | |
| **Slides_Time** | | | .806 | | | |
| **Video_Time** | | | .740 | | | |
| **TeacherSolution_Time** | .310 | | | .863 | | |
| **TeacherSolution_Requests** | | | | .843 | | |
| **InteractiveMaterials_T** | | | | | .671 | |
| **InteractiveMaterials_Visits** | | .305 | | | .639 | |
| **Questions_Skipped** | | | -.320 | | -.534 | |
| **Formative** | | | | | | .898 |
| **Summative** | | | | | | .896 |

As happened with the analysis of INFO055, the correlations found between the components are very low. The factor correlation matrix (Table 10) presents these correlations:

The highest correlation is found between the components Programming Activities and Quizzes-Interactive Examples (.459). This suggests that students performing exercises tend to perform self-assessment tasks in the lessons and vice versa; and that the content materials that seem to encourage the completion of lesson activities the most are interactive examples, whose design is inspired by Programming Visualization techniques.

The remaining correlations between activities interactions and videos or slides are positive (.083), whereas the correlation between activities interactions and interactive materials are negative (-.027). Both correlations are almost insignificant. This result suggests that, in lessons where interactive materials are available, their contents do not encourage the completion of exercises.

**Table 10.** *PCA23 Component Correlation Matrix*

| Component | Programming Activities | Quizzes – Interactive Examples | Videos - Slides | Teacher Solution | Interactive Materials | Academic Performance |
|---|---|---|---|---|---|---|
| Programming Activities | 1.000 | .459 | .083 | 2.67 | -.027 | .048 |
| Quizzes – Interactive Examples | .459 | 1.000 | .080 | -.088 | .033 | .022 |
| Videos - Slides | .083 | .080 | 1.000 | .142 | .153 | .034 |
| Teacher Solution | .267 | -.088 | .142 | 1.000 | .000 | .013 |
| Interactive Materials | -.027 | .033 | .153 | .000 | 1.000 | .194 |
| Academic Performance | .048 | .022 | .034 | .013 | .194 | 1.000 |

## 4.2 Learning Styles and Learning Metrics

### 4.2.1. Exploration of learning style groups

An initial exploration of students' learning styles was performed according to this categorization. Tables 11 and 12 show the number of students with each level of preference in both courses. The small size of the samples allow a limited study of the relationship between behavioural and learning metrics in terms of different learning styles.

With regard to the Active–Reflective (AR) dimension, both courses contain balanced and moderately reflective students, whereas only a group in INFO023 composed of four students will allow analysis of the influence of the moderately active preference.

A similar situation occurs with the existing groups for the Sensing–Intuitive (SI) dimension. Comparisons are possible between INFO055 and INFO023 for balanced and moderately intuitive students, whereas only INFO023 provides samples to analyse the Sensing preference in more detail.

There is more variability in the Visual–Verbal (VV) dimension in both samples. Establishing differences and similarities between these cohorts is possible with balanced, moderately visual and moderately verbal preferences; however, only INFO055 allows study of the strongly visual preference in contrast with INFO023.

Finally, regarding the Sequential–Global (SG) dimension, it is possible to analyse the balanced and moderately sequential preference across courses whilst only INFO055 provides a small sample to study the moderately global preference.

**Table 11.** *INFO055 Student Groups according to Learning Style Dimensions*

| **Learning Style Dimension** | Groups | | | | |
|---|---|---|---|---|---|
| **Preference** | Balanced | Moderated | | Strong | |
| **Ranges** | [-3,+3] | [+5,+7] | [-7,-5] | [+11,+9] | [-11,-9] |
| **Active–Reflective (AR)** | 6 | Active 0 | Reflective 2 | Active 0 | Reflective 0 |
| **Sensing–Intuitive (SI)** | 4 | Sensing 0 | Intuitive 4 | Sensing 0 | Intuitive 0 |
| **Visual–Verbal (VV)** | 2 | Visual 1 | Verbal 3 | Visual 0 | Verbal 2 |
| **Sequential–Global (SG)** | 4 | Sequential 1 | Global 3 | Sequential 0 | Global 0 |

**Table 12.** *INFO023 Student Groups according to Learning Style Dimensions*

| **Learning Style Dimension** | Groups | | | | |
|---|---|---|---|---|---|
| **Preference** | Balanced | Moderated | | Strong | |
| **Ranges** | [-3,+3] | [+5,+7] | [-7,-5] | [+11,+9] | [-11,-9] |
| **Active–Reflective (AR)** | 9 | Active 5 | Reflective 4 | Active 0 | Reflective 0 |
| **Sensing–Intuitive (SI)** | 9 | Sensing 3 | Intuitive 2 | Sensing 4 | Intuitive 0 |
| **Visual–Verbal (VV)** | 7 | Visual 7 | Verbal 1 | Visual 3 | Verbal 0 |
| **Sequential–Global (SG)** | 13 | Sequential 5 | Global 0 | Sequential 0 | Global 0 |

The learning style groups found are considered for the second part of the integrated analysis described in the research methodology: the Kruskal–Wallis ANOVA. The results obtained from this analysis are visualized and explained by the group classification.

The results obtained for the course INFO055 are summarized in Tables 13 to 30, whereas results obtained for the course INFO023 are summarized in Tables 31 to 34. In order to facilitate the understanding of these results it is important for the reader to notice that the figures and statistics referenced in these tables can also be found in Appendixes 1 to 4 and Appendixes 5 to 8 respectively at the end of this thesis[39].

[39] In addition the reader can also refer to Appendix 0, which offers an explanatory example of how to interpret these results step by step according to the graphics and statistics presented in Appendixes 1 to 8.

## 4.2.2. INFO055 Kruskal–Wallis H Test

When the K–W test was performed, the number of dependent variables analysed in these samples (21 variables) produced a tremendous amount of visualizations and statistical tables that initially retain the null hypothesis. For this reason, the results explained in the following subsection only report those metrics that rejected the null hypothesis in the first test, showing a K–W statistical significance below .05.

### 4.2.2.1. Active–Reflective groups

The Kruskal–Wallis H test was run to determine if there were differences in behavioural metrics between moderately reflective (n=2) and balanced (n=6) students. The hypothesis test results, distribution visualizations, and mean ranks obtained during this analysis are presented in Appendix 1 below.

The metrics related to content resources in the lessons and comprehension activities (i.e. quizzes) present similar distributions across the moderately reflective and balanced groups, with asymptotic significances above .05 (see Figures 25). However, most of the variables associated with programming activities show a good statistical significance (below .05) and reject the null hypothesis: `Exercises_Visits`, `Exercises_Answered`, `Exercises_Skipped`, `Exercises_Time`, `Tasks_Visits`, `Tasks_skipped` and `Tasks_Time`.

| | | | | |
|---|---|---|---|---|
| 14 | The distribution of Exercises_Visits is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .003 | Reject the null hypothesis. |
| 15 | The distribution of Exercises_Answered is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .010 | Reject the null hypothesis. |
| 16 | The distribution of Exercises_Skipped is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .007 | Reject the null hypothesis. |
| 17 | The distribution of Exercises_T is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .001 | Reject the null hypothesis. |
| 18 | The distribution of Tasks_Visits is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .012 | Reject the null hypothesis. |
| 20 | The distribution of Tasks_skipped is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .044 | Reject the null hypothesis. |
| 21 | The distribution of Tasks_T is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .000 | Reject the null hypothesis. |

**Figure 25.** INFO055 Active–Reflective Learning Dimension. Statistically Significant Hypothesis Test Results.

Distribution shapes for these variables present different shapes between moderately reflective and balanced groups, as shown in their respective boxplots. Since the cohort is divided into two groups the statistics obtained, along with the visualizations, allow distinguishing differences between groups' behaviour based on their respective mean ranks for each behavioural metric (Table 13).

These results show that, despite being a small group, moderately reflective students interacted much more with exercises in lessons than the students in the cohort who were balanced in this dimension. A similar trend can be noticed when analysing the interactions with programming tasks (Table 14).

**Table 13.** *Active–Reflective Groups.*
*Learning Metrics for Exercises with Statistically Significant Results*

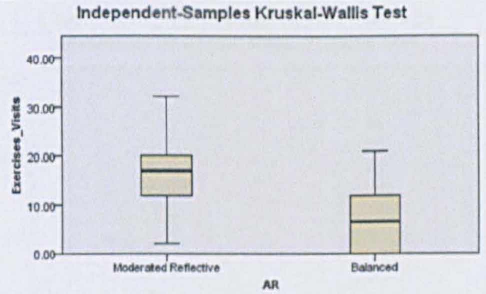
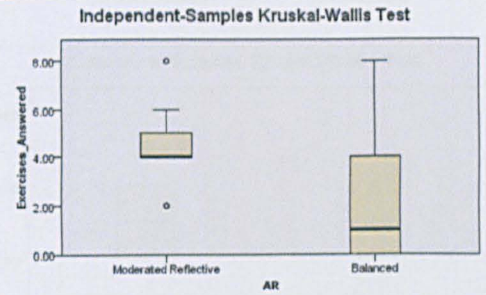
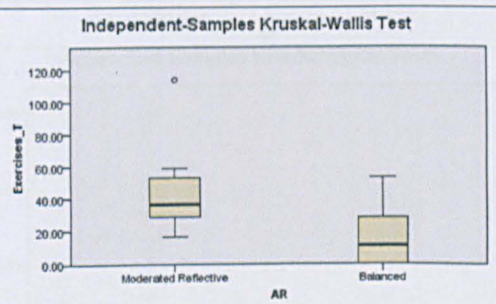
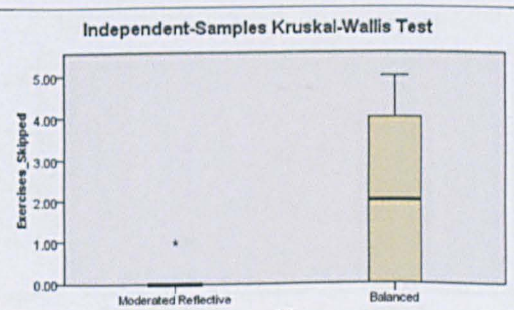
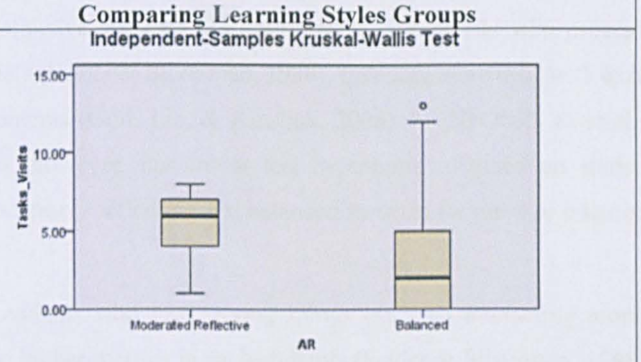
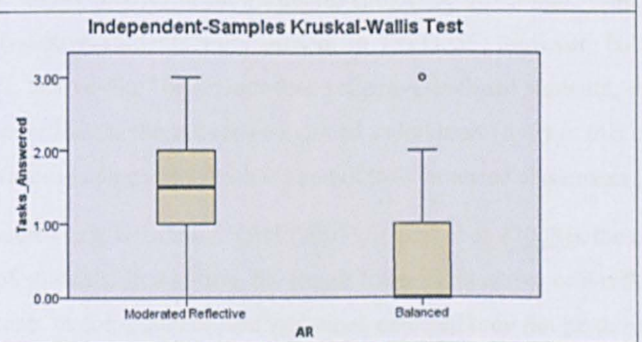
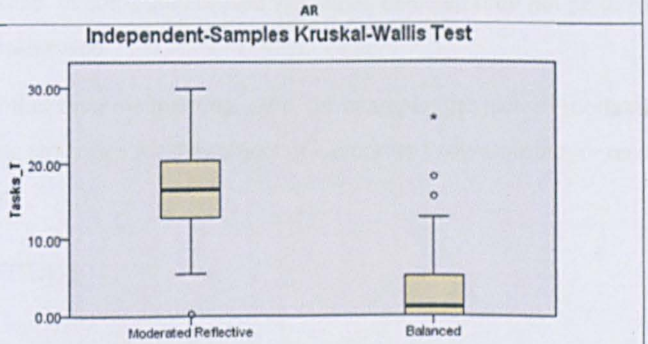
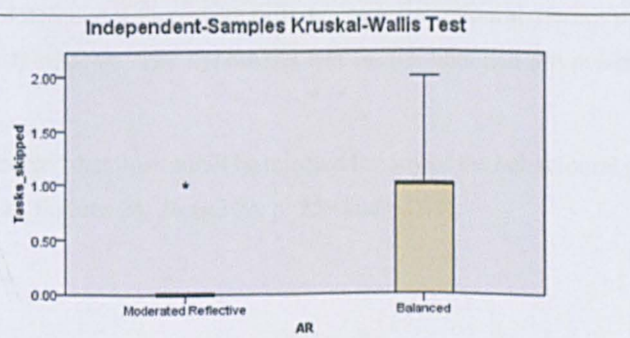
| Learning Interaction | K–W Mean Rank Box Plot Comparing Learning Styles Groups |
|---|---|
| **Visits to Exercises**<br>Dissimilar Distribution<br>Mean rank increased between moderate reflective (29.95) and balanced (17.35) students. The difference is statistically significant, $X^2$ (1) = 8.883, p=.003.<br><br>(Figure 1d) |  |
| **Number of Exercises Answered**<br>Dissimilar Distribution<br>Mean rank increased between moderate reflective (28.50) and balanced (17.93) students. The difference is statistically significant, $X^2(1) = 6.663$, p=.01.<br><br>(Figure 1e) |  |
| **Time Spent on Exercises**<br>Dissimilar Distribution<br>Mean rank increased between the moderate reflective (30.60) and the balanced (17.13) students, $X^2(1) = 10.109$, p=.001.<br><br>(Figure 1g) |  |
| **Number of Exercises Skipped**<br>Dissimilar Distribution<br>Mean rank increased between the balanced (23.1) and moderate reflective (12.7). The difference is statistically significant, $X^2(1) = 7.221$, p=.007.<br><br>(Figure 1f) |  |

**Table 14.** *Active–Reflective Groups.*
*Learning Metrics for Exercises with Statistically Significant Results*

| Learning Interaction | K–W Mean Rank Box Plot: Comparing Learning Styles Groups |
|---|---|
| **Visits to Tasks**<br>Dissimilar Distribution<br>Mean rank increased between moderate reflective (28.4) and balanced (17.87) students. The difference is statistically significant, $X^2(1) = 6.253$, p=.012.<br><br>(Figure 1h) |  |
| **Number of Tasks Answered**<br>Dissimilar Distribution<br>Mean rank increased between moderate reflective (26.05) and balanced (18.65) students. However, this difference is not statistically significant, $X^2(1) = 3.407$, p=.065.<br><br>(Figure 1k) |  |
| **Time Spent on Tasks**<br>Dissimilar Distribution<br>Mean rank is statistically significantly higher for the moderate reflective (31.6) than for the balanced (16.8) students, $X^2(1) = 12.274$, p=.000<br>(Figure 1j)<br>(SPSS shows K–W significances under .0005 as .000). |  |
| **Number of Tasks Skipped**<br>Dissimilar Distribution<br>Mean rank increased between the balanced (22.4) and moderate reflective (14.8). The difference is statistically significant, $X^2(1) = 4.07$, p=.044.<br><br>(Figure 1i) |  |

According to these results, a moderate reflective preference seems to have an important influence upon interacting with programming activities in lessons. However, this finding does not agree with the FSLSM or results reported by other related studies. Reflective students are described as individuals who process new information by reflecting upon content materials (Felder & Silverman, 1988), spending more time with examples and dealing more intensively with outline contents (Graf, Liu, & Kinshuk, 2008). In INFO055, examples and outlines are implemented in slide materials, however, our initial test hypothesis reflected no statistically significant differences in metrics between moderately reflective and balanced students for these or other content resources.

Active students, in contrast, are individuals who like "trying things out", so interacting more with exercises, tasks, or quizzes are expected to be higher metrics in such students (Felder & Silverman, 1988; Graf et al., 2008). Neither moderately or strongly-active students were present in INFO055, however, balanced students are supposed to show a slightly more "active-like" behaviour than reflective-inclined students, at least with the variables analysed in this section. Nevertheless, the reflective-inclined individuals (n=2) in this cohort interacted much more with programming activities in comparison with the rest of their balanced classmates (n=6).

In comparison with previous related studies (e.g. Kinshuk & Graf (2007) or Graf et al. (2008)), the results obtained correspond to a very small sample of students. In addition, the trends towards an active or a reflective preference in INFO055 is not strong in any case. In consequence, the variations detected may not be due to the influence of an active or reflective learning preference.

Instead, they might be due to factors other than the learning style, for example, the lack of motivation of balanced students, adopting the wrong learning strategies for the subject of Computer Programming, or resources designed with a very low pedagogical quality.

### 4.2.2.2. Sensing–Intuitive groups

The Kruskal–Wallis H test was run to determine if there were differences in behavioural metrics between moderately intuitive (n=4) and balanced (n=4) students. The hypothesis test results obtained are presented in Appendix 2 below.

The initial test of the null hypothesis showed that this cannot be rejected for any of the behavioural metrics observed for content resources or activities (see Figures 2a, 2b and 2c, p. 259 and p.261).

The statistical significances in this table are all above .05, which is an indication that the distribution and the median of each behavioural metric are similar across moderately intuitive and balanced groups. Therefore there are no variations in students' behaviour according to their preferences in this dimension.

### 4.2.2.3. Visual–Verbal groups

The Kruskal–Wallis H test was run to determine if there were differences in behavioural metrics between strongly verbal (n=2), moderately verbal (n=3), balanced (n=2) and moderately visual (n=1) students. The hypothesis test results, distribution visualizations, mean ranks, and post-hoc pairwise comparisons performed for this analysis are presented in Appendix 3 below.

The hypothesis test (Figure 26, extracted from Figures 3a, 3b and 3c, p. 265,267) indicated that the null hypothesis may be rejected for the variables: `Instructions_Time`, `Quiz_Visits`, `Hint_Requests` and `Exercises_Visits`. These variables correspond to interactions with different types of resources provided in lessons 2, 3, 4, 5 and 7 of the course: Instruction materials, Quiz activities and Exercise activities. The groups' behaviour concerning each variable is as follows:

| | | | | |
|---|---|---|---|---|
| 8 | The distribution of Instructions_Time is the same across categories of W. | Independent-Samples Kruskal-Wallis Test | .014 | Reject the null hypothesis. |
| 9 | The distribution of Quiz_Visits is the same across categories of W. | Independent-Samples Kruskal-Wallis Test | .026 | Reject the null hypothesis. |
| 11 | The distribution of Hint_Requests is the same across categories of W. | Independent-Samples Kruskal-Wallis Test | .035 | Reject the null hypothesis. |
| 14 | The distribution of Exercises_Visits is the same across categories of W. | Independent-Samples Kruskal-Wallis Test | .038 | Reject the null hypothesis. |

***Figure 26.*** *INFO055 Visual–Verbal Learning Dimension.*
Statistical Significant Hypothesis Test Results

First, regarding the time spent with Instruction materials, it was necessary to observe the shape of the distributions of the mean ranks calculated for each group. However, to observe specific differences between existing groups, post-hoc analysis was required. Table 15 below summarizes the results obtained.

**Table 15.** *INFO055 Visual–Verbal Groups.*
*Statistically Significant Results for Time spent with Instruction Materials.*

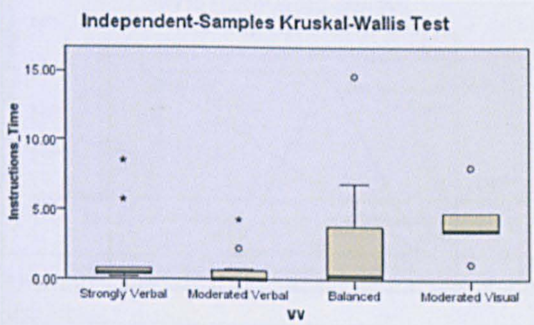
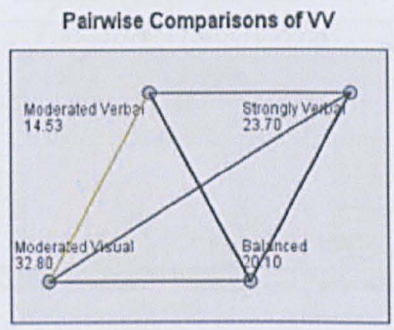
| **Learning Metric: Time spent with Instruction Materials** | |
|---|---|
| **K–W Mean Rank Box Plot:**<br>**Distribution Shape Comparisons** | **K–W Mean Rank**<br>**Pairwise Comparisons** |
| <br> | <br> |
| Mean rank distributions present dissimilar shapes across groups. It is necessary to perform post-hoc analysis (pairwise comparisons between these groups to observe differences)<br>(Figure 3d) | Six pairwise comparisons were performed.<br>Mean rank increased between moderately visual (32.8) and moderate verbal (14.53) students. It is statistically significant, p = .012<br>(Figure 3e) |
| **Statistically significant Median values**<br>(Table 3.2)<br>Moderate verbal = 0.0000<br>Moderate visual = 3.5592 | Influence of the visual style preference on the time spent on Instruction materials |

**Table 16.** *INFO055 Visual–Verbal Groups.*
*Statistically Significant Results for Visits to Quiz Activities.*

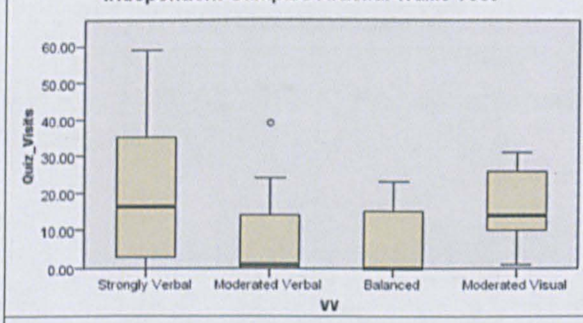
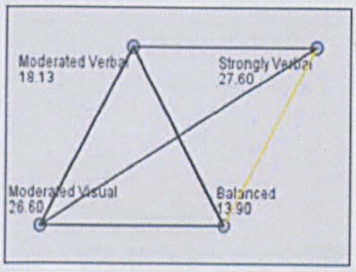
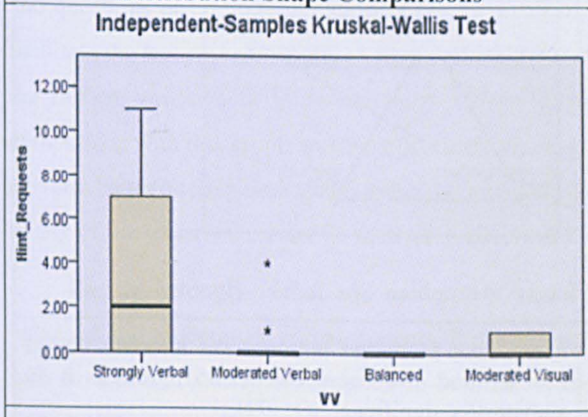
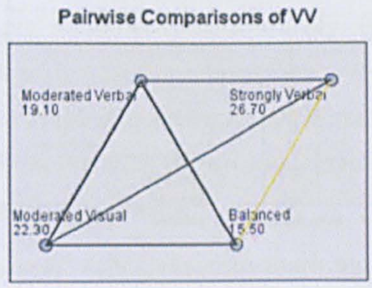
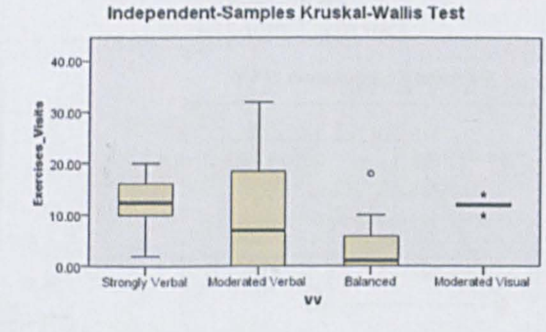
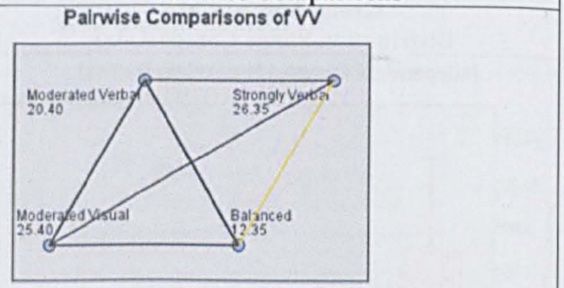
<table>
<tr><th colspan="2">Learning Metric: Visits to Quiz Activities</th></tr>
<tr><th>K–W Mean Rank Box Plot:<br>Distribution Shape Comparisons</th><th>K–W Mean Rank<br>Pairwise Comparisons</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>Mean rank distributions present dissimilar shapes across groups.<br><br>(Figure 3f)</td><td>Mean rank increased between strongly verbal (27.6) and balanced students (13.9). It is statistically significant, p = .044<br><br>(Figure 3g)</td></tr>
<tr><td>Statistically significant Median values<br>(Table 3.2)<br>Strongly verbal = 16.5<br>Balanced = 0.00</td><td>Influence of the verbal style preference on the amount of visits to quiz activities</td></tr>
</table>

**Table 17.** *INFO055 Visual–Verbal Groups.*
*Statistically Significant Results for Hint Requests in Quiz Activities*

| **Learning Metric: Hint Requests** | |
|---|---|
| **Group Mean Ranks**<br>**Distribution Shape Comparisons** | **Mean Rank**<br>**Pairwise Comparisons** |
|  |  |
| Dissimilar shape between the strongly verbal group and the others.<br><br>(Figure 3h) | Mean rank increased between strongly verbal (26.7) and balanced students (15.5). It is statistically significant, p = .029<br><br>(Figure 3i) |
| **Statistically significant Median values**<br>(Table 3.2)<br>Strongly verbal = 2.00<br>Balanced = 0.00 | Influence of the verbal style preference on the number of hint requests when performing quiz activities |

Strongly verbal and balanced groups are composed of the same number of individuals (n=2). This result indicates that a strong preference for the verbal style influences the interactions that consist of resorting to text-based hints to answer questions.

**Table 18.** *INFO55 Visual–Verbal Groups.*
*Statistically Significant Results for Visits to Exercises.*

| **Learning Metric: Visits to Exercises** | |
|---|---|
| **K–W Mean Rank Box Plot: Distribution Shape Comparisons** | **K–W Mean Rank Pairwise Comparisons** |
|  |  |
| Mean rank distributions present dissimilar shape across all groups.<br>(Figure 3j) | Mean rank increased between the strongly verbal (26.35) and the balanced (12.35) groups. It is statistically significant, p = .041<br>(Figure 3k) |
| **Statistically significant Median values**<br>(Table 3.2)<br>Strongly Verbal = 12.5<br>Balanced = 1.00 | Influence of the verbal style preference on the amount of visits to exercises in lessons |

The FSLSM observes the visual–verbal dimension by analysing the sensory channel through which external information is most effectively perceived (Felder & Silverman, 1988). Whereas visual students are described as individuals who "remember best what they can see" (e.g. images, graphics, films, demonstrations), verbal learners remember best what "they hear or say" (includes, for example, verbal explanations and text-based materials). In INFO055 the design of content resources and activities does not take account of visual or verbal preferences of students. In fact, most of them include a combination of textual explanations and images to clarify and facilitate understanding of concepts.

Among the resources provided in lessons, those with few images included are Instruction materials, since their purpose is to present students with the learning activities of the lesson, the intended learning objectives, and the concepts that they will practice. In other words, these materials are mostly "verbal". However, the results reported indicate that moderately visual learners (n=1) in the cohort interacted the most with these materials in comparison with balanced (n=2) or verbally-inclined students (n=5). The fact that this result has been obtained for the interactions of a single student in the cohort prevents me from confirming that this is a consequence of a learning style.

With regard to the results obtained for interactions with quizzes, i.e. visits and hint requests, in this case it seems that the strongly verbal students (n=2) in the cohort have interacted more with these activities than any other group. The questions are mainly "verbal", i.e. there are no questions based on interpretations of graphics or observation of figures. These are comprehensive questions about understanding and remembering concepts and questions on the interpretation of pieces of code. The hints provided act as a short text-based support to facilitate the learner arriving at the right answer. Accordingly, it makes sense that strongly verbal students show the highest medians in these variables. However, moderately verbal students show very low medians in comparison with this group and the moderately visual group. Previous related studies confirm that visual learners perform better on graphic-based questions (Graf et al., 2008); however, since there are no graphic-based questions in any of the lessons there are no metrics available that support such finding.

Finally, strongly verbal and moderately visual students visited exercises much more frequently than balanced and moderately verbal students. From a design perspective, exercises combine text-based instructions with images that clarify the program to implement, for example, by showing an example of the input and the output of the required program. Since the only statistically significant median is obtained from three students in the cohort, this finding is not associated with the visual–verbal preference.

#### 4.2.2.4. Sequential–Global groups

The Kruskal–Wallis H test was run to determine if there were differences in behavioural metrics between balanced (n=4), moderately global (n=3) and moderately sequential (n=1) students. The complete results of the hypothesis test, the distribution visualizations, the mean ranks and the post-hoc pairwise comparisons performed for this analysis are presented in Appendix 4 below.

The hypothesis test (Figure 27) indicated that the null hypothesis is rejected for 13 variables associated with interactions with lesson instruction materials (`Instructions_Visits` and `Instructions_Time`), quizzes (`Quizz_Visits`, `Questions_Answered`, `Questions_Skipped`, `Hint_Requests` and `Quizz_Time`), exercises (`Exercise_Visits`, `Exercises_Answered`, `Exercises_Skipped` and `Exercises_Time`) and tasks activities (`Tasks_Answered` and `Tasks_Skipped`).

| | Null Hypothesis | Test | Sig. | Decision |
|---|---|---|---|---|
| 7 | The distribution of Instructions_Visits is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .040 | Reject the null hypothesis. |
| 8 | The distribution of Instructions_Time is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .010 | Reject the null hypothesis. |
| 9 | The distribution of Quiz_Visits is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .001 | Reject the null hypothesis. |
| 10 | The distribution of Questions_Answered is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .005 | Reject the null hypothesis. |
| 11 | The distribution of Hint_Requests is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .001 | Reject the null hypothesis. |
| 12 | The distribution of Questions_Skipped is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .000 | Reject the null hypothesis. |
| 13 | The distribution of Quiz_T is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .001 | Reject the null hypothesis. |
| 14 | The distribution of Exercises_Visits is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .012 | Reject the null hypothesis. |
| 15 | The distribution of Exercises_Answered is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .002 | Reject the null hypothesis. |
| 16 | The distribution of Exercises_Skipped is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .001 | Reject the null hypothesis. |
| 17 | The distribution of Exercises_T is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .006 | Reject the null hypothesis. |
| 19 | The distribution of Tasks_Answered is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .009 | Reject the null hypothesis. |
| 20 | The distribution of Tasks_skipped is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .004 | Reject the null hypothesis. |

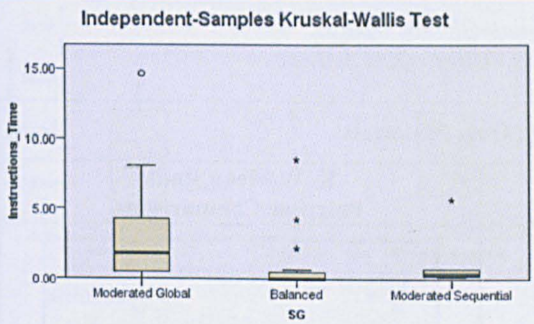
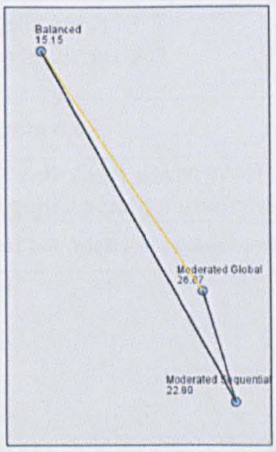
**Figure 27.** INFO055 Sequential–Global Learning Dimension.
Statistical Significant Hypothesis Test Results. (Extracted from Figures 4a, 4b and 4c)

The results are explained for each group of variables as follows:

i. Behavioural differences with Instruction materials

As assessed by observing the respective boxplots, the respective distribution shapes of both variables are dissimilar across groups. In the post-hoc analyses performed three pairwise comparisons were performed. The mean rank of visits to Instruction materials increases between the moderately sequential (26.0) and the moderately global (24.77) and the balanced (15.93) students, however, in the pairwise comparisons performed, no statistical significance was found in these differences.

**Table 19.** INFO055 Sequential–Global Groups.
Statistically Significant Results for Visits to Exercises.

<table>
<tr><th colspan="2">Learning Metric: Time spent with Instruction materials</th></tr>
<tr><th>K–W Mean Rank Box Plot:<br>Distribution Shape Comparisons</th><th>K–W Mean Rank<br>Pairwise Comparisons</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>Mean rank distributions present dissimilar shapes across groups.<br>(Figure 4f)</td><td>Mean rank increased between moderately global (26.87) and balanced students (15.15). It is statistically significant, p = .008<br>(Figure 4g)</td></tr>
<tr><td>Statistically significant Median values<br>(Table 4.2)<br>Moderate global = 1.7662<br>Balanced = 0.0000</td><td>Influence of the global style preference on the time spent on Instruction materials</td></tr>
</table>

Instruction materials offer a global vision of learning activities in each lesson and the learning objectives. Whereas moderately global students usually spend time reading instructions before or during the completion of activities, balanced and moderately sequential students in the cohort spend much less time with these materials. Global students are described as individuals who understand the "big picture" better rather than a sequence of details in a "step-by-step" form (Felder & Silverman, 1988). They tend to make connections between contents to develop their solutions. The purpose of instruction materials is to offer the connection between contents explained in a lesson and learning activities proposed. The usage of Instruction materials by moderately global students in INFO055 fits with their learning preference.

According to Graf and colleagues, the dimension Sequential–Global is connected to the Sensing–Intuitive dimension (Graf et al., 2008). Sensing learners are known for being practical, applying standard approaches to solving problems (Felder & Silverman, 1988) and starting new lessons by looking at materials than inform them about what they will learn (Graf et al., 2008). In this sense, the behaviour identified in moderate global students at INFO055 could be connected to their SI dimension, however, according to the SI results, this cannot be proved.

ii. Behavioural differences with Quizzes

**Table 20.** *INFO055 Sequential–Global Groups.*
*Statistically Significant Results for Visits to Quiz Activities*

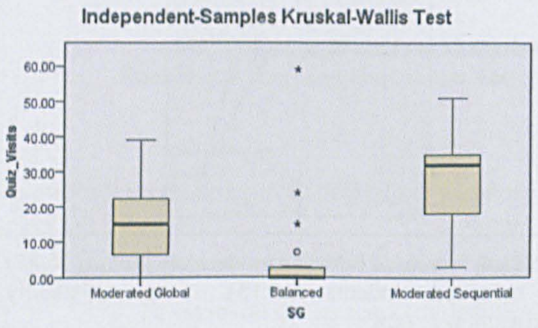
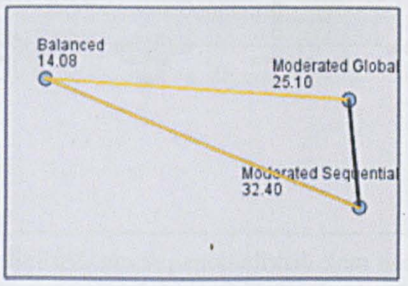
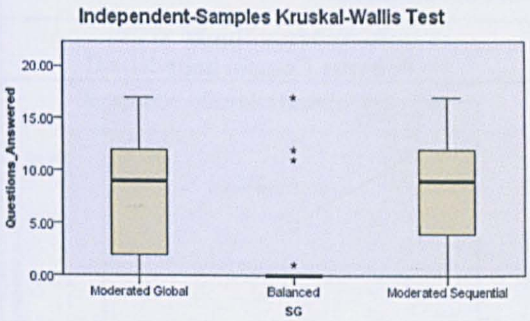
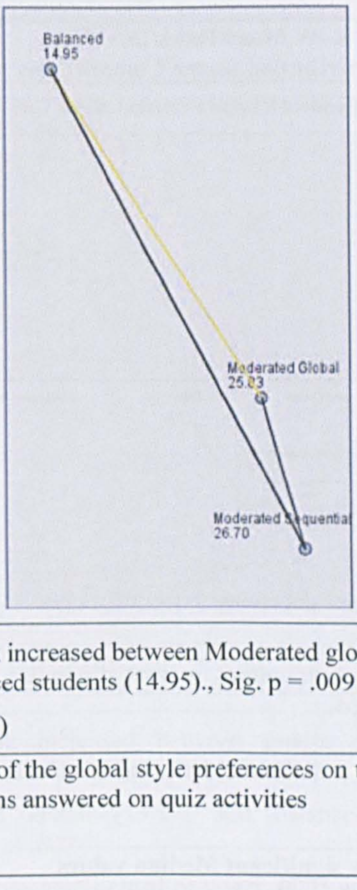
| **Learning Metric: Visits to Quiz Materials** | |
|---|---|
| **K–W Mean Rank Box Plot:**<br>**Distribution Shape Comparisons** | **K–W Mean Rank**<br>**Pairwise Comparisons** |
|  |  |
| Mean rank distributions present dissimilar shapes across groups.<br>(Figure 4h) | Mean rank increased between Moderated global (25.1) and balanced students (14.08)., Sig. p = .014<br>Moderated sequential (32.4) and balanced students (14.08). Sig. p = .004<br>(Figure 4i) |
| **Statistically significant Median values**<br>(Table 4.4)<br>Moderate global = 15.00<br>Moderate sequential = 32.00<br>Balanced = 0.00 | Influence of the global and sequential style preferences on the time spent with Instruction materials |

**Table 21.** *INFO055 Sequential–Global Groups.*
*Statistically Significant Results for Questions Answered in Quiz Activities*

| **Learning Metric: Number of Questions Answered** | |
|---|---|
| **K–W Mean Rank Box Plot:**<br>**Distribution Shape Comparisons** | **K–W Mean Rank**<br>**Pairwise Comparisons** |
|  |  |
| Mean rank distributions present dissimilar shapes across groups.<br>(Figure 4j) | Mean rank increased between Moderated global (25.83) and balanced students (14.95)., Sig. p = .009<br>(Figure 4k) |
| **Statistically significant Median values**<br>(Table 4.4)<br>Moderate global = 9.00 (n=3)<br>Balanced = 0.00 (n=4) | Influence of the global style preferences on the amount of questions answered on quiz activities |

It can be noticed that the moderate global mean rank (25.83) is lower than the moderate sequential mean (26.7). However no statistical significance has been found for this group in any of the combinations. This result may be due to the data for the moderately sequential group belonging to a single individual in the cohort.

**Table 22.** *INFO055 Sequential–Global Groups.*
*Statistically Significant Results for Hint Requests in Quiz Activities*

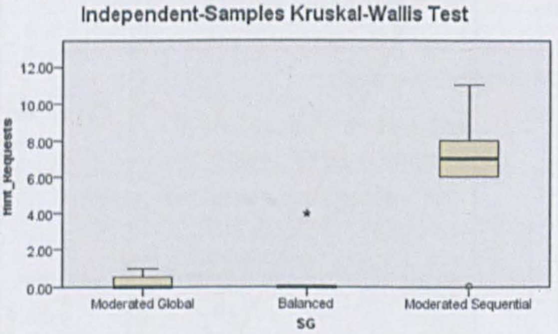
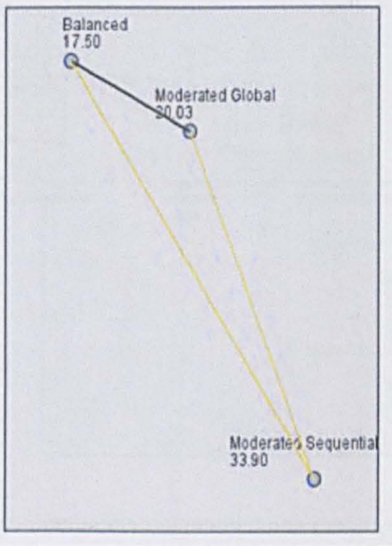
<table>
<tr><th colspan="2">Learning Metric: Number of Hint Requests</th></tr>
<tr><th>K–W Mean Rank Box Plot:<br>Distribution Shape Comparisons</th><th>K–W Mean Rank<br>Pairwise Comparisons</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>Mean rank distributions present dissimilar shapes across groups.<br><br>(Figure 4l)</td><td>Mean rank increased between: Moderated sequential (33.9) and global students (20.03)., p = .008<br><br>Moderated sequential (33.9) and balanced students (17.5), p = .001<br><br>(Figure 4m)</td></tr>
<tr><td>Statistically significant Median values<br>(Table 4.4)<br>Moderate sequential = 7.00 (n=1)<br>Moderate global = 0.00 (n=3)<br>Balanced = 0.00 (n=4)</td><td>Influence of the sequential style preference on the number of hint requests when completing quizzes</td></tr>
</table>

**Table 23.** *INFO055 Sequential–Global Groups.*
*Statistically Significant Results for Questions Skipped in Quiz Activities*

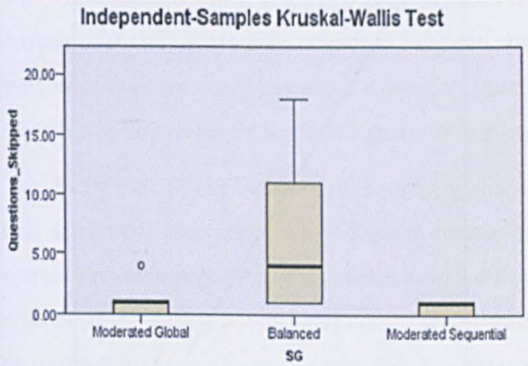
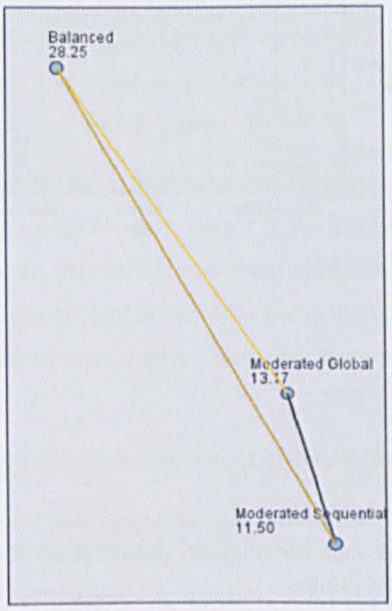
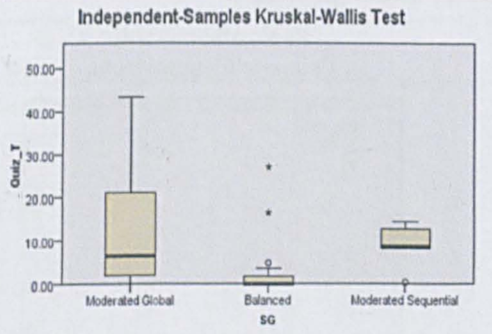
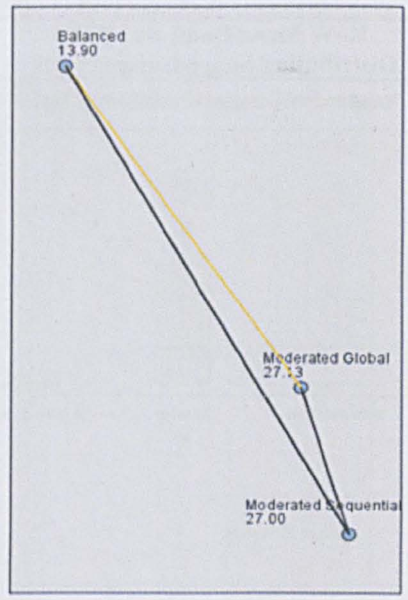
| **Learning Metric: Number of Questions Skipped** | |
|---|---|
| **K–W Mean Rank Box Plot:**<br>**Distribution Shape Comparisons** | **K–W Mean Rank**<br>**Pairwise Comparisons** |
|  |  |
| Mean rank distributions present dissimilar shapes across groups.<br>(Figure 4n) | Mean rank increased between groups: Moderated sequential (11.5) and balanced (28.25)., p = .008<br>Moderated global (13.17) and balanced students (28.25)., p = .000<br>(Significance levels equal or under .0005 are shown in SPSS as .000)<br>(Figure 4o) |
| **Statistically significant Median values**<br>(Table 4.4)<br>Moderate sequential = 1.00 (n=1)<br>Moderate global = 1.00 (n=3)<br>Balanced = 4.00 (n=4) | Influence of the balanced style on skipping questions when completing quizzes |

**Table 24.** *INFO055 Sequential–Global Groups.*
*Statistically Significant Results for Time Spent on Quiz Activities*

<table>
<tr><th colspan="2">Learning Metric: Time spent on Quiz Activities</th></tr>
<tr><th>K–W Mean Rank Box Plot:<br>Distribution Shape Comparisons</th><th>K–W Mean Rank<br>Pairwise Comparisons</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>Mean rank distributions present dissimilar shapes across groups.<br><br>(Figure 4p)</td><td>Mean rank increased between groups:<br><br>Moderated global (27.13) and balanced students (13.9)., p = .002<br><br>(Figure 4q)</td></tr>
<tr><td>Statistically significant Median values<br>(Table 4.4)<br>Moderate global = 6.4829 (n=3)<br>Balanced = 0.0000 (n=4)</td><td>Influence of the global style preference on the amount of time spent with Quiz activities in lessons</td></tr>
</table>

These results highlight the behaviour of the moderately sequential preference in comparison with moderately global and balanced students. Sequential students are described as individuals who learn in a linear order (Felder & Silverman, 1988). The general impression is that the sequential preference influences interactions with quizzes, especially when hints are available. Quizzes are proposed as the first activity in each lesson, followed by exercises and tasks. The sequential style's influence may be the reason the moderately sequential group shows the highest mean ranks in quiz visits and questions answered and the lowest mean rank in questions skipped. Quizzes are composed of a set of ordered questions; at the end of each question, particularly in lesson 3, a hint to answer the questions is offered, but is only delivered when the student requests it. Thus, after reading a question, the sequential style influences the request of a hint, regardless whether or not help is required to answer the question. Anyhow, this behaviour does not show statistical significance in most of these variables. It is associated with the fact that the data of the moderate group corresponds to a single individual in the cohort. For this reason, it is not possible to confirm the alternative hypothesis about the influence of the sequential style dimension upon behavioural metrics.

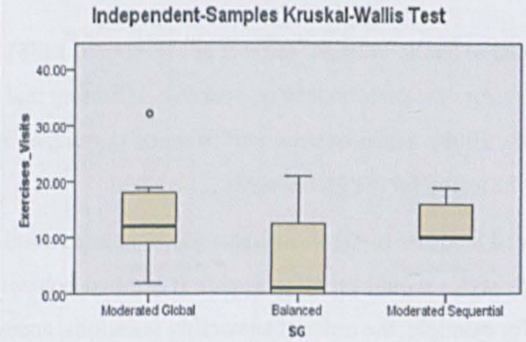
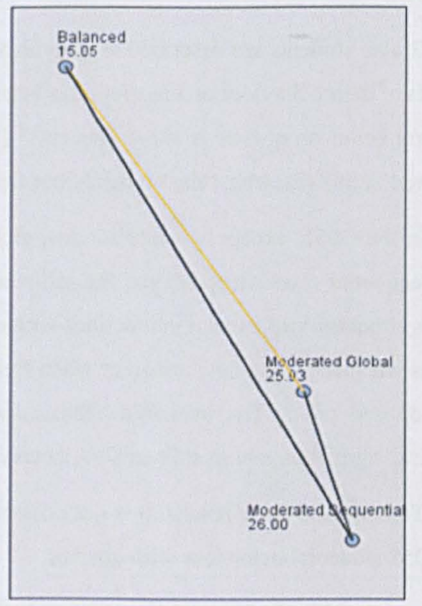
Global students are described as individuals who tend to learn "in leaps" (Felder & Silverman, 1988). The analysis of their behaviour on questions has been observed from the performance perspective, affirming that they "perform better on questions about concepts" (Graf et al., 2008). Since specific performance in quizzes is not measured in this research, this is a behaviour that cannot be tested for the global style.

In INFO055, except hint interactions, global-inclined students (n=3) show behavioural metrics similar to their sequential classmates. Maybe the influence of both styles would be more visible if we had behavioural metrics about the sequence of interactions with quizzes, for example, the order of answering questions, accessing quizzes when starting a new lesson or when finishing it, or skipping content materials or going through them in the proposed order. The available behavioural metrics associated with content resources have not shown statistical significance in this dimension, however.

To conclude these results, it is not possible to confirm that either the sequential or global styles influence INFO055 students' behaviour with quizzes.

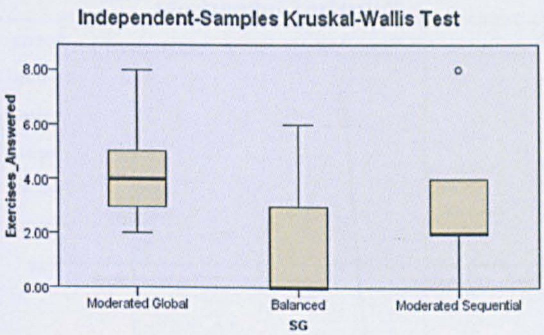
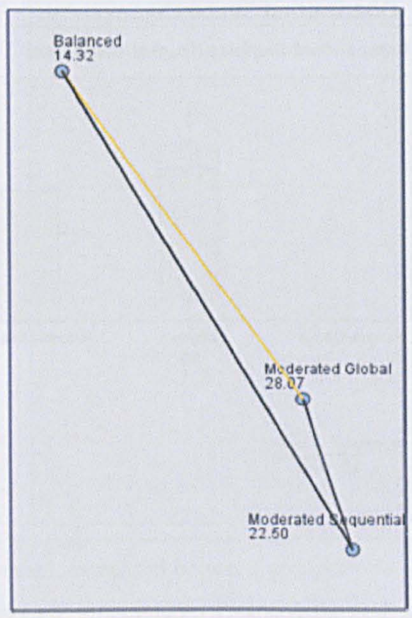
iii. Behaviour with Exercises

**Table 25.** *INFO055 Sequential–Global Groups. Statistically Significant Results for Visits to Exercises*

| **Learning Metric: Visits to Exercises** | |
|---|---|
| **K–W Mean Rank Box Plot: Distribution Shape Comparisons** | **K–W Mean Rank Pairwise Comparisons** |
|  |  |
| Mean rank distributions present dissimilar shapes across groups.<br>(Figure 4r) | Mean rank increased between groups:<br>Moderated global (25.93) and balanced students (15.05), p = .018<br>(Figure 4s) |
| **Statistically significant Median values**<br>(Table 4.6)<br>Moderate global = 12.00 (n=3)<br>Balanced = 1.00 (n=4) | Influence of the global style preference on the amount of visits to exercises in lessons |

The highest mean rank corresponds to the moderate sequential group (n=1, 26.0); however, it does not show a statistical significance with the other groups.

**Table 26.** *INFO055 Sequential–Global Groups.*
*Statistically Significant Results for Exercises Answered*

| **Learning Metric: Number of Exercises Answered** | |
|---|---|
| **K–W Mean Rank Box Plot:**<br>**Distribution Shape Comparisons** | **K–W Mean Rank**<br>**Pairwise Comparisons** |
|  |  |
| Mean rank distributions present dissimilar shapes across groups.<br>(Figure 4t) | Mean rank increased between groups:<br>Moderated global (28.07) and balanced students (14.32), p = .001<br>(Figure 4u) |
| **Statistically significant Median values**<br>(Table 4.6)<br>Moderate global = 12.00 (n=3)<br>Balanced = 1.00 (n=4) | Influence of the global style preference on the amount of exercises answered in lessons |

Despite being the highest, the mean rank of the moderate sequential (n=1, 22.5) does not show statistical significance with respect to the other groups.

**Table 27.** *INFO055 Sequential–Global Groups.*
*Statistically Significant Results for Exercises Skipped*

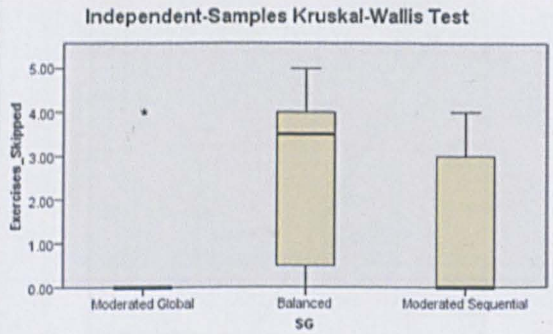
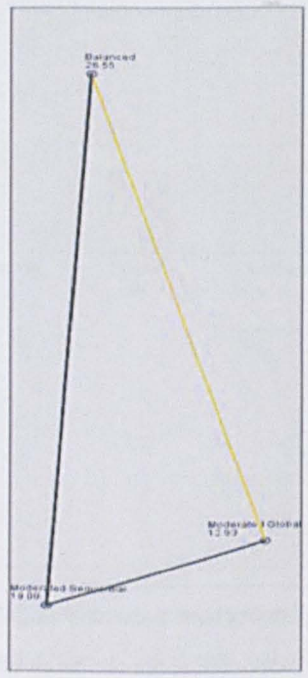
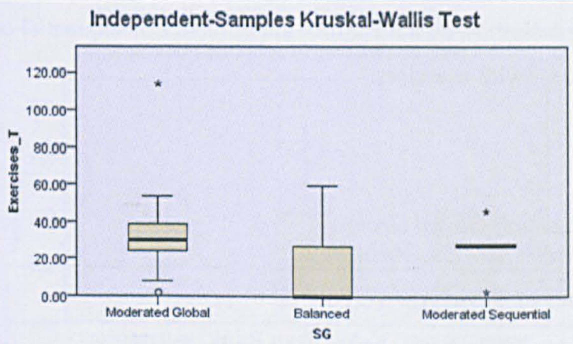
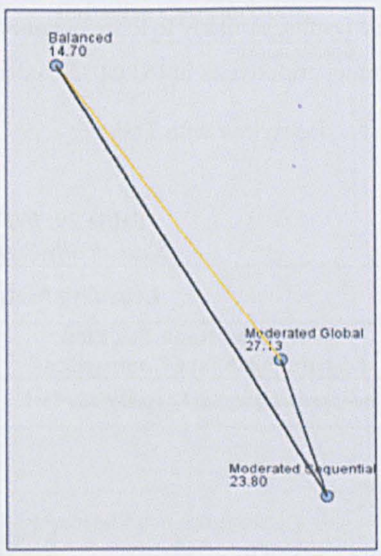
| **Learning Metric: Number of Exercises Skipped** | |
|---|---|
| **K–W Mean Rank Box Plot: Distribution Shape Comparisons** | **K–W Mean Rank Pairwise Comparisons** |
|   |  |
| Mean rank distributions present dissimilar shapes across groups.<br>(Figure 4v) | Mean rank increased between groups:<br>Moderated global (12.93) and balanced students (26.55), p = .001<br>(Figure 4w) |
| **Statistically significant Median values**<br>(Table 4.6)<br>Moderate global = 0.00 (n=3)<br>Balanced = 3.50 (n=4) | Influence of the balance style on the amount of skipped exercises in lessons |

**Table 28.** *INFO055 Sequential–Global Groups.*
*Statistically Significant Results for Time spent on Exercises*

| **Learning Metric: Time spent on Exercises** | |
|---|---|
| **K–W Mean Rank Box Plot: Distribution Shape Comparisons** | **K–W Mean Rank Pairwise Comparisons** |
|  |  |
| Mean rank distributions present dissimilar shapes across groups.<br>(Figure 4x) | Mean rank increased between groups:<br>Moderated global (27.13) and balanced students (14.7), p = .005<br>(Figure 4y) |
| **Statistically significant Median values**<br>(Table 4.6)<br>Moderate global = 12.00 (n=3)<br>Balanced = 1.00 (n=4) | Influence of the global style preference on the time spent on exercises provided in lessons |

The behaviour of the groups with programming exercises in lessons follow the same trend as their behaviour with quizzes: moderately sequential and moderately global groups have close values in their mean ranks, whereas balanced students present significantly lower mean ranks in all behavioural metrics, except exercises skipped. This cohort trend only helps to demonstrate that balanced students engaged much less with programming exercises than moderately global and sequential students. However it is not a behaviour that should be associated with the influence of the SG learning style dimension.

Programming activities in INFO055 lessons are presented after comprehension activities (i.e. quizzes). They are presented in a specific order; however, the characteristics of the KUOLE platform allow a student to choose any exercise in the sequence. The metric `Exercises_Skipped` refers to those exercises that have not been visited at all, as well as those exercises that were visited but where no answer was submitted on the student's behalf. If global students tend to skip exercises more than sequential students – as they tend to skip content materials (Graf et al., 2008) –, it is a behavioural pattern that the obtained mean ranks do not confirm.

These results, similarly to those obtained with quiz activities, do not confirm the influence of sequential or global learning preferences in INFO055 students' behaviour with exercises.

iv. Behaviour with Tasks

**Table 29.** *INFO055 Sequential–Global Groups. Statistically Significant Results for Tasks Answered*

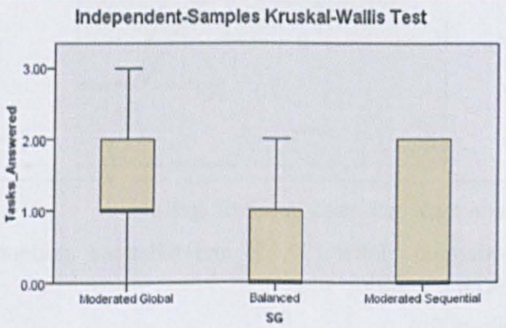
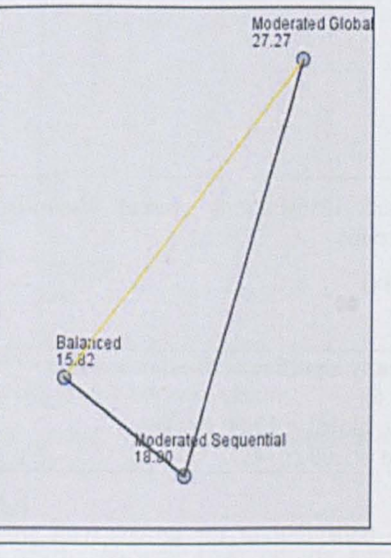
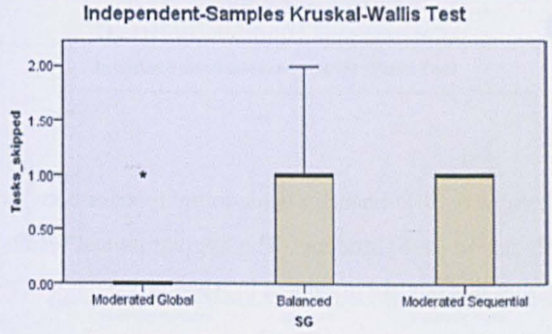
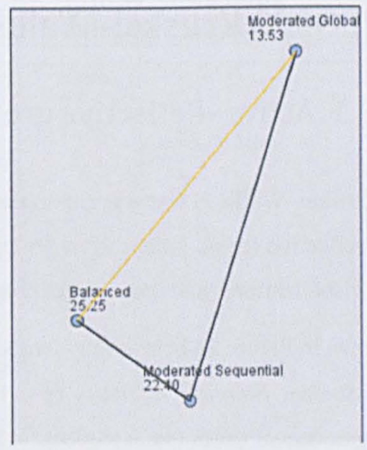
| **Learning Metric: Number of Tasks Answered** | |
|---|---|
| **K–W Mean Rank Box Plot:<br>Distribution Shape Comparisons** | **K–W Mean Rank<br>Pairwise Comparisons** |
|  |  |
| Mean rank distributions present dissimilar shapes across groups.<br>(Figure 4z) | Mean rank increased between groups:<br>Moderated global (27.27) and balanced students (15.82), p = .007<br>(Figure 4aa) |
| **Statistically significant Median values**<br>(Table 4.8)<br>Moderate global = 1.00 (n=3)<br>Balanced = 0.00 (n=4) | Influence of the global style preference on the amount of tasks answered in lessons |

**Table 30.** *INFO055 Sequential–Global Groups.*
*Statistically Significant Results for Tasks Skipped*

<table>
<tr><th colspan="2">Learning Metric: Number of Skipped Tasks</th></tr>
<tr><th>K–W Mean Rank Box Plot:<br>Distribution Shape Comparisons</th><th>K–W Mean Rank<br>Pairwise Comparisons</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>Mean rank distributions present dissimilar shapes across groups.<br>(Figure 4ab)</td><td>Mean rank increased between groups:<br>Moderated global (13.53) and balanced students (25.25), p = .003<br>(Figure 4ac)</td></tr>
<tr><td>Statistically significant Median values<br>(Table 4.8)<br>Moderate global = 0.00 (n=3)<br>Balanced = 1.00 (n=4)</td><td>Influence of the balance style on the amount of skipped programming tasks in lessons</td></tr>
</table>

Behaviour with programming tasks across groups resembles their behaviour with programming exercises, especially for moderately global and balanced students. Concerning programming tasks, the moderately sequential group shows a behaviour similar to the balanced group: higher interactivity with programming exercises and quizzes, but lower interactivity with programming tasks. Behavioural trends in moderate and balanced groups do not change across quizzes, exercises or tasks, however.

These differences in sequential behaviour may be due to the particular design applied to exercises and tasks: whereas exercises guide a student step-by-step through the resolution of a program, tasks offer a description of the program to implement, specifying the form of the program output as an example. Thus, a sequential student feels overwhelmed by not being able to "put everything together" and implement the program without a "set-by-step" guide. Another possibility is that there are not sufficient exercises for this student to practise through basics before facing a more complex activity. In any case, rather than placing too much emphasis on design faults, it should be recalled that the moderately sequential group is composed of one individual. The results, in this case, are too specific to extract reliable conclusions about design or the influence of sequential learning styles. Likewise, the small size of the moderately global (n=3) and balanced (n=4) groups do not permit conclusions about the influence of learning style upon behaviour in learning activities.

## 4.2.3 INFO023 Kruskal–Wallis H Test

### 4.2.3.1. Active–Reflective groups

The Kruskal–Wallis H test was run to determine if there were differences in behavioural metrics between moderately reflective (n=4), balanced (n=9) and moderately active (n=5) students. The hypothesis test results, distribution visualizations, and mean ranks obtained during this analysis are presented in Appendix 5.

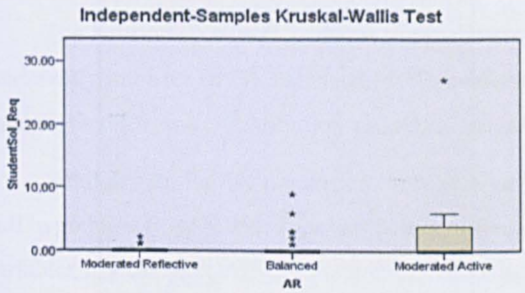
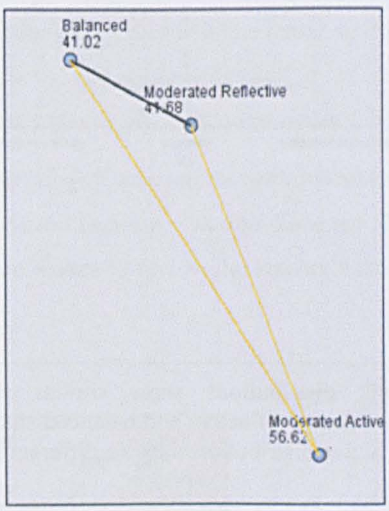
As shown in Figure 28 below, only two variables associated with interactions with exercises reject the null hypothesis: *Student_Solution_Requests* (p = .005) and *Students_Solution_Time* (p= .017). These variables indicate the number of times that a student reviews his or her solution to particular exercises and the time spent reviewing such solution.

| | | | | |
|---|---|---|---|---|
| 18 | The distribution of StudentSol_Req is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .005 | Reject the null hypothesis. |
| 19 | The distribution of StudentSol_T is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .017 | Reject the null hypothesis. |

**Figure 28.** INFO023 Active–Reflective Learning Dimension.
Statistically Significant Hypothesis Test Results (extracted from Figures 5a, 5b, 5c)

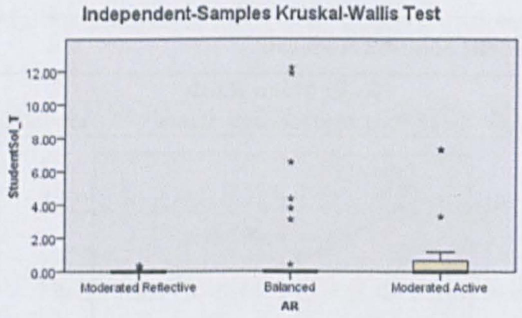
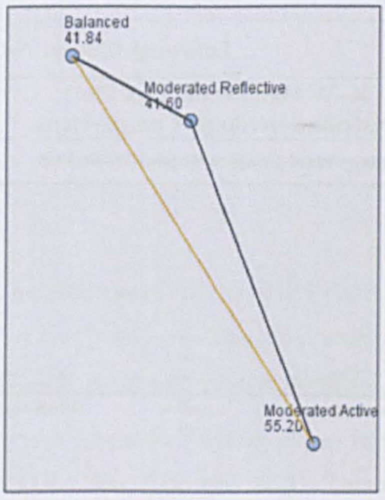
Tables 31 and 32 report the results obtained from the K–W method:

**Table 31.** *INFO023 Active–Reflective Groups.*
*Statistically Significant Results for Student Solution Requests in Exercises*

| **Learning Metric: Number of Student Solution Requests** | |
|---|---|
| **K–W Mean Rank Box Plot:**<br>**Distribution Shape Comparisons** | **K–W Mean Rank**<br>**Pairwise Comparisons** |
|  |  |
| Mean rank distributions similar shapes between moderate reflective and balanced students, whereas the moderate active, shows a different distribution shape<br>(Figure 5d) | Mean rank increased between groups:<br>Moderate active (56.62) and moderate reflective (41.68), p=.038.<br>Moderated active (56.62) and balanced students (41.02), p = .005<br>(Figure 5e) |
| **Statistically significant Median values**<br>(Table 5.2)<br>Moderate active = 0.00 (n=5)<br>Moderate global = 0.00 (n=4)<br>Balanced = 0.00 (n=9) | Influence of the active style preference on the amount of skipped programming tasks in lessons |

Pairwise comparisons were performed using Dunn's (1964) procedure with a Bonferroni correction for multiple comparisons.

**Table 32**. *INFO023 Active–Reflective Groups.*
*Statistically Significant Results for Time Spent with Student Solution in Exercises*

| **Learning Metric: Time spent with Student Solution** | |
|---|---|
| **K–W Mean Rank Box Plot:**<br>**Distribution Shape Comparisons** | **K–W Mean Rank**<br>**Pairwise Comparisons** |
|  |  |
| Mean rank distributions show similar shapes between moderate reflective and balanced students; moderate active distribution shows a different shape<br>(Figure 5f) | Mean rank increased between groups:<br>Moderated active (55.2) and balanced students (41.84), $p = .022$<br>(Figure 5g) |
| **Statistically significant Median values**<br>(Table 5.2)<br>Moderate active = 0.0000 (n=5)<br>Moderate global = 0.0000 (n=4)<br>Balanced = 0.0000 (n=9) | Influence of the active style preference on the amount of skipped programming tasks in lessons |

Despite statistical significance being found, the median value of both metrics does not show differences among groups (.00 and .0000 respectively). This results might be explained by the small sample size of data in this cohort: a small group's behaviour may influence statistically upon the distribution and mean ranks of a variable, however, the median statistic does not reflect these differences since it shows the most repeated value in the data set of each group.

Concerning the question: Is the frequency of students' requests for solutions and the time spent reviewing solutions influenced by the active–reflective learning style? The mean rank results suggest that in this cohort an active preference increases the requests and the time spent on the solutions. However, this particular behaviour has not been observed from the active or reflective dimension in previous related studies.

It is worth noting that, comparing this analysis with the results obtained for INFO055, active or reflective preferences in INFO023 do not influence other learning metrics with content resources or activities in the five lessons analysed.

### 4.2.3.2. Sensing–Intuitive groups

The Kruskal–Wallis H Test was run to determine if there were differences in behavioural metrics between moderately intuitive (n=2), balanced (n=9), moderately sensing (n=3) and strongly sensing (n=4) students. The hypothesis test results, distribution visualizations, and the mean ranks are presented in Appendix 6 below.

Similarly to the AR dimension, only two variables associated with interactions with exercises reject the null hypothesis (Figure 29): *Teacher_Solution_Requests* (p = .005) and *Teacher_Solution_Time* (p= .005). These variables indicate respectively the number of visits that a student makes to review the teacher's solution to an exercise and the time spent reviewing such solutions.

| | | | | |
|---|---|---|---|---|
| 20 | The distribution of TeacherSol_Req is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .005 | Reject the null hypothesis. |
| 21 | The distribution of TeacherSol_T is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .005 | Reject the null hypothesis. |

**Figure 29.** INFO023 Sensing–Intuitive Learning Dimension.
Statistically Significant Hypothesis Test Results. (Extracted from Figure 6c)

**Table 33.** *INFO023 Sensing–Intuitive Groups.*
*Statistically Significant Results for Teacher Solution Requests in Exercises*

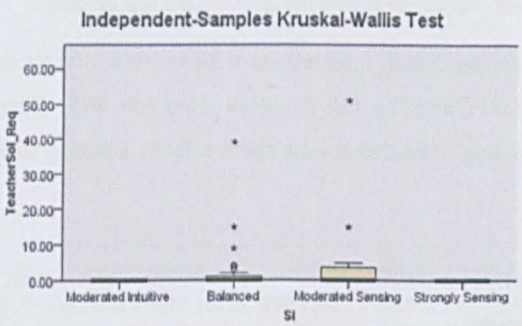
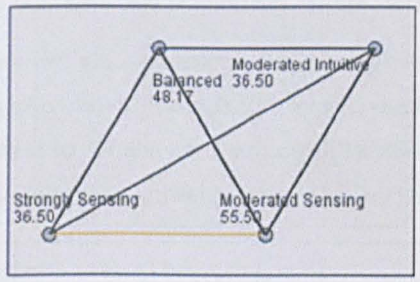
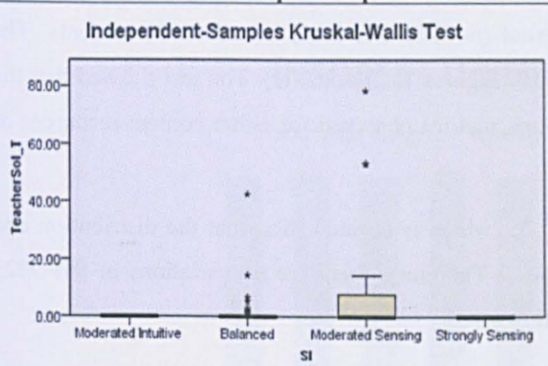
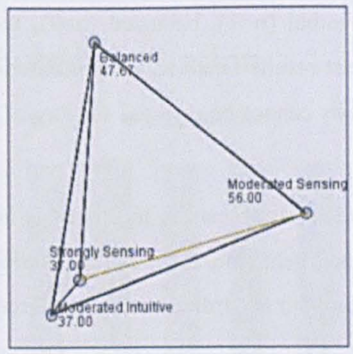
| Learning Metric: Number of Teacher Solution Requests | |
|---|---|
| **K–W Mean Rank Box Plot: Distribution Shape Comparisons** | **K–W Mean Rank Pairwise Comparisons** |
|   |   |
| Mean rank distributions similar shapes across groups.<br>(Figure 6d) | Mean rank increased between:<br>Strongly sensing (36.5) and the moderate sensing (55.5) groups. It is statistically significant, p=.014.<br>(Figure 6e) |
| **Statistically significant Median values**<br>(Table 6.2)<br>Moderate sensing = 0.00 (n=3)<br>Strongly sensing = 0.00 (n=4) | Influence of the moderate sensing preference on the number of requests for teacher's solution to exercises in the five lessons analysed. |

**Table 34.** *INFO023 Sensing–Intuitive Groups.*
*Statistically Significant Results for Time spent with Teacher Solution in Exercises*

| **Learning Metric: Time spent with Teacher Solution** | |
|---|---|
| **K–W Mean Rank Box Plot:**<br>**Distribution Shape Comparisons** | **K–W Mean Rank**<br>**Pairwise Comparisons** |
|  |  |
| Mean rank distributions show dissimilar shapes between moderate sensing group and the others.<br>(Figure 6f) | Mean rank increased between groups:<br>Strongly sensing (37.00) and the moderate sensing (56.00) groups. It is statistically significant, p=.011.<br>(Figure 6g) |
| **Statistically significant Median values**<br>(Table 6.2)<br>Moderate sensing = 0.0000 (n=3)<br>Strongly sensing = 0.0000 (n=4) | Influence of the moderate sensing style on the amount of time spent with teacher's solution provided in exercises |

Despite not showing a statistical significance, it is worth noting that moderately intuitive (n=2) and strongly sensing (n=4) students present the same mean ranks in both variables. This suggests that they have behaved in the same way despite having opposite learning preferences.

The difference between moderately sensing (n=3) and strongly sensing indicates counteracting conclusions about how the FSLSM describes sensing learners. These individuals like to apply well-known standard solutions to solve problems, so this explains why the highest mean rank in visiting and reviewing the teacher's solution belongs to a sensing group. However, for the more strongly sensing group whose mean rank is minor, the FSLSM description is not confirmed. The strongly sensing group should present the highest mean rank in these variables, according to the FSLSM, however, the balance's mean rank (n=9) is higher than that of the strongly sensing. This mismatch between the FSLSM and INFO023 SI results is clearly associated with the small sample size.

These behavioural metrics are the only ones that are statistically significant, whereas the other nineteen are not. In conclusion it cannot be confirmed that the SI preference impacts upon students' behaviour in this cohort.

#### 4.2.3.3. Visual–Verbal groups

The Kruskal–Wallis H test was run to determine if there were differences in behavioural metrics between moderately verbal (n=1), balanced (n=7), moderately visual (n=7) and strongly visual (n=3) students. The hypothesis test results obtained are presented in Appendix 7 (Figures 7a, 7b and 7c). The test showed that the null hypothesis cannot be rejected for any of the behavioural metrics observed for either content resources or activities.

Statistical significances in this table are all above .05, which is an indication that the distribution and median of each behavioural metric are similar across groups. Therefore, there are no variations in INFO023 students' behaviour according to their preferences in this dimension.

#### 4.2.3.4. Sequential–Global groups

The Kruskal–Wallis H test was run to determine if there were differences in behavioural metrics between balanced (n=13) and moderately sequential (n=5) students. The hypothesis test results obtained are presented in Appendix 8 below.

Similarly to the VV dimension in this cohort, the null hypothesis cannot be rejected for any of the behavioural metrics observed for content resources or activities (Figures 8a, 8b and 8c). Statistical significances in the hypothesis test table are above .05, which is an indication that the distribution and median of each behavioural metric are similar across both balanced and moderately sequential groups. Therefore, there are no variations in INFO023 students' behaviour according to their preferences in this dimension.

## 4.3. Usability Evaluation Results

The following charts help to visualize the frequency distribution of evaluation scores for each pedagogical attribute studied in this research. This evaluation reflects the impact of learning materials according to students' experiences and needs.

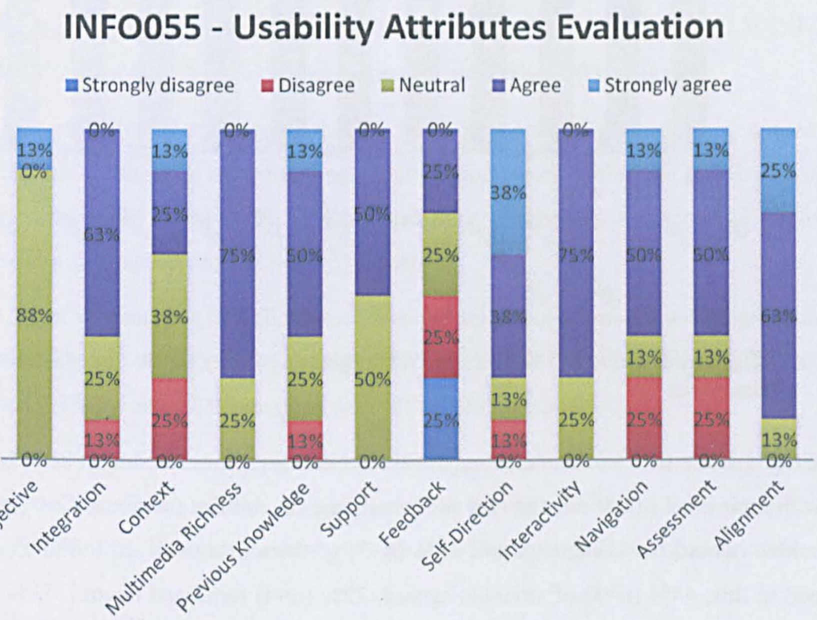



**Figure 30.** INFO055 Results of Pedagogical Usability Evaluation of e-Learning resources

In INFO055, 13% (n=1) of students strongly agreed that learning resources and activities in KUOLE lessons helped them to achieve the learning objectives of the course (attribute *Objective*), whereas the vast majority of the class (88%, n=7) did not agree or disagree. In INFO023, on the other hand, the class was divided: 55% (n=10) agreed, 39% (n=7) remained neutral and 6% (n=1) strongly disagreed.

In INFO055, 63% (n=5) of students agreed that the organization of contents and activities in lessons adjusted to their natural manner of learning (attribute *Integration*), 25% (n=2) did not agree or disagree and 13% (n=1) strongly disagreed. In INFO023, 17% (n=3) strongly agreed with this, 44% (n=8) of students agreed, 22% (n=4) neither agreed nor disagreed, 11% (n=2) disagreed, and 5.56% (n=1) strongly disagreed.

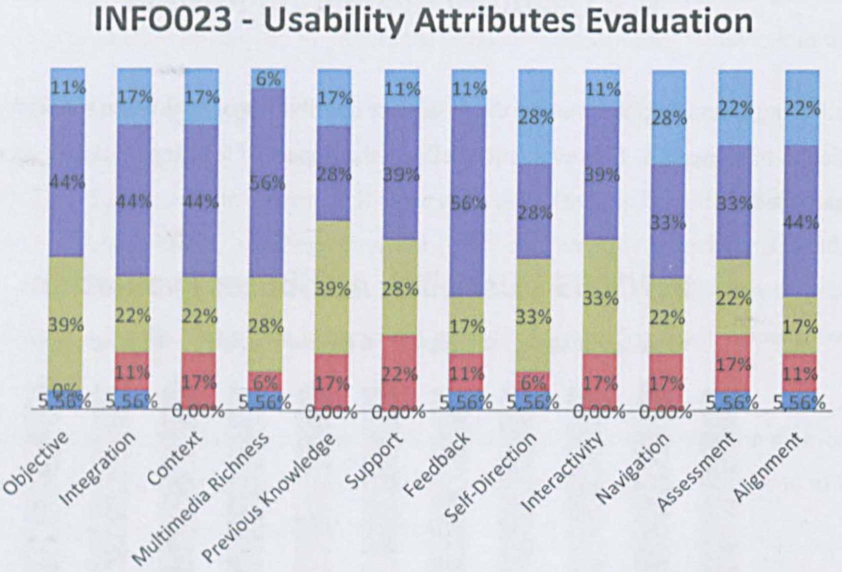



**Figure 31**. INFO023 Results of Pedagogical Usability Evaluation of e-Learning resources

In INFO055, 13% (n=1) of students agreed that content resources and activities in new lessons were in accordance with their level of knowledge and understanding capabilities (attribute *Context*), 25% (n=2) agreed, 38% (n=3) neither agreed nor disagreed, and 25% (n=2) of them disagreed. In INFO023, 17% (n=3) students strongly agreed to this, 44% (n=8) of students agreed, 22% (n=4) remained neutral, 11% (n=2) disagreed, and 5.56% (n=1) strongly disagreed.

In INFO055, 75% (n=6) of students agreed that multimedia elements in learning resources and videos facilitated their learning process (attribute *Multimedia Richness*), whereas 25% (n=2) neither agreed nor disagreed. In INFO023, 6% of students (n=1) strongly agreed, 56% of students (n=10) agreed, 28% (n=5) remained neutral, and 11% (n=2) disagreed.

In INFO055, 13% (n=1) of students felt that previous lessons in the course provided them with sufficient knowledge and skills to start the following new lesson (attribute *Previous Knowledge*), 50% (n=4) agreed, 25% (n=2) remained neutral, and 13% (n=1) disagreed. In INFO023, 17% of students strongly agreed, 28% agreed, 39% (n=7) remained neutral and 17% (n=5) disagreed.

In INFO055, 50% of students (n=4) agreed that content objects in lessons provided them with sufficient help and knowledge to complete learning activities (attribute *Support*), whereas the other 50% neither agreed nor disagreed. In INFO023, the evaluation was more dispersed: 50% (n=9) agreed with this, 28% (n=5) remained neutral and 22% (n=4) disagreed.

In INFO055, 25% (n=2) of students agreed that the feedback provided by learning resources was sufficient to their learning needs (attribute *Feedback*), 25% remained neutral, 25% disagreed and the remaining 25% strongly disagreed with this. In INFO023, 63% of the class (n=12) agreed, 17% (n=4) remained neutral, whereas roughly 16% (n=3) disagreed.

In INFO055, 38% of students (n=3) strongly agreed that they had the freedom to progress through the lessons and resources at their pace, satisfying their individual learning needs and interests (attribute *Self-direction*), another 38% agreed, 13% (n=1) remained neutral, and the other 13% disagreed. In INFO023, 28% (n=4) strongly agreed, 28% agreed, 33% (n=6) remained neutral and 16% (n=3) disagreed.

In INFO055, 75% of students (n=6) agreed that the level of interactivity provided by content resources and activities was sufficient for them to remain engaged during their work with them (attribute *Interactivity*), whereas 25% (n=2) remain neutral. In INFO023, 11% (n=2) strongly agreed with this aspect, 39% (n=7) agreed, 33% (n=6) neither agreed nor disagreed and 17% (n=3) disagreed.

In INFO055, 13% of students felt that all the contents and activities in lessons were significant (attribute *Navigation*), 50% of students agreed with this, 13% remained neutral, and 25% disagreed. In INFO023, 28% of students strongly agreed, 33% agreed, 22% remained neutral, and 17% disagreed.

In INFO055, 13% of students strongly agreed that learning activities in lessons allowed them assess the knowledge acquired on the concepts (attribute *Assessment*), 50% agreed with this, 13% remained neutral, and 25% disagreed. In INFO023, 22% of students strongly agreed, 33% agreed, 22% remained neutral and 21% disagreed.

In INFO055, 88% of students agreed that learning activities and final tests aligned with learning objectives in the course (attribute *Alignment*), whereas 13% remained neutral. In INFO023, 66% of the class agreed with this, 17% remained neutral, and 17% disagreed.

The statistics shown in Tables 35 and 36 below were produced in order to observe the differences in the evaluation of pedagogical aspects between courses. The general trend is neutral in both courses, except the attributes *Feedback*, *Self-direction* and *Alignment* in INFO055. In the context of learning resources design, a neutral score is not favourable, since it implies that any impact was irrelevant in comparison with the use of traditional learning materials.

**Table 35.** *INFO55*
*Pedagogical Usability Evaluation.*
Mean score of each attribute

| Attribute | Mean | Std. Deviation |
|---|---|---|
| Objective | 3.25 | .666 |
| Integration | 3.50 | .712 |
| Context | 3.25 | .974 |
| Multimedia Richness | 3.75 | .436 |
| Previous Knowledge | 3.63 | .862 |
| Support | 3.50 | .503 |
| Feedback | 2.50 | 1.125 |
| Self-direction | 4.00 | 1.006 |
| Interactivity | 3.75 | .436 |
| Navigation | 3.50 | 1.006 |
| Assessment | 3.50 | 1.006 |
| Alignment | 4.13 | .603 |

**Table 36.** *INFO23*
*Pedagogical Usability Evaluation.*
Mean score of each attribute

| Attribute | Mean | Std. Deviation |
|---|---|---|
| Objective | 3.56 | .899 |
| Integration | 3.56 | 1.069 |
| Context | 3.61 | .954 |
| Multimedia Richness | 3.50 | .901 |
| Previous Knowledge | 3.44 | .959 |
| Support | 3.39 | .954 |
| Feedback | 3.56 | 1.016 |
| Self-Direction | 3.67 | 1.109 |
| Interactivity | 3.44 | .899 |
| Navigation | 3.72 | 1.047 |
| Assessment | 3.50 | 1.171 |
| Alignment | 3.67 | 1.109 |

After the survey was administered to students, the reliability of the usability scores was computed the Cronbach Coefficient Alpha using SPSS. Cronbach Alpha is a popular method commonly used to measure the internal consistency of a test or questionnaire. "Internal consistency in a test measures the extent to which all items in a test measure the same concept" (Tavakol & Dennick, 2011). When more than one single concept or construct is evaluated in a questionnaire, it is recommended to perform a Cronbach test on the items that evaluate such concept (Tavakol & Dennick, 2011). In this case, each pedagogical attribute is evaluated with one single statement, therefore individual Cronbach tests do not make sense (since an item correlates with itself in 1.0). Instead, a Cronbach reliability test was applied to the scores provided by the students in each course. Tables 37 and 38 show the alpha values obtained.

**Table 37.** *INFO055 Reliability Statistics of Usability Evaluation Survey*

| Cronbach's Alpha | Number of Items |
|---|---|
| .508 | 12 |

**Table 38.** *INFO023 Reliability Statistics of Usability Evaluation Survey*

| Cronbach's Alpha | Number of Items |
|---|---|
| .843 | 12 |

Acceptable alpha values range between 0.7 and 0.95, however, in different research initiatives, reliability has been considered acceptable for alpha values of 0.5 (Gliem & Gliem, 2003; Tavakol & Dennick, 2011). It may be because, although it is desirable to have a high alpha, "items with quite low inter-correlations can yield an interpretable scale" (Cronbach, 1951, p.332).

The difference in alpha values obtained for both surveys is considerable; $\alpha$=.508 for INFO055, which, according to some authors, can be considered poor (George and Mallery, 2003, as cited in Gliem & Gliem (2003)). The value obtained for INFO023 is $\alpha$=.843, which is considered a very good level of reliability. This difference is associated with the inter-correlations between attributes' scores in the INFO055 course, which are very low in comparison with the score inter-correlations of INFO023. This difference can also be appreciated by looking at the charts above: INFO023 evaluation scores seem to follow a more "paired" evaluation score across the attributes, whereas INFO055 scores seem more "unpaired".

## 4.4 Discussion of Results

The results obtained from the analyses performed enable us to answer the research questions presented in this chapter:

- *Can pedagogical design attributes of e-learning resources be informed through the analysis of students' behaviour?*

PCA with Promax rotation and a usability evaluation survey was the method used to analyse students' behaviour and perceptions to answer this question. Whereas PCA has helped to identify the relevance of each group of behavioural and performance metrics and existing relationships between them, the usability survey helps to gather the impact of these resources on students' overall learning experience during the course.

Firstly, both PCA results for INFO055 and INFO023 show that interactions with programming activities occupy a primary role in these courses. Programming activities aim to facilitate the achievement of certain learning objectives for computer programming: to develop students' logical thinking through the implementation of algorithms and simultaneously application of programming concepts seen during the lecture. This is a fundamental objective common to introductory programming courses (Campos, 2013; Tuparov, Tuparova, & Jordanov, 2014; Tuparov, Tuparova, & Tsarnakova, 2012). Students in both cohorts mainly logged in to the KUOLE platform to access exercises. Therefore, it makes sense that interactions with programming activities (exercises and tasks) are located in Component 1 of both PCAs. This also makes intuitive sense with the conventional wisdom that programming is learnt by practice (Neve et al. 2012).

Secondly, quiz interactions appear and correlate positively with programming exercises in the first and second components of both PCAs, with their highest loadings in the second. This result implies that, during

KUOLE sessions, students also performed available quizzes in lessons, however, in comparison with the number of exercises (ranging between three and twelve, depending on the lesson and course), the number of quizzes is much lower (usually one or zero). This suggests that from the perspective of the designer of the lesson (the teacher in this case) as well as the students, comprehension activities have played a secondary role when learning to program.

Thirdly, the PCA matrices show that content materials have played a tertiary role in the learning process of the subject since interactions with different types of materials show their highest loadings from the third component forward. Interactive Examples are clearly the exception in materials in INFO023. The design of these resources provides two advantages over the others: first, it is inspired by programming visualization techniques and provides students with different representations of the algorithm implemented; and, second, the design provides more interactive elements in its interface, which seemed to gain the attention of students in INFO023.

In the absence of interactive examples, slide materials in INFO055 seem to have been frequently resorted to by students when performing activities. This is noticed by their loadings in components 2, 3, 5 and 6 of PCA55. Slide materials are (or are based on) the presentations given by the teacher during face-to-face lectures in both courses. These materials contain all the contents and examples of the lesson in the order explained by the teacher, however, there are no extra features that make their design engaging. For example, they have no animated presentations, embedded audio or video elements. Their "popularity", reflected by students' behavioural metrics, may be associated with the fact that students are already familiar with these materials, they are used during the lecture, and provide easy linear and direct access to navigation elements in their interface.

In both matrices, component 3 shows positive loadings for interactions with three content materials: slides, videos and worked examples in Table 7-PCA55, and slides and videos in Table 9-PCA23. The design of these materials, slides, and worked examples are connected in the sense that such examples are extracted from the slides and provided to students for them to "play and experiment" with the code. In contrast, video materials have been designed independently from slides or examples. These resources are all provided in a lesson, however, students are not advised or oriented by the contents or the platform about how these materials are connected or about the most appropriate sequence of access. Therefore, the loadings in component 3 suggest that students make use of all materials provided, regardless of their level of connection with certain attributes of their pedagogical design, which may be integration, previous knowledge, support, or navigation.

Metrics associated with Instruction materials in INFO055 appear separated in component 5. These materials do not provide the student with any programming knowledge, however they provide a general overview of the learning objectives that will be achieved through the completion of all lesson's activities. It is surprising that activities loadings are not significant in this component and it is also surprising that component 5 has no correlation with component 1 (.06). In contrast, the highest correlation found in the PCA55 factor correlation matrix is between the Instructions (component 5) and the other learning materials (component 3) (.434). This makes sense if we consider that both Instruction and the other learning materials – Slides, Worked Examples and Videos – are presented on the platform as the lesson's resources, so students who are visiting materials also visit instructions, even though they do not complete the activities afterwards. This suggests that students on this course accessed all materials provided in the lesson in the sequence they were provided but maybe students did not perceive the information provided in Instructions as relevant to their learning process.

A similar situation occurs with Interactive Materials in INFO023, which appear separated from the other types of learning objects. These resources do not provide the level of interactivity existing in interactive examples. Similarly to slide materials or videos, their purpose is to transmit knowledge. The difference lies in the integration of different types of multimedia elements to explain a programming concept: textual explanations combined with images to introduce the topic and audio-visual elements to demonstrate the topic within a practical scenario. The level of interactivity provided allows the student to navigate freely across content sections and interact with video elements. Therefore it is a lower level of interactivity than the one provided in interactive examples. The usage of these materials seems to counteract the usage of interactive examples provided in the same lesson. This may be due to integrations of contents in these materials being more effective for learning than the example provided. These materials are provided in one of the five lessons analysed, so it makes sense that interactions associated with them appear in one of the last components of the final solution.

These interpretations, about how the metrics are distributed across components, the correlations between them and how are they explained by resources design aspects, can be made when such design has been also assessed by the teacher according to these aspects, even if that assessment has not been methodologically and formally performed.

The statistical results obtained are a product of the students' purposes of using KUOLE and resources and the variability of resources provided in lessons analysed. Nevertheless, it is argued that this usage is due to the pedagogical design of these resources and the pedagogical design of the KUOLE platform. Such pedagogical design is manifested through a set of attributes. However, the PCAs do not distinguish whether metrics' distribution and correlations are a consequence of one design attribute or another. The results obtained from usability perception surveys cast a little light on this distinction. The general trend towards the pedagogical attributes of resources is neutral (score of 3) in both INFO023 and INFO055. This means that the impact of using KUOLE, the materials and activities provided has not been significant for these students, which is not "good news" in terms of pedagogical design. It suggests that both the blended learning strategy applied in the new INFO055 as well as the changes made in comparison with previous INFO023 courses –providing the platform and varied learning materials –, have barely had any impact on facilitating the learning of programming.

High scores in pedagogical usability correspond to very low percentages in these cohorts, which suggests that there are still many improvements that need to be done in the pedagogical design to increase the pedagogical usability scores. However, the following question arises and remains unanswered: Is it necessary to make changes in the pedagogical design of resources delivered, in the pedagogical design of the KUOLE platform, in the pedagogy reflected in teaching strategy, or in all of them?

Another aspect that arises is the level at which the pedagogical design of resources needs to be improved. The PCAs and evaluations of usability offer insights into the strengths and weaknesses of the pedagogical design, however, learning metrics components and usability scores do not clarify whether design improvements need to be performed at the level of the resource or the lesson. It is argued that if pedagogical design attributes were improved at both levels, i.e. *within* and *between* learning objects and activities in a lesson, the results obtained in the PCAs and usability evaluations would be very different. However, further case studies would be necessary to compare results and make design conclusions.

Finally, a very significant difference between PCA55 and PCA23 is noticed in the distribution of performance metrics – i.e. formative and summative grades – across the matrices components. These results do not permit conclusions on pedagogical design. Instead, they provide insights on the overall impact of KUOLE and learning resources upon students' academic performance. In the INFO055 cohort, these grades are mainly correlated with programming activities and self-assessment quizzes in Component 1, the most important component of the matrix. In the INFO023 course, such grades seem completely independent of programming activities or content materials and are grouped in component 6, the least important component in the PCA method. This difference does not mean that students in INFO023 did not learn to program by completing the exercises proposed. It is more a consequence of how the platform and resources were used by students and for which purposes. During the process of extracting learning metrics from the KUOLE database, a total of 4236 interaction records were gathered from a cohort of eight individuals (INFO055), while a total of 2980 records were extracted from a cohort of eighteen individuals (INFO023). This difference in the number of interactions can be associated with two factors: (1) the teaching strategy adopted by the teacher; and (2) students' attitudes towards integrating the platform and resources into their learning habits.

With regard to the influence of the teaching strategy, module leaders adopted different approaches towards the usage of the platform and resources. In INFO055, the teacher used the platform during face-to-face lectures to explain concepts and propose exercises. In INFO023, the teacher and helpers in face-to-face sessions did not use the platform for explaining or showing learning materials to students. Instead, they reminded the students to resort to the platform materials and submit their solutions to exercises. The consequences of the different teachers' usage of the platform during lectures are clearly visible in students' behavioural and learning metrics.

Both cohorts had the same previous experience with the usage of technologies (i.e. none), however, the INFO055 students engaged much more with them than did the INFO023 students.

Another difference is the assessment strategy adopted: students on INFO055 were evaluated during the course according to their responses to programming exercises and tasks in each lesson, whereas INFO023 students performed four formative in-class tests, so their work with proposed exercises in each lesson was never considered for the grade. Not considering students' work with exercises for the final grade is a factor that impacted negatively upon the usage of the platform and usage of resources.

Concerning students' attitudes, it was noticed that INFO055 students were not provided with attractive learning objects, exercises and tasks did not provide the teacher's solution or the possibility to recover their own solutions. As a consequence of this monotonous and disengaging design, the students' motivation in the course, access to the platform, and completed exercises decreased towards the end of the course. In contrast, INFO023 students were provided with interactive learning materials, more slide presentations with explanations, quizzes for self-assessment (not included in INFO023 before), and the possibility to access the teacher's solution to each exercise and to recover their code. According to behavioural metrics, interactive materials, despite being only available in a couple of lessons, gained much attention and satisfaction from the students. However, according to informal interviews with the module leader, those students who engaged more with the platform also ended up accessing it during formative and summative in-class tests for support purposes, interacting more with the teacher solutions provided.

❖ *Does students' learning style explain their behaviour with learning materials and activities or is it the discipline, in this case, Computer Programming, that determines such interactions and behaviour?*

The analysis of variance in students' behavioural metrics is the method used to evaluate the impact of learning styles when learning to program. The results obtained show a slight influence of students' learning styles upon their behaviour with the resources provided during the course. Althouh significant differences were detected in some behavioural metrics, these do not match across cohorts when analysing the same style group of students. For example:

- In the Active–Reflective dimension, moderately reflective and balanced groups in INFO055 differ in their visits to exercises, number of exercises answered, time spent with exercises and number of exercises skipped. In contrast, moderately reflective and balanced groups in INFO023 do not differ significantly in behavioural metrics. Furthermore, the moderately active group in INFO023 differs from the balanced group in unexpected behavioural metrics: the number of student's solution requests and time spent reviewing them.

- In the Visual–Verbal dimension, no statistically significant differences were found in the moderately verbal, balanced, moderately visual and strongly visual groups in INFO023; whereas in INFO055 the balanced and strongly verbal differed in three variables; visits to self-assessment quizzes, requests for hint, and visits to exercises. In INFO055 there were differences between moderately verbal and moderately visual students in the time spent with instruction materials; however, in INFO023 these groups did not show any difference in any behavioural metric.
- In the dimension Sequential–Global, differences were found in a wide set of variables between moderately global, balanced and moderately sequential students in INFO055. Most of these differences are found between moderately global and balanced students. In contrast balanced and moderately sequential students in INFO023 did not differ significantly in any behavioural metric.

The only match between INFO055 and INFO023 was found in the Sensing–Intuitive dimension, where no significant differences were found between their moderately intuitive and balanced groups, respectively.

Considering previous experimental studies that have applied the FSLSM, only a couple of results in this study intuitively coincide with them:

In INFO023, strongly sensing students interacted significantly more (in visits and time spent) with the teacher's solution to exercises than moderately sensing students. Sensing students are described as learners who prefer to use standard and well-known solutions to solve problems. The teacher's solution to exercises can be considered in this case as a "model solution" for the student to review, compare their own work with, or use. This suggests that this behaviour decreases with the strength of preference for the sensing style, but no studies have been found that show differences within different categories of the same style.

Another result found in INFO055 confirms the behaviour of moderately global students compared with more sequential students: the interactions with Instruction materials. Global students like to get the "big picture" in learning scenarios. Instructions provide this "big picture" in the form of information about which learning objectives are supposed to be achieved when completing the lesson activities; as a result these metrics are higher for them. In INFO023, there are no students with global preferences, and also, Instructions or equivalent materials were not provided.

The obtained results confirm a slight influence of learning styles on students' behaviour, but there are some factors specific to these case studies that prevent generalization of the findings.

In the first place, the sample sizes are too small in both cohorts, where some categories are constituted by a single individual, e.g. the moderately sequential student in INFO055. Apart of isolating the findings of this thesis, this condition has meant that some learning styles could not be analysed because of the lack of individuals manifesting them. Previous studies that have demonstrated or confirm the influence of learning styles on students' behaviour report results distinguishing between extreme categories of the dimensions. For example, active students in contrast with reflective students, sequential students in contrast with global students, etc. Those experiments were performed on big cohorts where extreme categories in each dimension were available for study and each group had a sufficient number of individuals.

In the case studies presented in this thesis, the cohorts are too small and for most dimensions the "balanced" students is usually the biggest group, which makes it difficult to determine the influence of learning preferences. The FSLSM is based on the concept of tendencies, which means that even individuals with very strong preferences can, sometimes, act differently (Felder & Silverman, 1988; Graf et al., 2008; Graf & Liu, 2010). For this reason, the model is also open to exceptions and unexpected behaviour with different types of learning resources and LMS features. According to the FSLSM description of categories, a balanced style does not show strong preferences in any dimension. Therefore, a trend in the behaviour of balanced individuals should not be associated with the influence of any learning style. In fact, no previous related study reviewed has reported conclusions or results about balanced preferences.

Second, in order to explore the influence of learning styles it would be necessary to consider different learning metrics from those selected in this work. The definitions that the FSLSM provides for each learning style and the expected behaviour of individuals provide insights into which interactions to observe. For example, Graf, Liu, and Kinshuk analysed academic performance in different types of assessments to extract differences between sensing and intuitive students, and the number of posts and readings in the course forum to distinguish between active and reflective students (Graf et al., 2008). In order to analyse the influence of sequential and global students, the authors analysed navigational patterns through different types of resources (Liu & Graf, 2009).

The results obtained in this research cannot confirm the influence of learning styles, however, there is enough evidence to recommend considering them as theories to inform instructional design, at least at the level of learning platform development (Akbulut & Cardak, 2012; Liu & Graf, 2009). This requires working with a tremendous amount of data since it is clear that the more variability and amount of content materials, learning activities and features in the LMS for students to interact with, the more types of learning metrics and patterns of behaviour can be extracted to study the influence of learning styles in students. However, in the same manner that these data are successfully applied in the development of adaptive learning systems, they can also be applied to both the design of instructional contexts (i.e. what it is known in the literature as learning designs, learning units, etc.) and the design of individual learning materials.

## 4.5. Limitations of Methodology

The results obtained from analysing the INFO055 and INFO023 case studies suggest that more information and methodological improvements are required to be able to inform pedagogical design with empirical data gathered from students. The methodology adopted and the statistical procedures used (PCA, Kruskal-Wallis Hypothesis Test, and Perceived Usability survey) provide clear results that lead to reflect upon the effectiveness of the pedagogical design of content materials and activities. Nonetheless, the methodology as well as the research methods chosen limit the findings of this thesis.

First, it is clear that there are improvements to be made in all pedagogical attributes of the design, however, it is not possible to distinguish whether the improvements are required at the level of resource or at the level of context (which may be the learning unit, the learning platform, the teaching strategy, etc.). Low correlations between interactions with resources and activities belonging to the same learning unit suggest that modifications are required to improve attributes like Objective, Context, or Integration. These would imply modifications in the pedagogical design of the lesson, which eventually lead to modify pedagogical attributes in the design of resources.

Second, it is not possible to distinguish which pedagogical attributes of design need to be improved. For example, the fact that interactions with programming activities are poorly correlated with interactions with video materials indicates that students are not using videos when completing the assignments of the lesson. From this result, multiple questions can emerge with respect to the pedagogical design of these resources, for example:

- *Does the attribute Objective in the design of video materials align with the attribute Objective of programming activities, or is there a mismatch between them?* It would be necessary to review how the design of video materials and the design of activities permit the student to achieve the same learning objective (attribute Objective).
- *Is this relationship between the video materials and activities clear in the design of both resources so that it is clear to the learner?* Such a relationship could be highlighted by, for example, improving the attributes Context, Support, Previous Knowledge or Self-direction.
- *Is a video the most appropriate mechanism to transmit the knowledge required to complete the assignments?* The answer to this question might lead to modification of the attribute Multimedia Richness of the lesson.

The results obtained from the students' usability evaluation survey to clarify which pedagogical attributes need to be improved. The instrument was useful to provide module leaders with informal but valuable feedback on students' perceptions of KUOLE and the materials, however, it does not associate positive or negative scores with specific types of materials and activities. The design of this survey constitutes the third limitation of this methodology: although it is a short and easy survey for students to complete, it is too general for the purposes of this research.

Concerning learning styles, their influence on students' behaviour has been deeply investigated and proved by some studies implementing adaptive learning systems and recommendation mechanisms, however; such influence has not been confirmed by the results obtained in the case studies presented. In the case studies presented, the small size of the groups of students, as well as the number of resources, constituted the main obstacle to this investigation.

Due to the low number of students in each cohort, statistical methods applied like PCA and Kruskal–Wallis ANOVA were not applied to specific groups of students to observe their behaviour in more depth neither were they able to detect more differences. For example, with more students, the PCA method could have been applied to distinguish the main behavioural trends between different populations in the cohort with different learning styles. Likewise, the Kruskal–Wallis ANOVA performed is affected by this factor. The sample size has limited the analysis of different learning style groups, and the analysis has been carried out on groups of students from a minimum of one individual to a maximum of 13. As a consequence of the low number of students in each style group, the findings obtained cannot be generalized or properly contrasted with similar studies.

Another sample size that impacts upon the results obtained on the influence of learning styles in behaviour with e-learning objects and activities is related to the variety and quantity of different content materials and activities. There is a mismatch in design across the lessons in the course, including the five lessons selected for the analysis. Videos, interactive materials, and interactive examples are very scarce in comparison with slide-based materials and only provided in two or three lessons, and these materials have not been developed to explain all the concepts covered in a programming topic. It has been observed that, with a small amount and variability of content materials, students access them all regardless of their learning style preferences or learning needs.

A similar situation occurs with the amount and variability of learning activities: in the lessons, programming assignments are more numerous than quizzes. The maximum number of quiz assessment activities in a lesson is one, whereas the number of exercises ranges between three and twelve. The consequences of this irregular design of learning units are visible in the results of the PCA. It is considered that the distribution of behavioural metrics across components might have been affected this sample size, but it also demonstrates that typical strategies adopted in teaching computer programming support this learning by coding. The conventional wisdom that "programming is learnt by practice" is therefore due to traditional teaching strategies. With respect to the analysis of variance in students' interactions with different types of resource, it is logical to conclude that low variability and amount of resources results in a low variance in students' behaviour.

## 4.6. Summary of Chapter 4

This chapter has proposed two research questions that aim to observe whether a certain set of metrics extracted from students' interactions with learning contents and programming activities is a solid data source to inform the pedagogical design of such contents and activities. Three sets of results have been obtained for each case study and used to answer the questions asked:

1. A structured matrix where the metrics are grouped according to the resources and activities that students more frequently interacted with and a correlation matrix that shows the relationship between each group of metrics.

   In both case studies, the information shown in these matrices helped to demonstrate students' behaviour trends with different types of resources and activities. The separation of interactions is very clear. However, the oblique rotation reveals that there is a poor correlation among interactions associated with different types of resources and activities. It suggests a disconnection in students' behaviour when learning. Although the main hypothesis could not be proved with this methodology, the results obtained make evident that it is necessary to improve the pedagogical attributes in the design of resources and the whole instructional context. These improvements also include:

- To modify the teaching strategy to encourage both students and teachers to use the virtual learning platform, resources, and activities in face-to-face lectures and individual study time.
- To improve the pedagogical design of KUOLE with additional features (e.g. chat/forum, connection to a repository, integration with a programming environment or a programming visualization tool, etc.) that foster students' motivation and engagement. The final chapter of this work will present in detail these and additional improvements needed to prove the main hypothesis.

2. Evaluation scores that represent students' perception about the impact that course resources and activities have exerted upon their learning of programming.

   The survey administered to students aims to evaluate the usability of resources and activities in the twelve pedagogical attributes identified in Chapter 2. Results in both cohorts reveal an average neutral perception in these aspects. These results suggest that improvements are required to improve students' perceptions of the usability of KUOLE courseware. However, the instrument designed for this evaluation does not detect at which level these modifications are needed. This aspect constitutes another limitation and future improvement suggested in the final chapter.

3. Felder–Silverman learning styles of the students and their semantic correlation with actual interactions with content materials and activities.

Within each cohort, students were grouped according to a style dimension so that each group's interactions could be analysed to find significant variations in their behaviour towards different types of materials and activities. Except two specific results in one of the cohorts that match the FSLSM descriptions, the results obtained do not allow us to confirm the influence of the Felder–Silverman learning style dimensions on students' behaviour with KUOLE courseware. From this experience it can be concluded that students' behaviour may be influenced by a learning style but not guided by it. Nonetheless, the small samples of students, resources, and learning metrics analysed prevetn generalization of any conclusion. In the particular aspect of the number of students, it is also not beneficial that the biggest groups fall into the categories of "balanced" and "moderate". The behavioural characteristics of these categories have not been described by Felder and Silverman or any other related study.

To conclude this chapter, the limitations associated with the methodology adopted and those associated with real-life scenarios that are common in practitioner-led research initiatives are discerned. A set of recommendations to overcome these limitations is presented in the next and final chapter of the thesis. Likewise, the future research work to prove the hypothesis and to continue this line of investigation will be described.

# Chapter 5

# Conclusions and Future Work

This final chapter summarizes the research work presented in this thesis, answers the research questions presented in Chapter 1, reveals the limitations of the research, and makes suggestions to overcome these limitations and undertake further work required to continue this line of investigation.

## 5.1. Summary of the Work Performed

By investigating a new empirical basis to help practitioners and instructional designers to create pedagogically informed e-learning resources, this thesis proposes the analysis of students' behaviour with content materials and activities delivered through e-learning platforms and adopts a practitioner-led methodological approach to undertaking the research.

The review of multiple evaluation frameworks for learning objects allowed a variety of aspects to be distinguished that determine the capability of a resource as a learning or teaching tool. This was followed by the selection of common pedagogical aspects to evaluate in the design of a learning object: *Objective, Integration, Context, Multimedia richness, Previous knowledge, Support, Feedback, Self-direction, Interactivity, Navigation, Assessment* and *Alignment*. Each of these pedagogical aspects has been described in accordance with the different understandings identified in the frameworks that suggest a variety of interactive and non-interactive design approaches. Investigating pedagogical design at the level of the pedagogical attribute has allowed this research to confirm the importance and impact of the instructional context in which a learning resource is used (Cochrane, 2005; Kay & Knaak, 2008; Krauss & Ally, 2005; Nokelainen, 2006). From a pure design perspective, the instructional design of the e-learning resource considered in this work is formed primarily by other learning resources and activities belonging to the same learning unit. The attributes investigated suggest that the pedagogical design of a learning resource influences and is influenced by the pedagogical design of the others. Therefore, we conducted empirical research to analyse the students' behaviour within this context. Likewise, we investigated the influence of learning styles upon students' behaviour as this pedagogical theory, traditionally used to inform and assess pedagogical features in learning systems, might also offer the potential to inform the attributes selected.

The methodology presented is based on two case studies, where a variety of data were collected from two introductory Computer Programming courses which applied different teaching strategies and materials. To observe possible trends in students' learning behaviour with these materials, behavioural data was collected in the form of students' interactions with the resources and actitivities and, accordingly, a set of learning metrics was produced for each cohort. These metrics were analysed from two perspectives: (1) looking for relationships between different materials and activities, and (2) contrasting their correlations with students' learning styles. In parallel, and following traditional approaches towards the evaluation of learning objects, students' perceptions of the usability of the resources in terms of these attributes were gathered.

The results obtained and presented in the previous chapter are affected by circumstantial factors specific to the context where this research took place and by methodological issues that could be improved in future research. Nonetheless, these results help to answer some of the research questions stated in the introduction and provide interesting guidance to inform the continuance of the research undertaken in this work.

## 5.2. Using Behavioural Data to Inform Design

One of the main contributions of this thesis is the novel proposal of using data extracted from the actual use of a set of online-delivered learning resources. Additionally, since there is evidence that individual learning styles influence students' behaviour, their interactions and learning styles were measured and used as empirical data sources to inform the design of e-learning resources. In this regard, the following research question was stated in the introductory chapter:

- *Do students' interactions with materials and information about their respective learning styles represent a sufficient data source to inform pedagogical design attributes of learning resources empirically?*

The set of learning metrics extracted from students' behaviour and the methodology applied help identify the pedagogical design attributes that have the greatest impact upon the learning process. These attributes are *Interactivity, Support, Feedback*, and *Assessment*. It seems that the students engaged more with those resources that presented higher levels interactivity, motivating active learning or learning by doing and engaged much less with those materials that supported reflective or passive learning. This coincides with previous studies reviewed in Chapter 3, where the same attributes are highly valued by teachers and students of different ages evaluating learning objects from a wide range of topics. Therefore, it can be concluded that design should be enriched in these four aspects regardless of the discipline or subject to be learned.

Behavioural and usability data have confirmed that the design of resources needs to provide higher levels interactivity, support, feedback, and assessment. However, it does not clarify where to improve each attribute or how to improve it. The reason is that interactive elements that provide support, feedback, and assessment elements are scarce and homogeneous across programming exercises, tasks, and quizzes; on the other hand, most of the content resources provide even fewer interactive items in their interface. As a consequence, students' interactions with resources do not show much variation and, therefore, the information that can be extracted to improve design attributes individually is very limited.

Regarding other pedagogical attributes, more variability in learning metrics generated is also necessary to inform them. For example, this is the case of the *Self-Direction* and *Navigation* attributes: in many content resources, the level of interactivity offered corresponds to the navigational options through their sections. Capturing users' interactions with navigation elements can be used to detect their navigational patterns (Graf & Liu, 2010) and differentiate sequential access from direct access scenarios. Metrics about sequences of interactions required to inform about these attributes were not included in the set of metrics analysed.

The need to incorporate different types of metrics is also linked to the fact that there are attributes not represented with interactive elements within resources – like, for example, *Objective, Integration, Context, Previous knowledge*, or *Alignment* – therefore it is not possible to capture students' interactions and generate metrics. Nonetheless, if we consider the meaning of these attributes, they represent the connection existing between a resource and its instructional context which, at the same time, is composed of the other resources in the lesson and the learning platform. It is necessary to incorporate learning metrics generated by the interactions with the context to inform pedagogical aspects of design through behaviour. For instance, there might be incorporated metrics extracted from the sequences of interactions across resources in the lesson, resources in other lessons, or interactions captured from special features in the platform (e.g. the "search" functionality, student's annotations on materials, etc.).

Metrics and sequences extracted from interactions with different resources make it possible to detect patterns of association between contents, assessments, and performance, and to distinguish efficient from inefficient learning patterns. In the experimental research performed, the metrics analysed have constituted a sufficient data source to discover disconnections and imbalance in the usage of content resources and activities of lessons. Applying this information to the design of learning resources, some improvements include: (1) add items to the design to increase the levels of *Interactivity, Support, Feedback*, and *Assessment*; and (2) work on the attributes *Objective, Context, Previous Knowledge, Support*, and *Alignment* to make evident to students the connection between contents and activities in the lesson. Although useful, the information does not reveal which attribute needs to be improved, however, recommendations on how to overcome this limitation that can inform continuance of this line of research are presented in Section 5 of this chapter.

Despite the limitations mentioned, I am inclined to think that behavioural data constitutes a stronger tool to inform pedagogical design attributes than learning style data. The experimental research presented in this thesis has shown evidence of the influence of all dimensions of learning style in certain metrics. It cannot be considered cogent evidence, however: first, because of the lack of coincidence between metrics and style dimensions across both cohorts; second, because of the low variability in learning resources used in both courses and low variability in their design: and third, because of the small sample of students in each learning style group.

These factors lead me to conclude that the students' behaviour has been practically independent of individual learning styles and much more determined by the design of lessons and resources, as well as students' learning needs and their motivation towards the subject. Given the conditions and specifics of this work, this does not mean that learning styles do not exert any influence on the learning process. Several empirical studies on the FSLSM have provided good evidence of this impact upon the usage of lessons and resources in learning platforms. Other studies agree with this work in empirical results, considering learning styles a secondary factor influencing the learning process (Wilson, 2011). The following section discusses in more detail the existing debate around the usage of learning style models and their utility to inform the design of instruction.

## 5.3. Learning Styles and Pedagogical Design

The second research question stated in Chapter 1 invites reflection on how learning style information can be used to inform the pedagogical design of e-learning resources:

*Should the pedagogical attributes of learning resources be designed on the grounds of learning styles instead of existing learning theories and principles of instruction?*

The application of learning styles to the design of instruction and learning materials was established by Felder and Silverman (1988), who associated each dimension with an aspect of the design of instruction. Felder and Silverman established a relationship between the dimensions of their model (the FSLSM) and five dimensions of design. Figure 32 shows these associations.

According to the schema in Figure 32, the aspects of design that are informed through learning styles are: the type of contents presented to students (according with the sensing–intuitive dimension), the presentation of the contents (visual–verbal dimension), the organization of contents (inductive–deductive dimension), the role of the student during learning (active–reflective dimension), and the perspective taken to explain the contents (sequential–global dimension).

| *Preferred Learning Style* | | *Corresponding Teaching Style* | |
|---|---|---|---|
| sensory<br>intuitive | perception | concrete<br>abstract | content |
| visual<br>auditory | input | visual<br>verbal | presentation |
| inductive<br>deductive | organization | inductive<br>deductive | organization |
| active<br>reflective | processing | active<br>passive | student participation |
| sequential<br>global | understanding | sequential<br>global | perspective |

**Figure 32.** Mapping of Dimensions of Learning and Teaching Styles by Felder and Silverman (1988).

These associations could be useful to associating these five dimensions to the 12 pedagogical attributes selected in Chapter 2. It would require a deep and complex research study that might open an interesting field of research, however, the important question is the following: should information about learning styles change the design of teachers' proven instructional methods? The validity of using learning styles theories to guide instruction has been a topic of debate over the past 20 years and still is.

The theory of learning styles is based on the idea that not all students are the same and therefore they learn in different ways. Although this idea makes sense at first sight, its implications for pedagogy and instruction give rise to two schools of thought, one in favour of using learning styles to inform teaching strategies and other against it. As presented in Chapter 2 of this thesis, in the field of learning technologies, learning styles have been tested in two main fields of research: (1) to investigate how presenting learning materials and tools according to some learning style models can influence students' academic achievements, and (2) to improve personalization in learning environments (Dağ & Geçer, 2009).

There are available in the literature useful reviews that attempt to clarify the existence of empirical evidence in support of one position or the other (e.g. Akbulut & Cardak, 2012; Coffield, Moseley, Hall, & Ecclestone, 2004; Dağ & Geçer, 2009; Wilson, 2011, 2012; Workman, 2012). Researchers and academic practitioners in favour of adopting learning styles for instruction design present empirical evidence of their results and defend the improvement of learning performance and students' satisfaction with the learning experience offered by Adaptive Hypermedia Systems (e.g. Graf, Lan, Liu & Kinshuk, 2009; IGUAL). The problem is that most of these empirical studies are "small-scale applications of particular models to small samples of students in specific contexts" and "there are very few robust studies which offer, for example, reliable and valid evidence and clear implications for practice based on empirical findings" (Coffield et al., 2004, Section 1, p. 1). A review of 71 studies published between 2000 and 2011 concluded that the findings on learning outcomes are not strong enough; however, they also confirm the satisfaction of students with the instruction received from adaptive platforms. A study in 2002 concluded that, "For each research study supporting the principle of matching instructional style and learning style, there is a study rejecting the matching hypothesis" (Sekar and Townsend, 2002, p. 411, as cited in Coffield et al., 2004).

Despite of these findings, the collected evidence that recommends design instruction according to students' learning styles has been enough to influence the educational industry and extend misconceptions within the academic community in this regard (Sanne, Lee, Howard-Jones & Jolles, 2012), Neuroscience research has shown that, although individuals may have preferences for the modality through which they receive information, they do not process information more effectively when they are educated according to their preferred learning style (Coffield et al., 2004). From the perspective of the brain, it has been proven that visual, auditory, and kinesthetic information is processed in different parts of the brain however, these parts are highly interconnected between them, they mutually activate each other by transferring and exchanging information (Sanne, Lee, Howard-Jones & Jolles, 2012). This connectedness brings great implications for instruction and pedagogy (Pickering & Howard-Jones 2007, Devonshire & Dommett, 2010) however, "the evidence consistently shows that modifying a teaching approach to cater for differences in learning styles does not result in any improvement in learning outcomes" (Geake, 2008, p.130).

A possible way to end the debate might be to find empirical evidence from new research with improvements in the methodologies applied so far. Similarly to the circumstances of this investigation, the main obstacle in these studies is that the sample sizes of participant students and the diversity of instructional materials and methods are too small (Wilson, 2012). An additional problem found in these methodologies is that typically research is carried out through prepared experiments where the groups of students, the materials, and the instructional methods are designed for the purposes of the research interest. It is my opinion that real-life, practitioner-led methodologies that use systematic methods to collect and analyse the same data, from a minimum amount of students and for a minimum period of time, can contribute with empirical and more reliable findings about learning styles theories.

Regarding how this research contributes to this debate, the empirical evidence gathered does not support the design of instruction according to learning styles, and this accords with my personal opinion. The results show that the influence of their learning styles on students' interactions with materials is not as strong as the influence of certain aspects of design, such as the levels of interactivity, feedback, support, and assessment, which impact directly upon students' motivation and engagement with e-learning resources and with their own learning of the subject. In the best-case scenario, in both of my case studies learning styles played a secondary role with respect to the students' behaviour. According to Felder (1988), learning styles only represent tendencies that may manifest during the learning process. Empirical evidence exists because the tendency also exists and this has been proven.

From a learning perspective, we are all born with own natural dispositions for learning, however, we adapt to the tools, conditions, requirements, and constraints of the instructional context and the discipline we experience. Our learning styles adapt and grow through strategies, precisely because we learn to master a variety of contexts (Pritchard, 2013). Moreover, the objective of learning technologies and education is to make students' minds and learning styles more flexible and thus enable them to become more efficient learners (Zaharias & Poulymenakou, 2009).

From a teaching perspective, it could be said that learning style theories and models can help teachers understand different ways of learning so that they can enrich their teaching strategies (Workman, 2012). I also believe that it is valuable to enrich these strategies by formally documenting and sharing the pedagogical practices applied to overcome specific learning difficulties. This is another scenario where practitioner-led methodologies in the area of Education and Learning Technologies can contribute significantly.

## 5.4 e-Learning Resources for Computer Programming Courses

This section addresses the third research question stated in Chapter 1 of this thesis:

❖ *Are typical activities and associated learning objects designed for introductory programming subjects an effective manner for novice students to learn programming?*

Typical content materials delivered in introductory Computer Programming courses are slide presentations and videos, while typical activities are programming exercises that ask students to develop simple algorithms and increase their complexity along with the cohort's progress. In the case studies presented, these are the contents and activities delivered in face-to-face lectures and are also available for individual study.

New elements were incorporated in the teaching strategy for these two courses. First, new resources – such as interactive examples and interactive materials – and optional activities – such as quizzes and optional exercises – were introduced. Second, all these resources and activities were delivered through the KUOLE platform, which was a new approach for teaching introductory programming subjects at UACh.

As the empirical results in this thesis demonstrate, when learning programming, these resources as well as the delivery platform constitute an optional support instead of being a primary learning tool of programming concepts. In addition, usability results indicate that these materials have only been effective for a small percentage of students in the cohorts. In general terms and from a pedagogical perspective, not having any effect, or having some effect on a small percentage of learners, can be considered no better than ineffective.

When addressing effective courseware to facilitate the learning of programming subjects, the case studies presented in this thesis have adopted a blended learning approach, where face-to-face lectures and workshops have been combined with the usage of learning objects delivered through a virtual learning environment. Therefore, the main support provided to students was formed by the variety of learning resources that could be accessed whilst working with the programming environment, according to each learner's needs for information. In this sense, both learning resources and the learning platform are the subjects of effectiveness analysis:

Examples of effective learning objects for helping the learning of programming can be found in initiatives by Codewitz, where materials are developed on the grounds of students' learning needs and whose design is inspired by programming visualization tools (Bodrow & Bodrow, 2006; Matthíasdóttir, 2004). The design of these objects is not grounded on any particular pedagogical principle or theory but in the difficulties identified by practitioners in the student population. A similar initiative is presented by Boyle (2003) and Jones and Boyle (2007), who proposed a pedagogically informed template to develop learning objects for computer programming subjects. It would be interesting to evaluate the characteristics of these learning objects on the grounds of the set of pedagogical design attributes established in this thesis.

Another example of effective learning environments to support students' learning has been mentioned in this thesis. Adaptive learning platforms – such as IGUAL used in UACh – do not integrate with programming tools but they can be considered effective as they provide a personalized learning process based on students' cultural backgrounds, learning needs, and learning styles (Campos, 2013). A small number of approaches are proposed by practitioners who develop their own didactic programming environment, integrating learning materials with a customized and intuitive interface and support for students (e.g. Nooblab by Neve et al. (2013), see also Radošević, Orehovački, and Lovrenčić (2009)).

Regardless of the e-learning solution adopted, whether blended learning is an effective manner to facilitate novice students to learn computer programming may be the right question to ask. Considering the results obtained from students' usability evaluation scores, presented in the previous chapter, as well as the differences in academic performance between students in INFO055 and INFO023 respectively, it seems that none of the traditional or novel materials have exerted positive or negative impacts upon the learning of programming in these courses. Now, these results might be associated with the pedagogical design and usability of the KUOLE platform, the resources, or how these particular e-learning tools have been used in these courses, that is, how the teaching strategy incorporated these tools to facilitate or motivate the students' learning of the subject. Based on the experience I have gained at UACh, I agree that adopting blended learning strategies for teaching computer programming subjects does not bring any advantage unless their usage and integration in the teaching strategy are grounded on learning theories and pedagogical principles (Hadjerrouit, 2008).

## 5.5. Recommendations and Future Work

Current empirical data used to assess and inform design come from usability evaluation instruments. It is considered that these instruments are powerful mechanisms to collect data but, in order to be effective, they need to be meticulously designed to avoid too much subjectivity or too much influence from the circumstances in which the evaluation is performed. These are factors associated with evaluation methodologies which have been identified because of their impact upon the reliability of evaluation frameworks.

Given the value of these evaluations to inform design, this thesis argues that learning behaviour constitutes a source of information which has great potential to inform pedagogical design. The results obtained in this research indicate that learning metrics and behavioural trends can be used to deduce the pedagogical design attributes that impact upon learning, which encourages and supports further research on the line of investigation opened in this work.

To this end, the first recommendation is to investigate in depth each pedagogical attribute so that interactive approaches for design can be associated with it. This will facilitate its evaluation in terms of students' behaviour. At this point, I would recommend taking into account interactions that take place with the interactive elements of the learning object and with the instructional design of its usage. This may include the design of the learning unit with the other learning objects and activities, and the learning platform with its features. A wide variety of types of learning interactions could be collected from the literature that link these interactions with a pedagogical design attribute.

In this context, it is recommended to use a more advanced learning environment which integrates a variety of features (e.g. meaningful navigation options, search tools, annotation tools, forum, discipline-related learning tools, etc.). In the case studies presented, KUOLE is the basic online learning environment used for delivery of learning resources and collecting students responses to activities, therefore interactions with the platform are scarce and pedagogically meaningless for the purposes of this research. It is assumed that richer learning environments offer much more opportunities and variety for interaction. This also implies the need to enhance sufficiently the amount and variety of resources and activities, and to define behavioural interactions associated with each different type. Having a great variety of interactions at these levels (learning resource, learning unit, and learning platform) would enrich the variety of learning metrics that can be extracted from students' behaviour.

The use of learning behaviour as the empirical basis to inform design implies collecting behavioural data periodically in a variety of contexts and applying appropriate statistical research methods in order to discover and get to know behavioural patterns in the particular subject of study (in this case, higher education introductory Computer Programming courses). It is envisaged that this would provide a good repository of empirical and research-validated data to inform the design of learning objects at the level of pedagogical design attribute.

It would be also valuable to establish links between individuals' behavioural patterns, their perceived usability scores, and academic performance as empirical data that measures individuals' learning process to inform design. Likewise it would be meaningful to associate this set of information to data related to individuals' learning profiles, characterized by their learning styles, learning needs, interests, and motivation. Associating these various types of information would open the door for further research on pedagogical design. For example, in the case of learning styles, it would be possible to investigate and inform each pedagogical design attribute with associated dimensions of the FSLSM, investigate which dimensions relate to pedagogical design aspects, and apply different approaches according to the trends stated by each style in one dimension.

In this way, further research questions associated with pedagogical design can be derived from the investigation presented in this thesis. If pedagogical design of learning objects and instructional context are dependent on each other, what are the relationships and boundaries between the design of a learning platform and the design of learning resources? Exploratory and confirmatory analyses of behavioural interactions associated with a pedagogical design aspect may provide some answers to this. My review of existing frameworks for the evaluation of learning objects has demonstrated that many of them exist to evaluate isolated learning resources, however, there is barely any such framework that allows the assessment of the pedagogical characteristics of learning designs. An exceptional example of the latter is the conversational framework proposed by Llaurilard (2013), or Morales Morgado et al. (2009). This has been also identified as one of the current and future lines of research in the area of Learning Analytics (Lockyer, Heathcote, & Dawson, 2013), which proposes the analysis of learning behaviour not only to understand individuals' learning processes but to inform the instructional design of learning materials.

Proving the effectiveness e-learning solutions in contrast with traditional instructional methods, such as learning platforms and learning objects, continues to be one of the main purposes of the current research. From the experience acquired in this investigation, such effectiveness has been tested through the evaluation of design and academic performance. For further research, it is crucial that the evaluation of the pedagogical effectiveness of any type of educational software (learning platforms, learning objects, etc. ) evaluates whether it satisfies a set of teaching and learning needs. Therefore, to inform the pedagogical design of a learning object (or any other learning tool) it is vital to know in detail the characteristics of the target instructional context, how the learning object will be used in practical settings, and for which purpose. A tremendous amount of information can be extracted from analysing the actual usage of learning objects in practical settings, nonetheless it is fundamental to develop systematic mechanisms to extract meaningful information from students' interactions with materials and with their instructional context and to develop relationships that allow such information to be interpreted in terms of instructional and learning design.

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# Appendices

# List of Tables in Appendices

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# APPENDIX 0

## Interpretation of Graphics and Data in Appendices 1–8

Whereas Chapter 4 presented a brief summary of meaningful results obtained from the Kruskal–Wallis hypothesis test, the following Appendices 1–8 contain the whole set of results obtained from this analysis. To facilitate their understanding, this introduction aims to explain how these results are organized and the meaning of the different tables and graphics presented.

### Organization and description of results

Each appendix corresponds to one learning style dimension analysed in one cohort. Since there are four dimensions and two case studies, there are eight appendices:

**Table 0.1.** *Case Studies Appendices*

| FSLSM Dimension | Case Study | |
|---|---|---|
| | **INFO055** | **INFO023** |
| *1- Active-Reflective* | Appendix 1 | Appendix 5 |
| *2- Sensing-Intuitive* | Appendix 2 | Appendix 6 |
| *3- Visual-Verbal* | Appendix 3 | Appendix 7 |
| *4- Sequential-Global* | Appendix 4 | Appendix 8 |

As shown in Table 0.1 above, Appendices 1 to 4 correspond to the analysis performed for INFO055 and Appendices 5 to 8 correspond to INFO023. Appendix 1 and Appendix 5 contain the results of analysing the learning style dimension Active–Reflective in these two cohorts, Appendix 2 and Appendix 6 present results from analysing the dimension Sensing–Intuitive, and so on.

Graphical visualizations and statistical results are presented in a sequence in accordance with the methodology described in Section 3.4.2 of the main thesis and summarized in Figure 24.

The reader will find that the appendices do not include all the tables, graphics, and statistics generated with the Kruskal–Wallis method. This is due to the results from one step determining whether or not to undertake the following step.

In the most complete scenario, results generated from this analysis are presented in three components: (i) a table that contains the results from the hypothesis test (H-test); (ii) two graphics that enable analysis of the distribution of data across groups and differences between them and; (iii) the groups' mean ranks and median statistics.

These three components are explained in more detail below by using as an example the learning style dimension Sequential–Global in the cohort INFO055 (Appendix 4) and the learning metric *Exercises_Answered*.

**1 – Table with hypothesis test results**

Kruskal–Wallis analysis begins with an initial test applied to all learning metrics in order to determine for which of them the null hypothesis can be rejected. The results of this test are presented at the beginning of each appendix.

In Appendix 4, 13 learning metrics have been initially identified that reject the null hypothesis. Figure 0.1 below shows the result of the hypothesis test for the metric *Exercises_Answered*:

| | | | | |
|---|---|---|---|---|
| 15 | The distribution of Exercises_Answered is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .002 | Reject the null hypothesis. |

Figure 0.1 – Example of Result of the Hypothesis Test in Kruskal–Wallis Analysis.

If none of the 21 metrics tested rejects the null hypothesis, then the analysis ends at this point. This is the case of the dimension Sensing–Intuitive in INFO055 (Appendix 2) and the dimensions Visual–Verbal and Sequential–Global in INFO023 (Appendices 7 and 8 respectively).

For those scenarios where this test throws a high number of metrics that reject the null hypothesis, as is the case of Appendix 4, graphics and tables are grouped according to the resource they are related to, for example: the results obtained for *Exercises Answered* are presented along with the results obtained for the metrics *Exercises_Visits, Exercises_Skipped* and *Exercises_Time*.

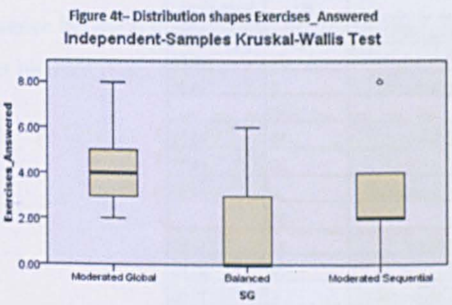
**2 – Similarity between the distribution shape and post-hoc analysis between learning style groups**

For each one of the metrics rejecting the null hypothesis, two types of graphics are presented: the distribution shape boxplots and the post-hoc analysis performed to compare pairs of groups.

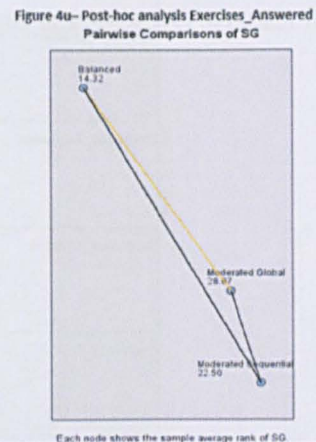
In those cases where there are only two groups of students – like, for example, Appendix 1 where there are only two groups of students in the Active–Reflective dimension –, the box plot also represents the pairwise comparison and, hence, the reader will not find post-hoc analysis visualizations. In those cases with more than two groups, boxplots and the post-hoc analysis corresponding to the same metric, are presented together in the same page (as shown in Figure 0.2). This is the case of the example selected where there are three groups of students in the cohort: *Moderated Global, Balanced* and *Moderated Sequential*.

The boxplot graphic (Figure 4t, in the left side) is used to observe similarity among the distribution shapes of the mean rank calculated (ordinate axis) for each group of students (abscise axis). The statistics provided correspond to a Chi-square test for the sample of data provided by 8 students in five lessons (Total N = 40). The p-value obtained (Sig. = .002) is similar to that shown in the initial hypothesis test.

In this case, this graphic detects there is a significant change in data across the three groups of students, however, in order to distinguish specific groups, it is necessary to observe the post-hoc analysis (Figure 4u, on the right side).




| | |
|---|---|
| Total N | 40 |
| Test Statistic | 12.816 |
| Degrees of Freedom | 2 |
| Asymptotic Sig. (2-sided test) | .002 |




| Sample1-Sample2 | Test Statistic | Std. Error | Std. Test Statistic | Sig. | Adj.Sig. |
|---|---|---|---|---|---|
| Balanced-Moderated Sequential | -8.175 | 5.659 | -1.445 | .149 | .448 |
| Balanced-Moderated Global | 13.742 | 3.866 | 3.555 | .000 | .001 |
| Moderated Sequential-Moderated Global | 5.567 | 5.844 | .953 | .341 | 1.000 |

Figure 0.2 – Example of Distribution shape boxplot and Post-hoc analysis visualization for the learning metric *Exercises_Answered*

Figure 4u shows, firstly, the visualization of comparisons performed between each pair of groups. In the example selected three pairwise comparisons have been performed between the following groups of students:

*-Balanced and Moderated Sequential*

*-Balanced and Moderated Global*

*-Moderated Sequential and Moderated Global*

The post-hoc analysis graphic distinguishes in yellow those comparisons where the difference in the number of exercises answered is statistically significant. In the figure it is only the comparison between *Balanced* and *Moderated Global* groups. The table 4.5 showed in Figure 0.3 below contains the statistics obtained from these comparisons and also highlights in yellow the significance found for the *Balanced-Moderated Global* comparison (Adj. Sig. = .001). This confirms that the difference in the number of exercises answered is significant between these two groups and might be due to the influence of the *Sequential-Global* learning style of the students.

### 3 –Summary of groups' mean rank and median statistics

All appendices where potentially significant differences have been identified in the hypothesis test results include two separate tables to present the mean ranks and the median calculated for each group. In our example, these are Tables 4.5 and 4.6 which are available in pages 274.

**Table 4.5 – Exercise interactions Group Mean Ranks**

| | SG | N | Mean Rank |
|---|---|---|---|
| Exercises_Visits | Moderated Global | 15 | 25,93 |
| | Balanced | 20 | 15,05 |
| | Moderated Sequential | 5 | 26,00 |
| | Total | 40 | |
| Exercises_Answered | Moderated Global | 15 | 28,07 |
| | Balanced | 20 | 14,33 |
| | Moderated Sequential | 5 | 22,50 |
| | Total | 40 | |
| Exercises_Skipped | Moderated Global | 15 | 12,93 |
| | Balanced | 20 | 26,55 |
| | Moderated Sequential | 5 | 19,00 |
| | Total | 40 | |
| Exercises_T | Moderated Global | 15 | 27,13 |
| | Balanced | 20 | 14,70 |
| | Moderated Sequential | 5 | 23,80 |
| | Total | 40 | |

Figure 0.3 – Example of visualization of student groups mean ranks for the learning metric *Exercises_Answered*

It can be noticed that the mean ranks reported in this table are also shown in the graphic of pairwise comparisons showed in Figure 0.2.

**Table 4.6 – Exercise interactions Group Median Report**

| SG | | Exercises_Visits | Exercises_Answered | Exercises_Skipped | Exercises_T |
|---|---|---|---|---|---|
| Moderated Global | N | 15 | 15 | 15 | 15 |
| | Median | 12,00 | 4,00 | ,00 | 30,5886 |
| Balanced | N | 20 | 20 | 20 | 20 |
| | Median | 1,00 | ,00 | 3,50 | ,1128 |
| Moderated Sequential | N | 5 | 5 | 5 | 5 |
| | Median | 10,00 | 2,00 | ,00 | 27,8873 |
| Total | N | 40 | 40 | 40 | 40 |
| | Median | 10,00 | 2,00 | ,00 | 25,7705 |

Figure 0.4 – Example of visualization of student groups median report for the learning metric *Exercises_Answered*

Mean ranks provide insights about which group has a stronger trend to answer proposed exercises and can be used to report and interpret results when the median values do not change between two groups. For example:

In our example with the metric *Exercises_Answered*, it is possible to use medians to interpret results: the number of exercises answered is significantly higher for 3 students in five lessons (N= 3x5 =15) than it is for 4 students (N= 4x5 =20). The moderated global students answered a median of four exercises, whereas balanced students answered a median of zero.

However, if we look at the metric *Exercises_Skipped*, the number of exercises skipped for moderated sequential and moderated global students (are zero in both cases). We cannot use medians to interpret the difference between these groups however, their corresponding mean ranks (19.00 and 12.93 respectively) might be used if necessary.

# APPENDIX 1

## INFO055

## KRUSKAL–WALLIS ANALYSIS

## ACTIVE–REFLECTIVE

## LEARNING STYLE GROUPS

| | Null Hypothesis | Test | Sig. | Decision |
|---|---|---|---|---|
| 1 | The distribution of Slides_Visits is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .199 | Retain the null hypothesis. |
| 2 | The distribution of Slides_Time is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .106 | Retain the null hypothesis. |
| 3 | The distribution of Video_Visits is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .758 | Retain the null hypothesis. |
| 4 | The distribution of Video_Time is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .385 | Retain the null hypothesis. |
| 5 | The distribution of Donwloads_Visits is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .633 | Retain the null hypothesis. |
| 6 | The distribution of Downloads_Time is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .651 | Retain the null hypothesis. |
| 7 | The distribution of Instructions_Visits is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .949 | Retain the null hypothesis. |

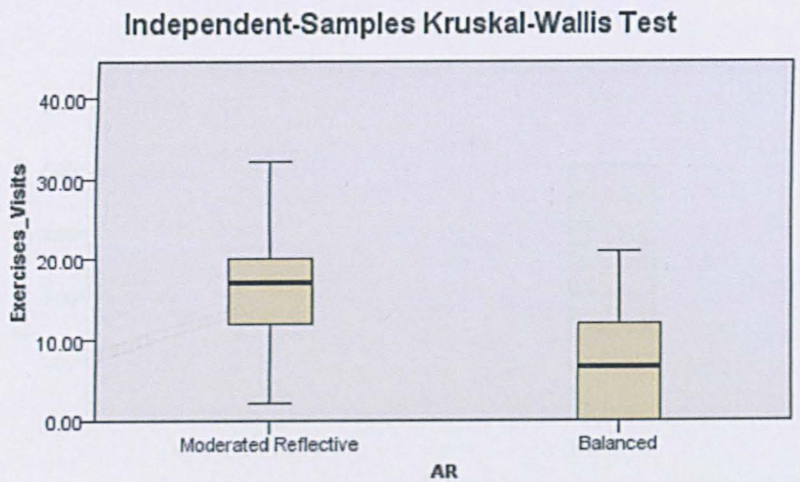
**Figure 1a – INFO055 Active–Reflective Style. Test Hypothesis Results**

| | | | | |
|---|---|---|---|---|
| 8 | The distribution of Instructions_Time is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .949 | Retain the null hypothesis. |
| 9 | The distribution of Quiz_Visits is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .103 | Retain the null hypothesis. |
| 10 | The distribution of Questions_Answered is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .271 | Retain the null hypothesis. |
| 11 | The distribution of Hint_Requests is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .869 | Retain the null hypothesis. |
| 12 | The distribution of Questions_Skipped is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .249 | Retain the null hypothesis. |
| 13 | The distribution of Quiz_T is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .129 | Retain the null hypothesis. |
| 14 | The distribution of Exercises_Visits is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .003 | Reject the null hypothesis. |

**Figure 1b – INFO055 Active–Reflective Style. Test Hypothesis Results**

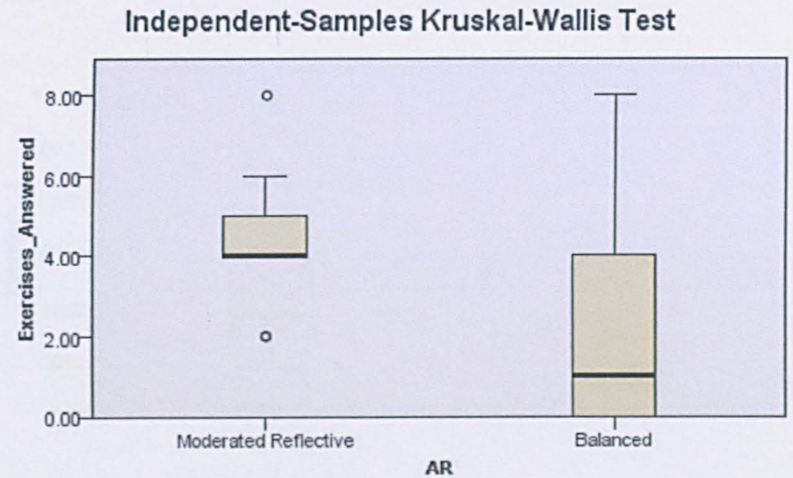
| | | | | |
|---|---|---|---|---|
| 15 | The distribution of Exercises_Answered is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .010 | Reject the null hypothesis. |
| 16 | The distribution of Exercises_Skipped is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .007 | Reject the null hypothesis. |
| 17 | The distribution of Exercises_T is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .001 | Reject the null hypothesis. |
| 18 | The distribution of Tasks_Visits is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .012 | Reject the null hypothesis. |
| 19 | The distribution of Tasks_Answered is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .065 | Retain the null hypothesis. |
| 20 | The distribution of Tasks_skipped is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .044 | Reject the null hypothesis. |
| 21 | The distribution of Tasks_T is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .000 | Reject the null hypothesis. |

**Figure 1c – INFO055 Active–Reflective Style. Test Hypothesis Results**




| | |
|---|---|
| **Total N** | 40 |
| **Test Statistic** | 8.883 |
| **Degrees of Freedom** | 1 |
| **Asymptotic Sig. (2-sided test)** | .003 |

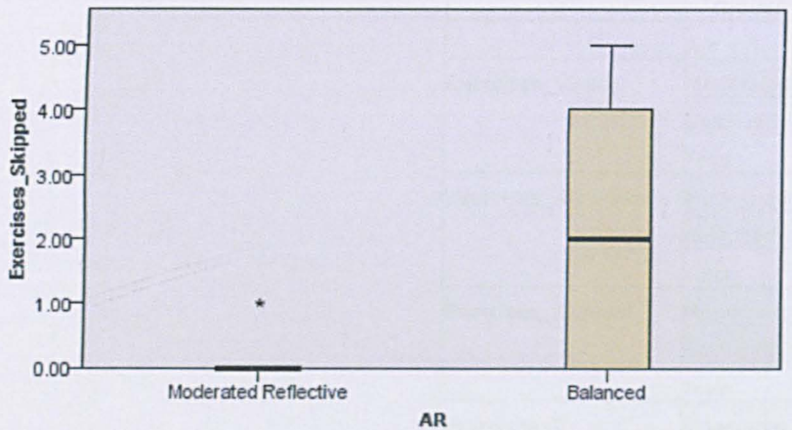
Figure 1d – INFO055 Active–Reflective Style. Distribution shape visualization for Exercises_Visits




| | |
|---|---|
| **Total N** | 40 |
| **Test Statistic** | 6.663 |
| **Degrees of Freedom** | 1 |
| **Asymptotic Sig. (2-sided test)** | .010 |

Figure 1e – INFO055 Active–Reflective Style. Distribution shape visualization for Exercises_Answered

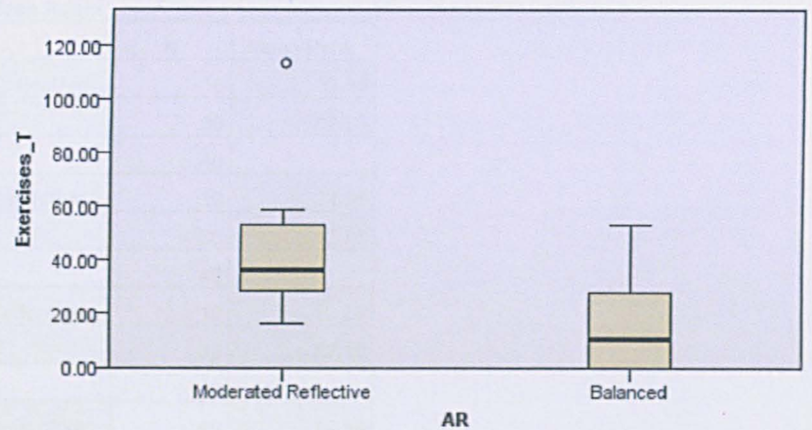
Independent-Samples Kruskal-Wallis Test




| | |
|---|---|
| Total N | 40 |
| Test Statistic | 7.221 |
| Degrees of Freedom | 1 |
| Asymptotic Sig. (2-sided test) | .007 |

Figure 1f – INFO055 Active–Reflective Style. Distribution shape Exercises_skipped

Independent-Samples Kruskal-Wallis Test

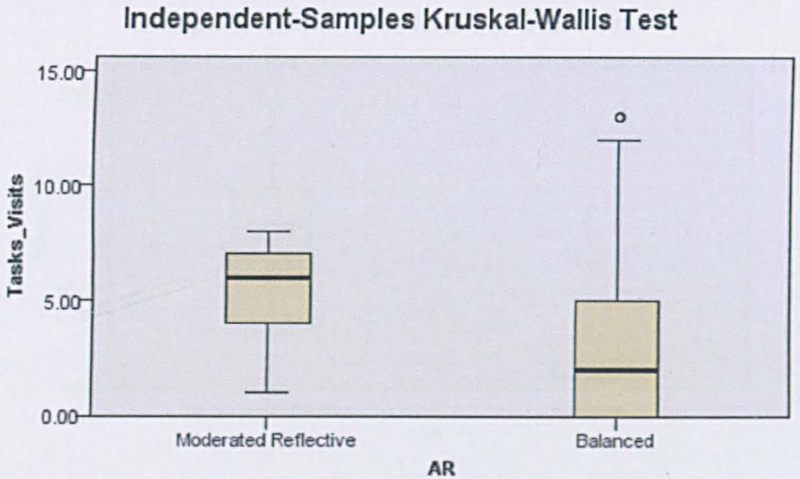



| | |
|---|---|
| Total N | 40 |
| Test Statistic | 10.109 |
| Degrees of Freedom | 1 |
| Asymptotic Sig. (2-sided test) | .001 |

Figure 1g – INFO055 Active–Reflective Style. Distribution shape Exercises_time

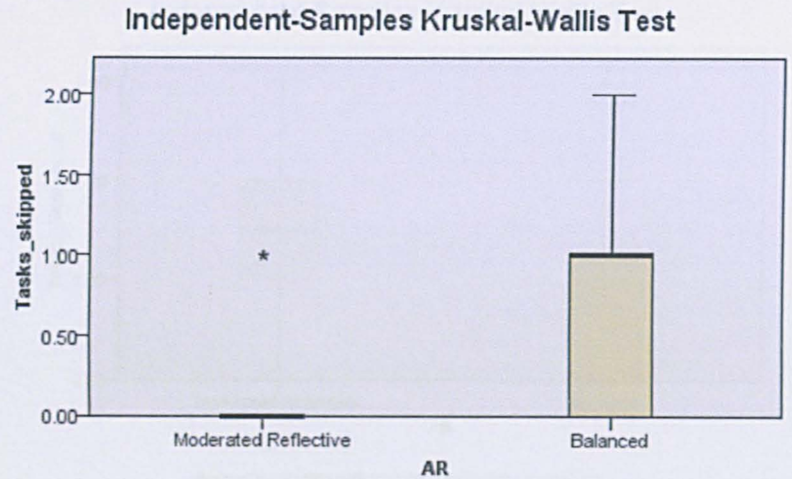
| Table 1.1 – INFO055 Active–Reflective Style. Exercises Interactions Groups Mean Ranks | | | |
|---|---|---|---|
| | AR | N | Mean Rank |
| **Exercises_Visits** | **Moderated Reflective** | 10 | **29.95** |
| | **Balanced** | 30 | **17.35** |
| | Total | 40 | |
| **Exercises_Answered** | **Moderated Reflective** | 10 | **28.50** |
| | **Balanced** | 30 | **17.83** |
| | Total | 40 | |
| **Exercises_Skipped** | **Moderated Reflective** | 10 | **12.70** |
| | **Balanced** | 30 | **23.10** |
| | Total | 40 | |
| **Exercises_T** | **Moderated Reflective** | 10 | **30.60** |
| | **Balanced** | 30 | **17.13** |
| | Total | 40 | |

| Table 1.2 – INFO055 Active–Reflective Style. Exercises Interactions Groups Median Report | | | | | |
|---|---|---|---|---|---|
| AR | | Exercises_Visits | Exercises_Answered | Exercises_Skipped | Exercises_T |
| **Moderated Reflective** | **Median** | **17.00** | **4.00** | **.00** | **36.3463** |
| | N | 10 | 10 | 10 | 10 |
| **Balanced** | **Median** | **6.50** | **1.00** | **2.00** | **10.5941** |
| | N | 30 | 30 | 30 | 30 |
| Total | Median | 10.00 | 2.00 | .00 | 25.7705 |
| | N | 40 | 40 | 40 | 40 |




| | |
|---|---|
| **Total N** | 40 |
| **Test Statistic** | 6.253 |
| **Degrees of Freedom** | 1 |
| **Asymptotic Sig. (2-sided test)** | .012 |

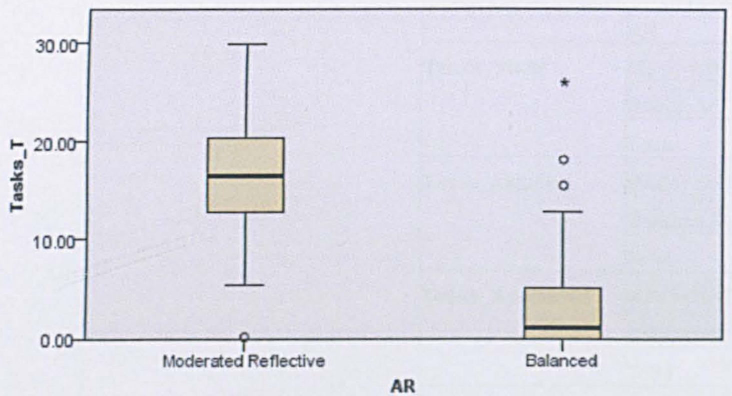
**Figure 1h – INFO055 Active–Reflective Style. Distribution shape Tasks_Visits**




| | |
|---|---|
| **Total N** | 40 |
| **Test Statistic** | 4.070 |
| **Degrees of Freedom** | 1 |
| **Asymptotic Sig. (2-sided test)** | .044 |

**Figure 1i – INFO055 Active–Reflective Style. Distribution shape Tasks_Skipped**

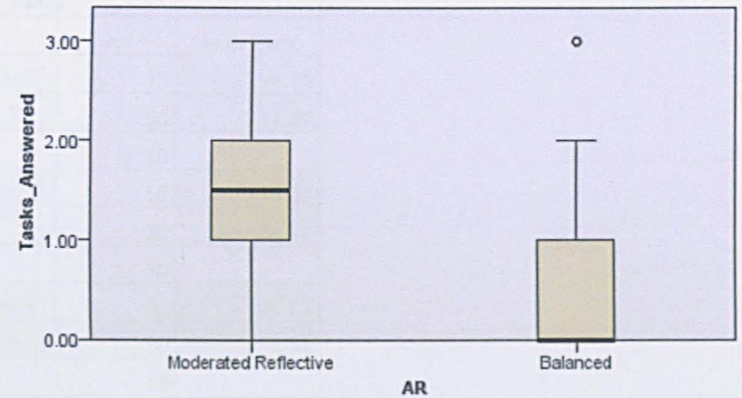
Independent-Samples Kruskal-Wallis Test




| | |
|---|---|
| **Total N** | 40 |
| **Test Statistic** | 12.274 |
| **Degrees of Freedom** | 1 |
| **Asymptotic Sig. (2-sided test)** | .000 |

**Figure 1j – INFO055 Active–Reflective Style. Distribution shape Tasks_Time**

Independent-Samples Kruskal-Wallis Test




| | |
|---|---|
| **Total N** | 40 |
| **Test Statistic** | 3.407 |
| **Degrees of Freedom** | 1 |
| **Asymptotic Sig. (2-sided test)** | .065 |

**Figure 1k – INFO055 Active–Reflective Style. Distribution shape Tasks_Answered**

**Table 1.3 – INFO055 Active–Reflective Style. Tasks Interactions Groups Mean Ranks**

| | AR | N | Mean Rank |
|---|---|---|---|
| **Tasks_Visits** | **Moderated Reflective** | 10 | **28.40** |
| | **Balanced** | 30 | **17.87** |
| | Total | 40 | |
| **Tasks_skipped** | **Moderated Reflective** | 10 | **14.80** |
| | **Balanced** | 30 | **22.40** |
| | Total | 40 | |
| **Tasks_Answered** | **Moderated Reflective** | 10 | **26.05** |
| | **Balanced** | 30 | **18.65** |
| | Total | 40 | |
| **Tasks_T** | **Moderated Reflective** | 10 | **31.60** |
| | **Balanced** | 30 | **16.80** |
| | Total | 40 | |

**Table 1.4 – INFO055 Active–Reflective Style. Tasks Interactions groups Median Report**

| AR | | **Tasks_Visits** | **Tasks_skipped** | **Tasks_Answered** | **Tasks_T** |
|---|---|---|---|---|---|
| **Moderated Reflective** | **Median** | **6.00** | **.00** | **1.50** | **16.5114** |
| | N | 10 | 10 | 10 | 10 |
| **Balanced** | **Median** | **2.00** | **1.00** | **.00** | **.9884** |
| | N | 30 | 30 | 30 | 30 |
| Total | Median | 3.00 | .00 | 1.00 | 2.7776 |
| | N | 40 | 40 | 40 | 40 |

# APPENDIX 2

# INFO055

# KRUSKAL–WALLIS ANALYSIS

# SENSING–INTUITIVE

# LEARNING STYLE GROUPS

## Hypothesis Test Summary

| | Null Hypothesis | Test | Sig. | Decision |
|---|---|---|---|---|
| 1 | The distribution of Slides_Visits is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .150 | Retain the null hypothesis. |
| 2 | The distribution of Slides_Time is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .125 | Retain the null hypothesis. |
| 3 | The distribution of Video_Visits is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .534 | Retain the null hypothesis. |
| 4 | The distribution of Video_Time is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .152 | Retain the null hypothesis. |
| 5 | The distribution of Donwloads_Visits is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .965 | Retain the null hypothesis. |
| 6 | The distribution of Downloads_Time is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .948 | Retain the null hypothesis. |
| 7 | The distribution of Instructions_Visits is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .257 | Retain the null hypothesis. |

Figure 2a– INFO055 Sensing-Intuitive Style. Test Hypothesis Results

| | | | | |
|---|---|---|---|---|
| 8 | The distribution of Instructions_Time is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .088 | Retain the null hypothesis. |
| 9 | The distribution of Quiz_Visits is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .369 | Retain the null hypothesis. |
| 10 | The distribution of Questions_Answered is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .340 | Retain the null hypothesis. |
| 11 | The distribution of Hint_Requests is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .355 | Retain the null hypothesis. |
| 12 | The distribution of Questions_Skipped is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .101 | Retain the null hypothesis. |
| 13 | The distribution of Quiz_T is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .333 | Retain the null hypothesis. |
| 14 | The distribution of Exercises_Visits is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .881 | Retain the null hypothesis. |

Figure 2b– INFO055 Sensing-Intuitive Style. Test Hypothesis Results

| | | | | |
|---|---|---|---|---|
| 14 | The distribution of Exercises_Visits is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .001 | Retain the null hypothesis. |
| 15 | The distribution of Exercises_Answered is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .342 | Retain the null hypothesis. |
| 16 | The distribution of Exercises_Skipped is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .276 | Retain the null hypothesis. |
| 17 | The distribution of Exercises_T is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .913 | Retain the null hypothesis. |
| 18 | The distribution of Tasks_Visits is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .279 | Retain the null hypothesis. |
| 19 | The distribution of Tasks_Answered is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .445 | Retain the null hypothesis. |
| 20 | The distribution of Tasks_skipped is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .382 | Retain the null hypothesis. |
| 21 | The distribution of Tasks_T is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .155 | Retain the null hypothesis. |

**Figure 2c– INFO055 Sensing-Intuitive Style. Test Hypothesis Results**

# APPENDIX 3

# INFO055

# KRUSKAL–WALLIS ANALYSIS

# VISUAL–VERBAL

# LEARNING STYLE GROUPS

| | Null Hypothesis | Test | Sig. | Decision |
|---|---|---|---|---|
| 1 | The distribution of Slides_Visits is the same across categories of VV. | Independent-Samples Kruskal-Wallis Test | .155 | Retain the null hypothesis. |
| 2 | The distribution of Slides_Time is the same across categories of VV. | Independent-Samples Kruskal-Wallis Test | .810 | Retain the null hypothesis. |
| 3 | The distribution of Video_Visits is the same across categories of VV. | Independent-Samples Kruskal-Wallis Test | .570 | Retain the null hypothesis. |
| 4 | The distribution of Video_Time is the same across categories of VV. | Independent-Samples Kruskal-Wallis Test | .331 | Retain the null hypothesis. |
| 5 | The distribution of Downloads_Visits is the same across categories of VV. | Independent-Samples Kruskal-Wallis Test | .841 | Retain the null hypothesis. |
| 6 | The distribution of Downloads_Time is the same across categories of VV. | Independent-Samples Kruskal-Wallis Test | .893 | Retain the null hypothesis. |
| 7 | The distribution of Instructions_Visits is the same across categories of VV. | Independent-Samples Kruskal-Wallis Test | .267 | Retain the null hypothesis. |

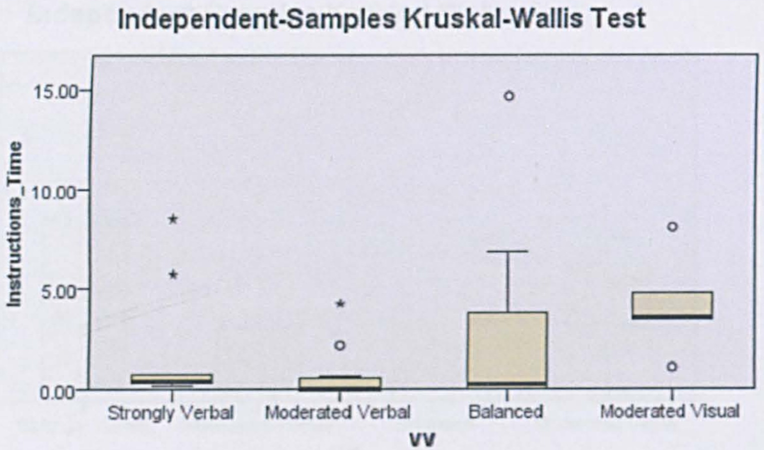
Figure 3a– INFO055 Visual-Verbal Style. Test Hypothesis Results

| | | | | |
|---|---|---|---|---|
| 8 | The distribution of Instructions_Time is the same across categories of VV. | Independent-Samples Kruskal-Wallis Test | .014 | Reject the null hypothesis. |
| 9 | The distribution of Quiz_Visits is the same across categories of VV. | Independent-Samples Kruskal-Wallis Test | .026 | Reject the null hypothesis. |
| 10 | The distribution of Questions_Answered is the same across categories of VV. | Independent-Samples Kruskal-Wallis Test | .264 | Retain the null hypothesis. |
| 11 | The distribution of Hint_Requests is the same across categories of VV. | Independent-Samples Kruskal-Wallis Test | .035 | Reject the null hypothesis. |
| 12 | The distribution of Questions_Skipped is the same across categories of VV. | Independent-Samples Kruskal-Wallis Test | .095 | Retain the null hypothesis. |
| 13 | The distribution of Quiz_[illegible] is the same across categories of VV. | Independent-Samples Kruskal-Wallis Test | .147 | Retain the null hypothesis. |
| 14 | The distribution of Exercises_Visits is the same across categories of VV. | Independent-Samples Kruskal-Wallis Test | .038 | Reject the null hypothesis. |

Figure 3b– INFO055 Visual-Verbal Style. Test Hypothesis Results

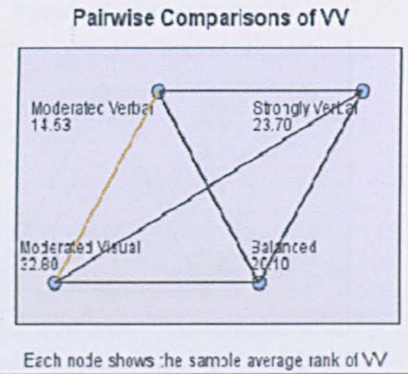
| | | | | |
|---|---|---|---|---|
| 15 | The distribution of Exercises_Answered is the same across categories of VV. | Independent-Samples Kruskal-Wallis Test | .064 | Retain the null hypothesis. |
| 16 | The distribution of Exercises_Skipped is the same across categories of VV. | Independent-Samples Kruskal-Wallis Test | .053 | Retain the null hypothesis. |
| 17 | The distribution of Exercises_T is the same across categories of VV. | Independent-Samples Kruskal-Wallis Test | .121 | Retain the null hypothesis. |
| 18 | The distribution of Tasks_Visits is the same across categories of VV. | Independent-Samples Kruskal-Wallis Test | .059 | Retain the null hypothesis. |
| 19 | The distribution of Tasks_Answered is the same across categories of VV. | Independent-Samples Kruskal-Wallis Test | .228 | Retain the null hypothesis. |
| 20 | The distribution of Tasks_skipped is the same across categories of VV. | Independent-Samples Kruskal-Wallis Test | .100 | Retain the null hypothesis. |
| 21 | The distribution of Tasks_T is the same across categories of VV. | Independent-Samples Kruskal-Wallis Test | .153 | Retain the null hypothesis. |

**Figure 3c– INFO055 Visual-Verbal Style. Test Hypothesis Results**




| | |
|---|---|
| **Total N** | 40 |
| **Test Statistic** | 10.564 |
| **Degrees of Freedom** | 3 |
| **Asymptotic Sig. (2-sided test)** | .014 |

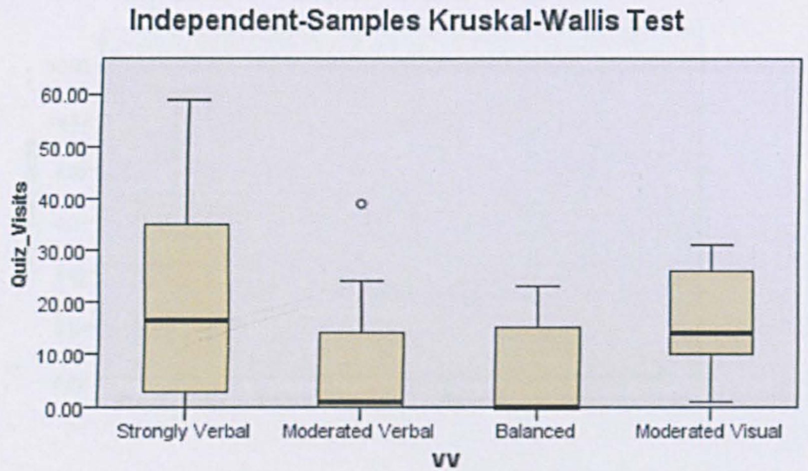
Figure 3d – INFO055 Visual-Verbal Style. Distribution shape Instructions_Time




| Sample1-Sample2 | Test Statistic | Std. Error | Std. Test Statistic | Sig. | Adj.Sig. |
|---|---|---|---|---|---|
| Moderated Verbal-Balanced | -5.567 | 4.690 | -1.187 | .235 | 1.000 |
| Moderated Verbal-Strongly Verbal | 9.167 | 4.690 | 1.954 | .051 | .304 |
| Moderated Verbal-Moderated Visual | -18.267 | 5.933 | -3.079 | .002 | .012 |
| Balanced-Strongly Verbal | 3.600 | 5.138 | .701 | .484 | 1.000 |
| Balanced-Moderated Visual | -12.700 | 6.293 | -2.018 | .044 | .261 |
| Strongly Verbal-Moderated Visual | -9.100 | 6.293 | -1.446 | .148 | .889 |

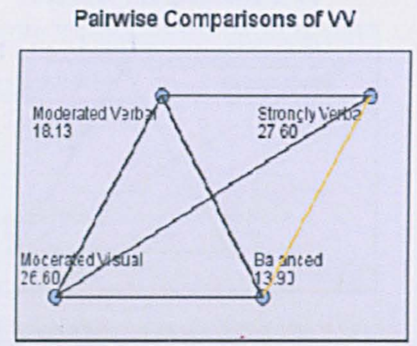
Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .05.

Figure 3e – INFO055 Visual-Verbal Style. Post-hoc analysis Instructions_Time




| | |
|---|---|
| **Total N** | 40 |
| **Test Statistic** | 9.255 |
| **Degrees of Freedom** | 3 |
| **Asymptotic Sig. (2-sided test)** | .026 |

Figure 3f– INFO055 Visual-Verbal Style. Distribution shape Quiz_Visits



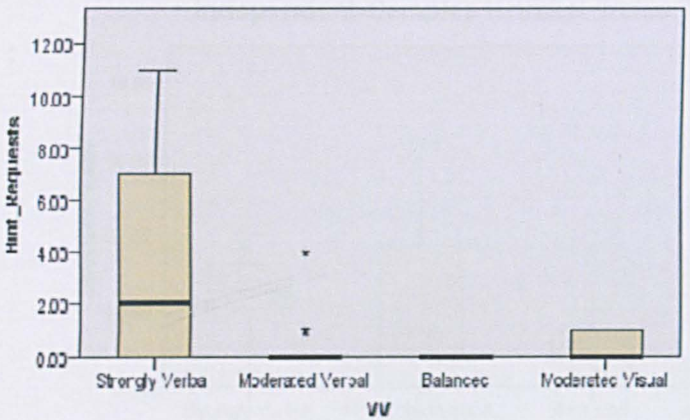

Each node shows the sample average rank of VV.

| Sample1-Sample2 | Test Statistic | Std. Error | Std. Test Statistic | Sig. | Adj.Sig. |
|---|---|---|---|---|---|
| Balanced-Moderated Verbal | 4.233 | 4.668 | .907 | .364 | 1.000 |
| Balanced-Moderated Visual | -12.700 | 6.262 | -2.028 | .043 | .255 |
| Balanced-Strongly Verbal | 13.700 | 5.113 | 2.679 | .007 | .044 |
| Moderated Verbal-Moderated Visual | -8.467 | 5.904 | -1.434 | .152 | .909 |
| Moderated Verbal-Strongly Verbal | 9.467 | 4.668 | 2.028 | .043 | .255 |
| Moderated Visual-Strongly Verbal | 1.000 | 6.262 | .160 | .873 | 1.000 |

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .05.

Figure 3g– INFO055 Visual-Verbal Style. Post-hoc analysis Quiz_Visits

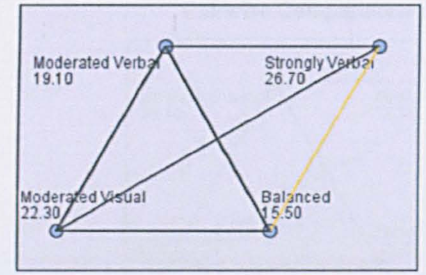
## Independent-Samples Kruskal-Wallis Test




| | |
|---|---|
| **Total N** | 40 |
| **Test Statistic** | 8.619 |
| **Degrees of Freedom** | 3 |
| **Asymptotic Sig. (2-sided test)** | .035 |

Figure 3h – INFO055 Visual-Verbal Style. Distribution shape Hint_Requests

## Pairwise Comparisons of VV



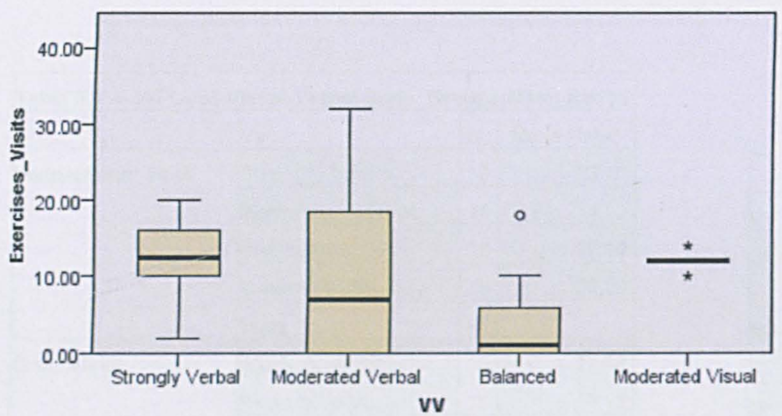

Each node shows the sample average rank of VV.

| Sample1-Sample2 | Test Statistic | Std. Error | Std. Test Statistic | Sig. | Adj.Sig. |
|---|---|---|---|---|---|
| Balanced-Moderated Verbal | 3.600 | 3.626 | .993 | .321 | 1.000 |
| Balanced-Moderated Visual | -6.800 | 4.865 | -1.398 | .162 | .973 |
| Balanced-Strongly Verbal | 11.200 | 3.972 | 2.819 | .005 | .029 |
| Moderated Verbal-Moderated Visual | -3.200 | 4.587 | -.698 | .485 | 1.000 |
| Moderated Verbal-Strongly Verbal | 7.600 | 3.626 | 2.096 | .036 | .217 |
| Moderated Visual-Strongly Verbal | 4.400 | 4.865 | .904 | .366 | 1.000 |

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .05.

Figure 3i – INFO055 Visual-Verbal Style. Post-hoc analysis Hint_Requests

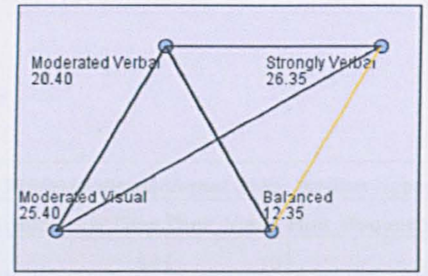
## Independent-Samples Kruskal-Wallis Test




| | |
|---|---|
| **Total N** | 40 |
| **Test Statistic** | 8.405 |
| **Degrees of Freedom** | 3 |
| **Asymptotic Sig. (2-sided test)** | .038 |

Figure 3j– INFO055 Visual-Verbal Style. Distribution shape Exercises_Visits

### Pairwise Comparisons of VV




Each node shows the sample average rank of VV.

| Sample1-Sample2 | Test Statistic | Std. Error | Std. Test Statistic | Sig. | Adj.Sig. |
|---|---|---|---|---|---|
| **Balanced-Moderated Verbal** | 8.050 | 4.726 | 1.703 | .089 | .531 |
| **Balanced-Moderated Visual** | -13.050 | 6.341 | -2.058 | .040 | .238 |
| **Balanced-Strongly Verbal** | 14.000 | 5.178 | 2.704 | .007 | .041 |
| **Moderated Verbal-Moderated Visual** | -5.000 | 5.979 | -.836 | .403 | 1.000 |
| **Moderated Verbal-Strongly Verbal** | 5.950 | 4.726 | 1.259 | .208 | 1.000 |
| **Moderated Visual-Strongly Verbal** | .950 | 6.341 | .150 | .881 | 1.000 |

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .05.

Figure 3k – INFO055 Visual-Verbal Style. Post-hoc analysis Exercises_Visits

Table 3.1 – INFO055 Visual-Verbal Style. Groups Mean Ranks

| | VV | N | Mean Rank |
|---|---|---|---|
| **Instructions_Time** | **Strongly Verbal** | 10 | **23.70** |
| | **Moderated Verbal** | 15 | **14.53** |
| | **Balanced** | 10 | **20.10** |
| | **Moderated Visual** | 5 | **32.80** |
| | Total | 40 | |
| **Quiz_Visits** | **Strongly Verbal** | 10 | **27.60** |
| | **Moderated Verbal** | 15 | **18.13** |
| | **Balanced** | 10 | **13.90** |
| | **Moderated Visual** | 5 | **26.60** |
| | Total | 40 | |
| **Hint_Requests** | **Strongly Verbal** | 10 | **26.70** |
| | **Moderated Verbal** | 15 | **19.10** |
| | **Balanced** | 10 | **15.50** |
| | **Moderated Visual** | 5 | **22.30** |
| | Total | 40 | |
| **Exercises_Visits** | **Strongly Verbal** | 10 | **26.35** |
| | **Moderated Verbal** | 15 | **20.40** |
| | **Balanced** | 10 | **12.35** |
| | **Moderated Visual** | 5 | **25.40** |
| | Total | 40 | |

Table 3.2 – INFO055 Visual-Verbal Style. Median Report

| VV | | Instructions_Time | Quiz_Visits | Hint_Requests | Exercises_Visits |
|---|---|---|---|---|---|
| **Strongly Verbal** | N | 10 | 10 | 10 | 10 |
| | **Median** | **,4153** | **16,50** | **2,00** | **12,50** |
| **Moderated Verbal** | N | 15 | 15 | 15 | 15 |
| | **Median** | **,0000** | **1,00** | **,00** | **7,00** |
| **Balanced** | N | 10 | 10 | 10 | 10 |
| | **Median** | **,2061** | **,00** | **,00** | **1,00** |
| **Moderated Visual** | N | 5 | 5 | 5 | 5 |
| | **Median** | **3,5592** | **14,00** | **,00** | **12,00** |
| Total | N | 40 | 40 | 40 | 40 |
| | Median | ,3955 | 3,00 | ,00 | 10,00 |

# APPENDIX 4

# INFO055

# KRUSKAL–WALLIS ANALYSIS

# SEQUENTIAL–GLOBAL

# LEARNING STYLE GROUPS

| | Null Hypothesis | Test | Sig. | Decision |
|---|---|---|---|---|
| 1 | The distribution of Slides_Visits is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .267 | Retain the null hypothesis. |
| 2 | The distribution of Slides_Time is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .501 | Retain the null hypothesis. |
| 3 | The distribution of Video_Visits is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .556 | Retain the null hypothesis. |
| 4 | The distribution of Video_Time is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .835 | Retain the null hypothesis. |
| 5 | The distribution of Downloads_Visits is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .603 | Retain the null hypothesis. |
| 6 | The distribution of Downloads_Time is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .590 | Retain the null hypothesis. |
| 7 | The distribution of Instructions_Visits is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .040 | Reject the null hypothesis. |

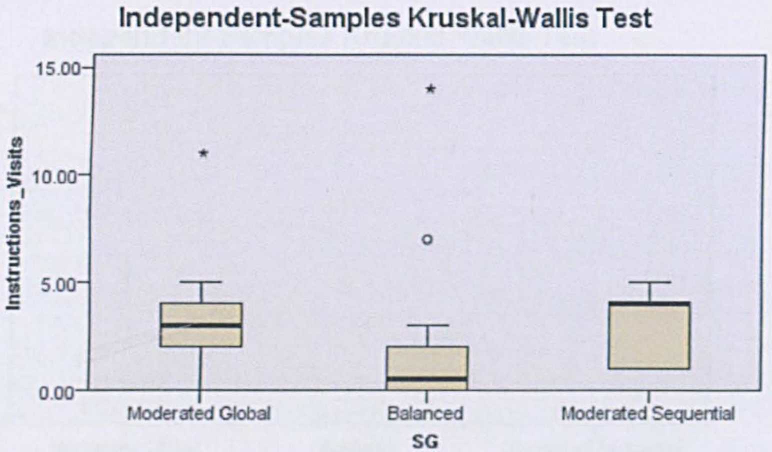
**Figure 4a– INFO055 Sequential-Global Style. Test Hypothesis Results**

| | | | | |
|---|---|---|---|---|
| 8 | The distribution of Instructions_Time is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .010 | Reject the null hypothesis. |
| 9 | The distribution of Quiz_Visits is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .001 | Reject the null hypothesis. |
| 10 | The distribution of Questions_Answered is the same across categories of SG | Independent-Samples Kruskal-Wallis Test | .005 | Reject the null hypothesis. |
| 11 | The distribution of Hint_Requests is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .001 | Reject the null hypothesis. |
| 12 | The distribution of Questions_Skipped is the same across categories of SG | Independent-Samples Kruskal-Wallis Test | .000 | Reject the null hypothesis. |
| 13 | The distribution of Quiz_T is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .001 | Reject the null hypothesis. |
| 14 | The distribution of Exercises_Visits is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .012 | Reject the null hypothesis. |

**Figure 4b– INFO055 Sequential-Global Style. Test Hypothesis Results**

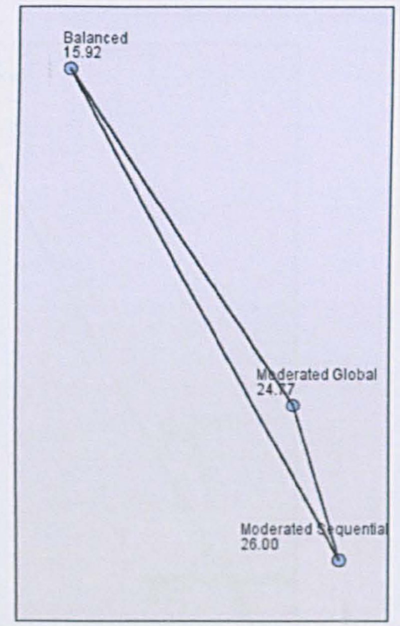
| | | | | |
|---|---|---|---|---|
| 15 | The distribution of Exercises_Answered is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .002 | Reject the null hypothesis. |
| 16 | The distribution of Exercises_Skipped is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .001 | Reject the null hypothesis. |
| 17 | The distribution of Exercises_T is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .006 | Reject the null hypothesis. |
| 18 | The distribution of Tasks_Visits is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .072 | Retain the null hypothesis. |
| 19 | The distribution of Tasks_Answered is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .009 | Reject the null hypothesis. |
| 20 | The distribution of Tasks_skipped is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .004 | Reject the null hypothesis. |
| 21 | The distribution of Tasks_T is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .169 | Retain the null hypothesis. |

**Figure 4c– INFO055 Sequential-Global Style. Test Hypothesis Results**




| | |
|---|---|
| **Total N** | 40 |
| **Test Statistic** | 6.440 |
| **Degrees of Freedom** | 2 |
| **Asymptotic Sig. (2-sided test)** | .040 |

Figure 4d– INFO055 Sequential-Global Style. Distribution shapes Instructions_Visits

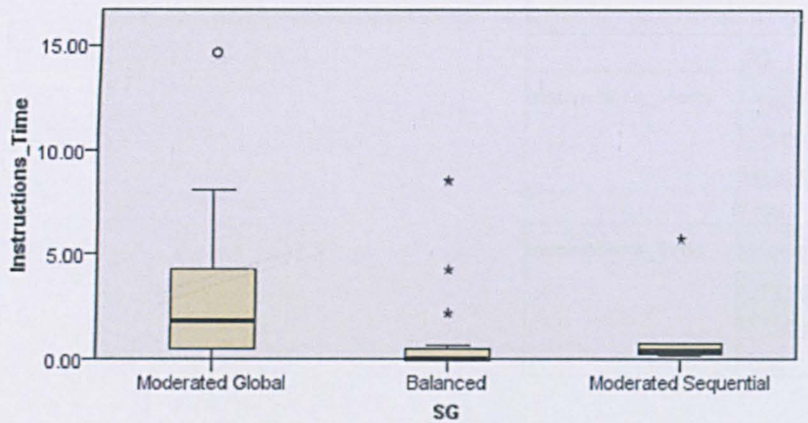



Each node shows the sample average rank of SG.

| Sample1-Sample2 | Test Statistic | Std. Error | Std. Test Statistic | Sig. | Adj.Sig. |
|---|---|---|---|---|---|
| Balanced-Moderated Global | 8.842 | 3.908 | 2.263 | .024 | .071 |
| Balanced-Moderated Sequential | -10.075 | 5.721 | -1.761 | .078 | .235 |
| Moderated Global-Moderated Sequential | -1.233 | 5.908 | -.209 | .835 | 1.000 |

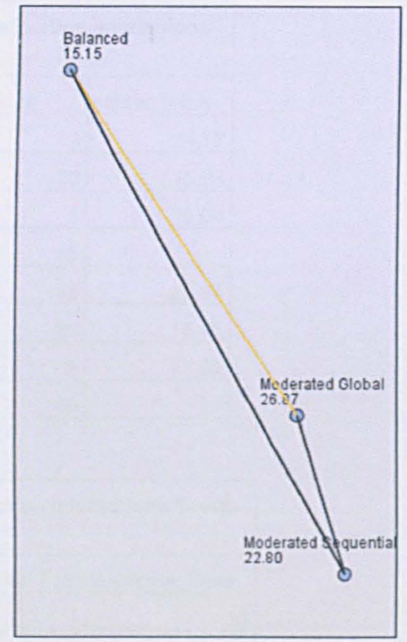
Figure 4e– INFO055 Sequential-Global Style. Post-hoc analysis Instructions_Visits

Independent-Samples Kruskal-Wallis Test




| | |
|---|---|
| **Total N** | 40 |
| **Test Statistic** | 9.143 |
| **Degrees of Freedom** | 2 |
| **Asymptotic Sig. (2-sided test)** | .010 |

Figure 4f– INFO055 Sequential-Global Style. Distribution shapes




Each node shows the sample average rank of SG.

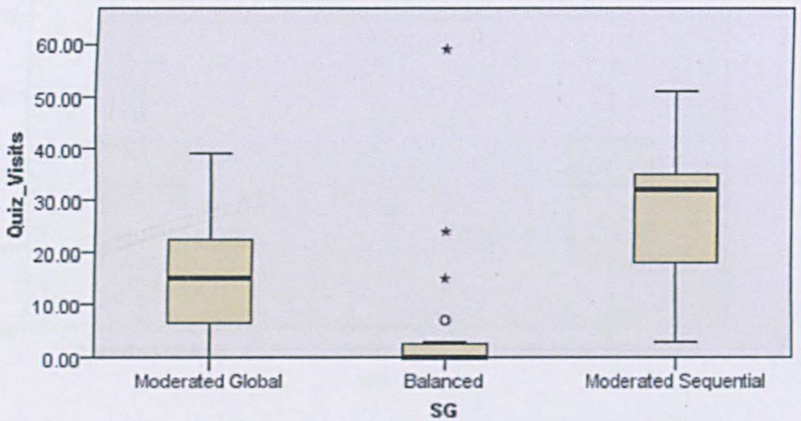
| Sample1-Sample2 | Test Statistic | Std. Error | Std. Test Statistic | Sig. | Adj.Sig. |
|---|---|---|---|---|---|
| Balanced-Moderated Sequential | -7.650 | 5.745 | -1.332 | .183 | .549 |
| Balanced-Moderated Global | 11.717 | 3.924 | 2.986 | .003 | .008 |
| Moderated Sequential-Moderated Global | 4.067 | 5.933 | .685 | .493 | 1.000 |

Figure 4g– INFO055 Sequential-Global Style. Post-hoc analysis

| Table 4.1 – INFO055 Sequential-Global Style. Instruction interactions Group Mean Ranks | | | |
|---|---|---|---|
| | SG | N | Mean Rank |
| **Instructions_Visits** | Moderated Global | 15 | 24,77 |
| | Balanced | 20 | 15,93 |
| | Moderated Sequential | 5 | 26,00 |
| | Total | 40 | |
| **Instructions_Time** | Moderated Global | 15 | 26,87 |
| | Balanced | 20 | 15,15 |
| | Moderated Sequential | 5 | 22,80 |
| | Total | 40 | |

| Table 4.2 – INFO055 Sequential-Global Style. Instruction Interactions Group Median Report | | | |
|---|---|---|---|
| **SG** | | **Instructions_Visits** | **Instructions_Time** |
| Moderated Global | N | 15 | 15 |
| | Median | 3,00 | 1,7662 |
| Balanced | N | 20 | 20 |
| | Median | ,50 | ,0000 |
| Moderated Sequential | N | 5 | 5 |
| | Median | 4,00 | ,3743 |
| Total | N | 40 | 40 |
| | Median | 2,00 | ,3955 |

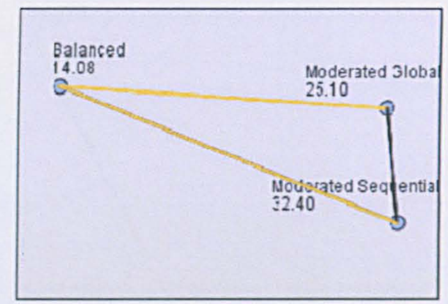
## Independent-Samples Kruskal-Wallis Test




| | |
|---|---|
| **Total N** | 40 |
| **Test Statistic** | 14.161 |
| **Degrees of Freedom** | 2 |
| **Asymptotic Sig. (2-sided test)** | .001 |

**Figure 4h– INFO055 Sequential-Global Style. Distribution shapes Quiz Visits**

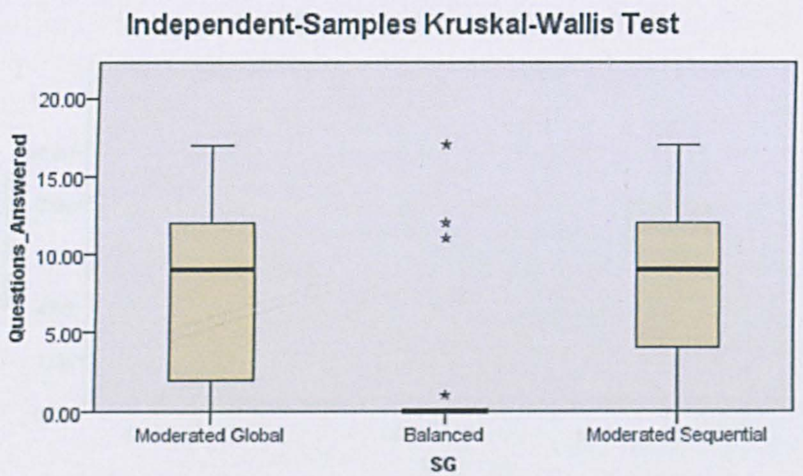
## Pairwise Comparisons of SG




Each node shows the sample average rank of SG.

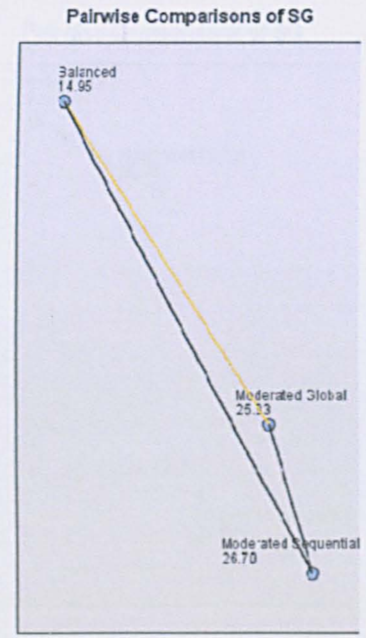
| Sample1-Sample2 | Test Statistic | Std. Error | Std. Test Statistic | Sig. | Adj.Sig. |
|---|---|---|---|---|---|
| Balanced-Moderated Global | 11.025 | 3.905 | 2.823 | .005 | .014 |
| Balanced-Moderated Sequential | -18.325 | 5.717 | -3.206 | .001 | .004 |
| Moderated Global-Moderated Sequential | -7.300 | 5.904 | -1.236 | .216 | .649 |

**Figure 4i– INFO055 Sequential-Global Style. Post-hoc analysis Quiz Visits**




| | |
|---|---|
| Total N | 40 |
| Test Statistic | 10.625 |
| Degrees of Freedom | 2 |
| Asymptotic Sig. (2-sided test) | .005 |

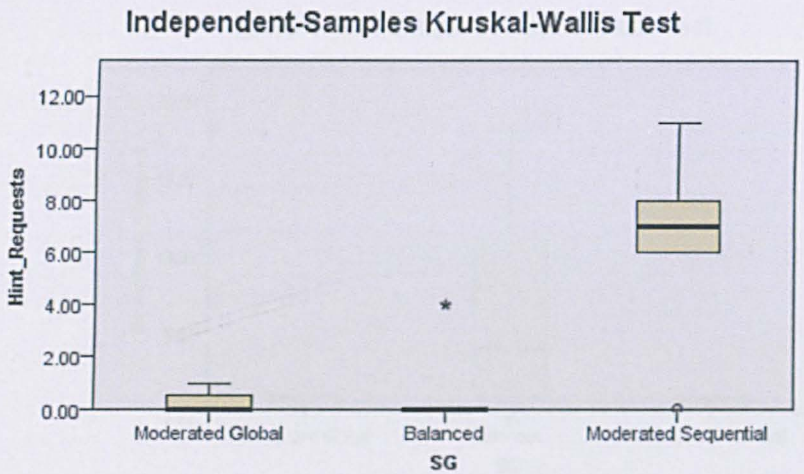
Figure 4j– INFO055 Sequential-Global Style. Distribution shapes Questions_Answered




Each node shows the sample average rank of SG.

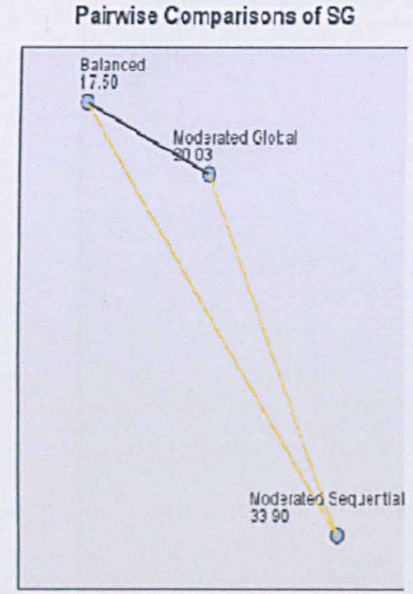
| Sample1-Sample2 | Test Statistic | Std. Error | Std. Test Statistic | Sig. | Adj.Sig. |
|---|---|---|---|---|---|
| Balanced-Moderated Global | 10.883 | 3.682 | 2.955 | .003 | .009 |
| Balanced-Moderated Sequential | -11.750 | 5.391 | -2.180 | .029 | .088 |
| Moderated Global-Moderated Sequential | -.867 | 5.567 | -.156 | .875 | 1.000 |

Figure 4k– INFO055 Sequential-Global Style. Post-hoc analysis Questions_Answered




| | |
|---|---|
| **Total N** | 40 |
| **Test Statistic** | 13.702 |
| **Degrees of Freedom** | 2 |
| **Asymptotic Sig. (2-sided test)** | .001 |

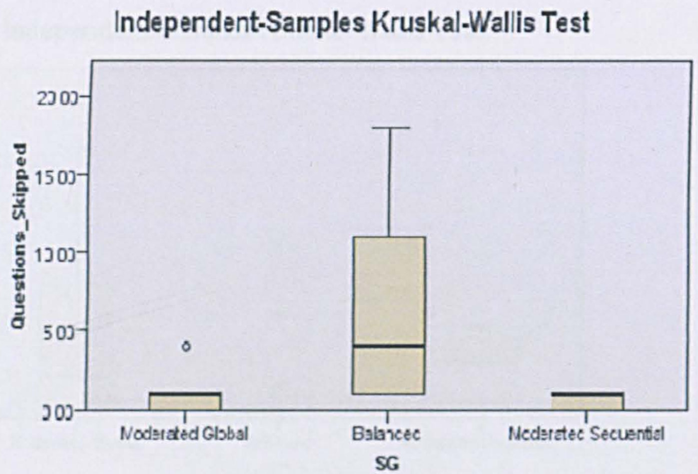
Figure 4l– INFO055 Sequential-Global Style. Distribution shapes Hint_Requests




Each node shows the sample average rank of SG

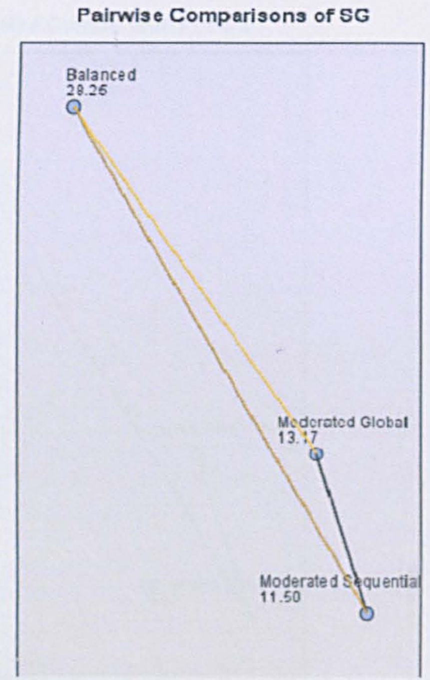
| Sample1-Sample2 | Test Statistic | Std. Error | Std. Test Statistic | Sig. | Adj.Sig. |
|---|---|---|---|---|---|
| Balanced-Moderated Global | 2.533 | 3.334 | .836 | .404 | 1.000 |
| Balanced-Moderated Sequential | -16.400 | 4.441 | -3.693 | .000 | .001 |
| Moderated Global-Moderated Sequential | -13.867 | 4.587 | -3.023 | .003 | .008 |

Figure 4m– INFO055 Sequential-Global Style. Post-hoc analysis Hint_Requests




| | |
|---|---|
| Total N | 40 |
| Test Statistic | 19.593 |
| Degrees of Freedom | 2 |
| Asymptotic Sig. (2-sided test) | .000 |

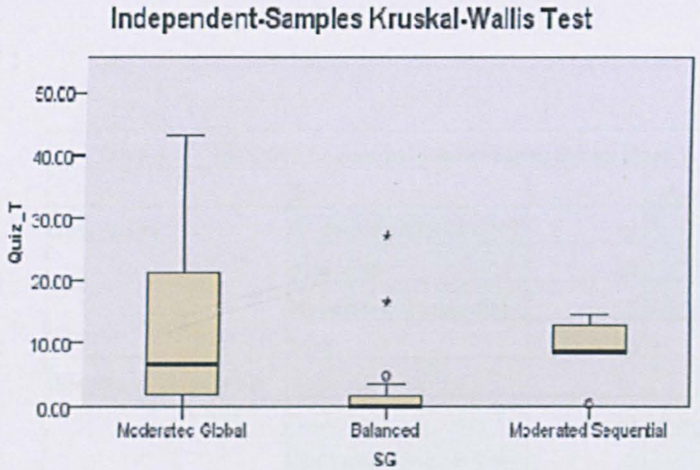
Figure 4n– INFO055 Sequential-Global Style. Distribution shapes Questions_Skipped




Each node shows the sample average rank of SG.

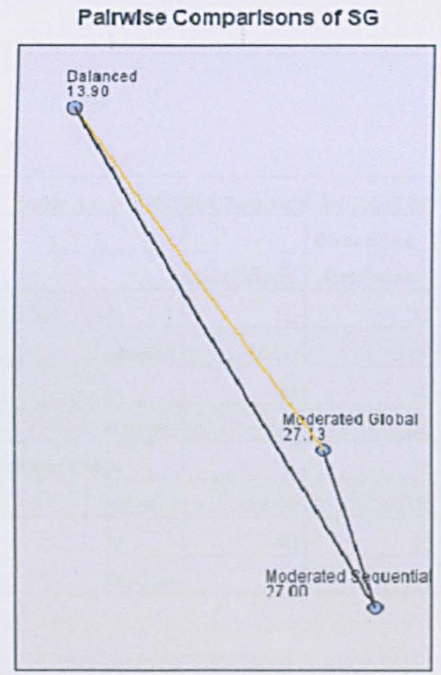
| Sample1-Sample2 | Test Statistic | Std. Error | Std. Test Statistic | Sig. | Adj.Sig. |
|---|---|---|---|---|---|
| Moderated Sequential-Moderated Global | 1.667 | 5.731 | .291 | .771 | 1.000 |
| Moderated Sequential-Balanced | 16.750 | 5.549 | 3.019 | .003 | .008 |
| Moderated Global-Balanced | -15.083 | 3.791 | -3.979 | .000 | .000 |

Figure 4o– INFO055 Sequential-Global Style. Post-hoc analysis Questions_Skipped




| | |
|---|---|
| Total N | 40 |
| Test Statistic | 13.318 |
| Degrees of Freedom | 2 |
| Asymptotic Sig. (2-sided test) | .001 |

Figure 4p– INFO055 Sequential-Global Style. Distribution shapes Quiz_Time



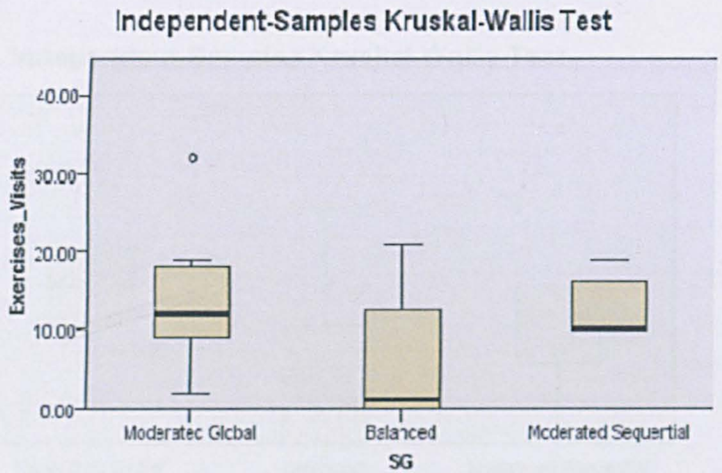

Each node shows the sample average rank of SG.

| Sample1-Sample2 | Test Statistic | Std. Error | Std. Test Statistic | Sig. | Adj.Sig. |
|---|---|---|---|---|---|
| Balanced-Moderated Sequential | -13.100 | 5.719 | -2.291 | .022 | .066 |
| Balanced-Moderated Global | 13.233 | 3.907 | 3.387 | .001 | .002 |
| Moderated Sequential-Moderated Global | .133 | 5.907 | .023 | .982 | 1.000 |

Figure 4q– INFO055 Sequential-Global Style. Post-hoc analysis Quiz_Time

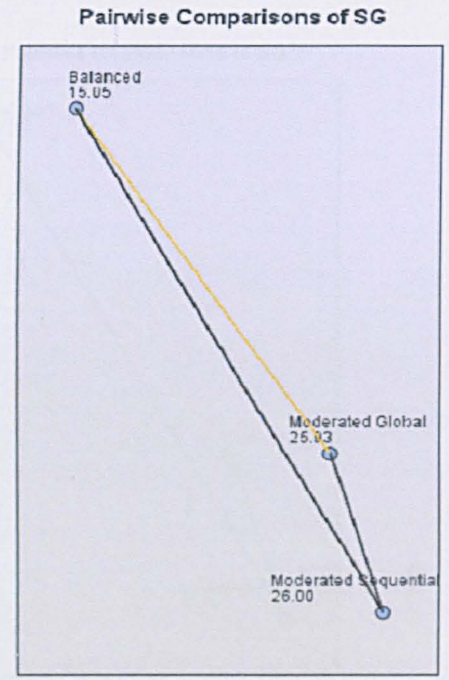
| Table 4.3 – INFO055 Sequential-Global Style. Group Mean Rank | | | |
|---|---|---|---|
| | SG | N | Mean Rank |
| Quiz_Visits | **Moderated Global** | 15 | **25,10** |
| | **Balanced** | 20 | **14,08** |
| | **Moderated Sequential** | 5 | **32,40** |
| | Total | 40 | |
| Questions_Answered | **Moderated Global** | 15 | **25,83** |
| | **Balanced** | 20 | **14,95** |
| | **Moderated Sequential** | 5 | **26,70** |
| | Total | 40 | |
| Hint_Requests | **Moderated Global** | 15 | **20,03** |
| | **Balanced** | 20 | **17,50** |
| | **Moderated Sequential** | 5 | **33,90** |
| | Total | 40 | |
| Questions_Skipped | **Moderated Global** | 15 | **13,17** |
| | **Balanced** | 20 | **28,25** |
| | **Moderated Sequential** | 5 | **11,50** |
| | Total | 40 | |
| Quiz_T | **Moderated Global** | 15 | **27,13** |
| | **Balanced** | 20 | **13,90** |
| | **Moderated Sequential** | 5 | **27,00** |
| | Total | 40 | |

| Table 4.4 – INFO055 Sequential-Global Style. Group Median Report | | | | | | |
|---|---|---|---|---|---|---|
| SG | | Quiz_Visits | Questions_ Answered | Hint_Requests | Questions_ Skipped | Quiz_T |
| Moderated Global | N | 15 | 15 | 15 | 15 | 15 |
| | Median | 15,00 | 9,00 | ,00 | 1,00 | 6,4829 |
| Balanced | N | 20 | 20 | 20 | 20 | 20 |
| | Median | ,00 | ,00 | ,00 | 4,00 | ,0000 |
| Moderated Sequential | N | 5 | 5 | 5 | 5 | 5 |
| | Median | 32,00 | 9,00 | 7,00 | 1,00 | 8,6893 |
| Total | N | 40 | 40 | 40 | 40 | 40 |
| | Median | 3,00 | ,00 | ,00 | 1,00 | 1,8608 |




| | |
|---|---|
| Total N | 40 |
| Test Statistic | 8.664 |
| Degrees of Freedom | 2 |
| Asymptotic Sig. (2-sided test) | .012 |

Figure 4r– INFO055 Sequential-Global Style. Distribution shapes Exercises_Visits

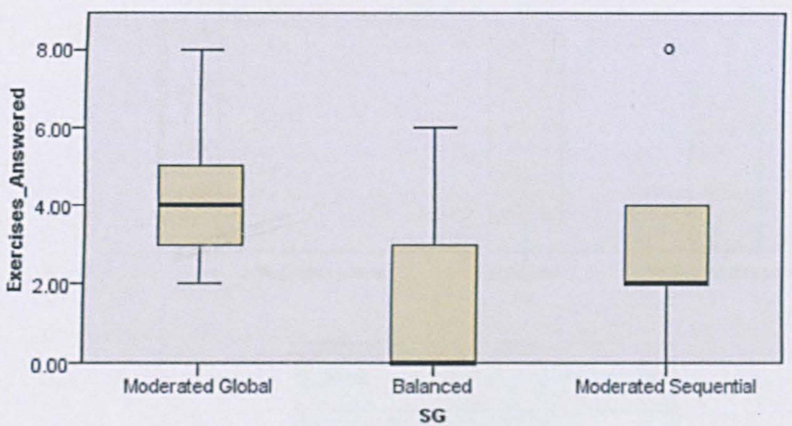



Each node shows the sample average rank of SG.

| Sample1-Sample2 | Test Statistic | Std. Error | Std. Test Statistic | Sig. | Adj.Sig. |
|---|---|---|---|---|---|
| Balanced-Moderated Global | 10.883 | 3.954 | 2.752 | .006 | .018 |
| Balanced-Moderated Sequential | 10.950 | 5.789 | 1.892 | .059 | .176 |
| Moderated Global-Moderated Sequential | -.067 | 5.979 | -.011 | .991 | 1.000 |

Figure 4s– INFO055 Sequential-Global Style. Post-hoc analysis Exercises_Visits

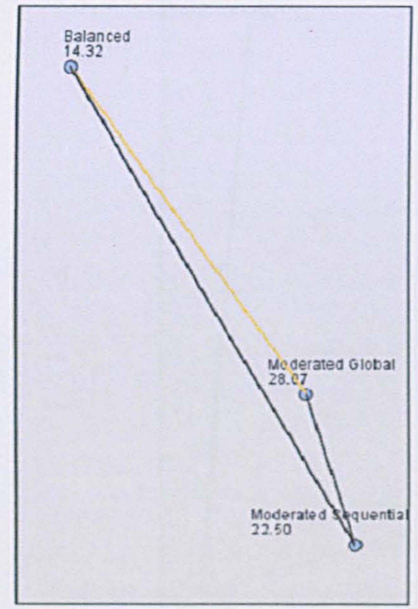
## Independent-Samples Kruskal-Wallis Test




| | |
|---|---|
| **Total N** | 40 |
| **Test Statistic** | 12.816 |
| **Degrees of Freedom** | 2 |
| **Asymptotic Sig. (2-sided test)** | .002 |

Figure 4t– INFO055 Sequential-Global Style. Distribution shapes Exercises_Answered

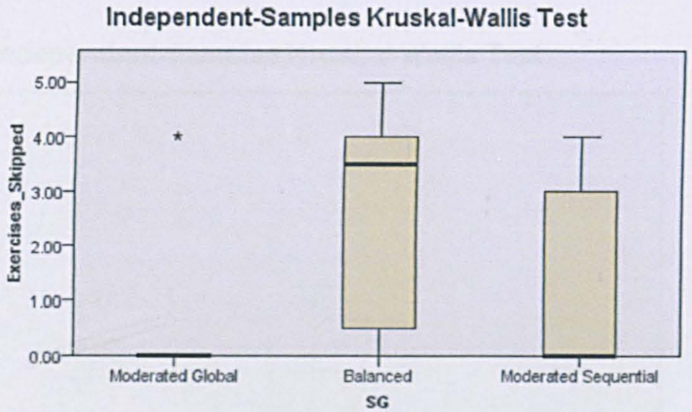
**Pairwise Comparisons of SG**




Each node shows the sample average rank of SG.

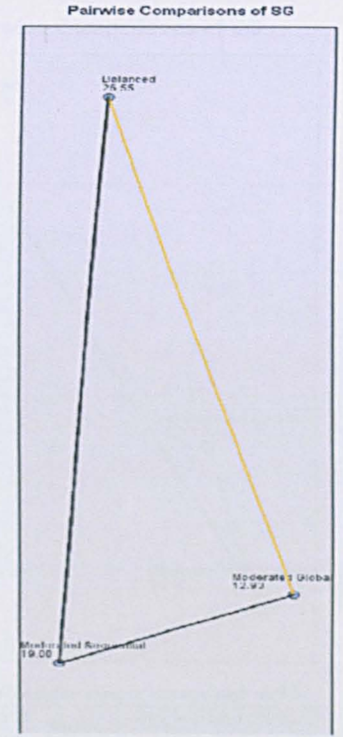
| Sample1-Sample2 | Test Statistic | Std. Error | Std. Test Statistic | Sig. | Adj.Sig. |
|---|---|---|---|---|---|
| Balanced-Moderated Sequential | -8.175 | 5.659 | -1.445 | .149 | .446 |
| Balanced-Moderated Global | 13.742 | 3.866 | 3.555 | .000 | .001 |
| Moderated Sequential-Moderated Global | 5.567 | 5.844 | .953 | .341 | 1.000 |

Figure 4u– INFO055 Sequential-Global Style. Post-hoc analysis Exercises_Answered




| | |
|---|---|
| **Total N** | 40 |
| **Test Statistic** | 14.262 |
| **Degrees of Freedom** | 2 |
| **Asymptotic Sig. (2-sided test)** | .001 |

Figure 4v– INFO055 Sequential-Global Style. Distribution shapes Exercises_Skipped

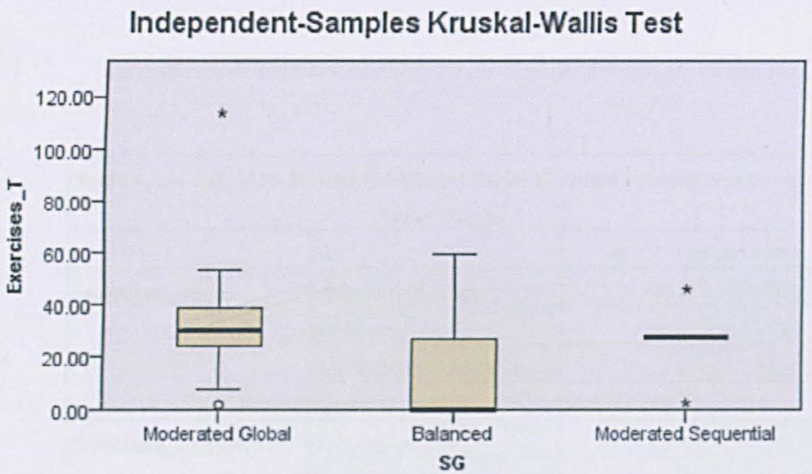



Each node shows the sample average rank of SG.

| Sample1-Sample2 | Test Statistic | Std. Error | Std. Test Statistic | Sig. | Adj.Sig. |
|---|---|---|---|---|---|
| Moderated Global-Moderated Sequential | -6.067 | 5.473 | -1.100 | .200 | .003 |
| Moderated Global-Balanced | -13.617 | 3.620 | -3.761 | .000 | .001 |
| Moderated Sequential-Balanced | 7.660 | 5.299 | 1.425 | .154 | .463 |

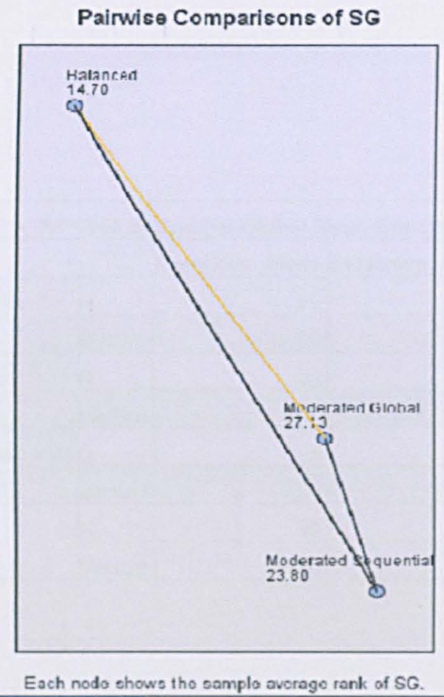
Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .05.

Figure 4w– INFO055 Sequential-Global Style. Post-hoc analysis Exercises_Skipped




| | |
|---|---|
| Total N | 40 |
| Test Statistic | 10.310 |
| Degrees of Freedom | 2 |
| Asymptotic Sig. (2-sided test) | .006 |

Figure 4x– INFO055 Sequential-Global Style. Distribution shapes Exercises_Time




| Sample1 Sample2 | Test Statistic | Std. Error | Std. Test Statistic | Sig. | Adj.Sig. |
|---|---|---|---|---|---|
| Balanced-Moderated Sequential | -9.100 | 5.800 | -1.569 | .117 | .350 |
| Balanced-Moderated Global | 12.433 | 3.962 | 3.130 | .002 | .005 |
| Moderated Sequential-Moderated Global | 3.333 | 5.990 | .556 | .578 | 1.000 |

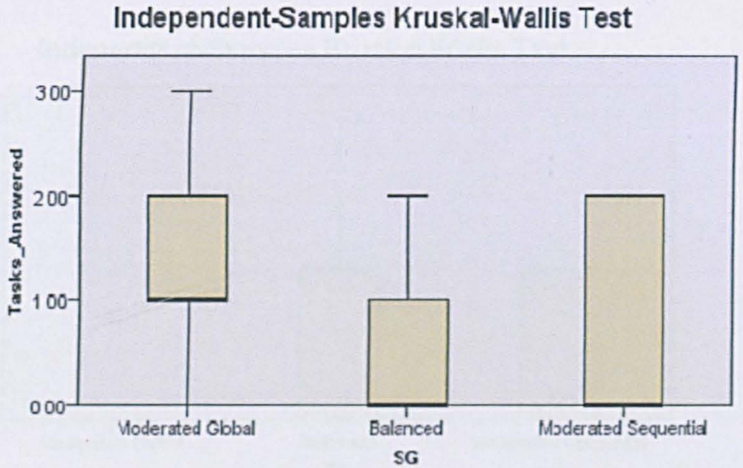
Figure 4y– INFO055 Sequential-Global Style. Post-hoc analysis Exercises_Time

**Table 4.5 – INFO055 Sequential-Global Style. Exercise interactions Group Mean Ranks**

| | SG | N | Mean Rank |
|---|---|---|---|
| Exercises_Visits | Moderated Global | 15 | 25,93 |
| | Balanced | 20 | 15,05 |
| | Moderated Sequential | 5 | 26,00 |
| | Total | 40 | |
| Exercises_Answered | Moderated Global | 15 | 28,07 |
| | Balanced | 20 | 14,33 |
| | Moderated Sequential | 5 | 22,50 |
| | Total | 40 | |
| Exercises_Skipped | Moderated Global | 15 | 12,93 |
| | Balanced | 20 | 26,55 |
| | Moderated Sequential | 5 | 19,00 |
| | Total | 40 | |
| Exercises_T | Moderated Global | 15 | 27,13 |
| | Balanced | 20 | 14,70 |
| | Moderated Sequential | 5 | 23,80 |
| | Total | 40 | |

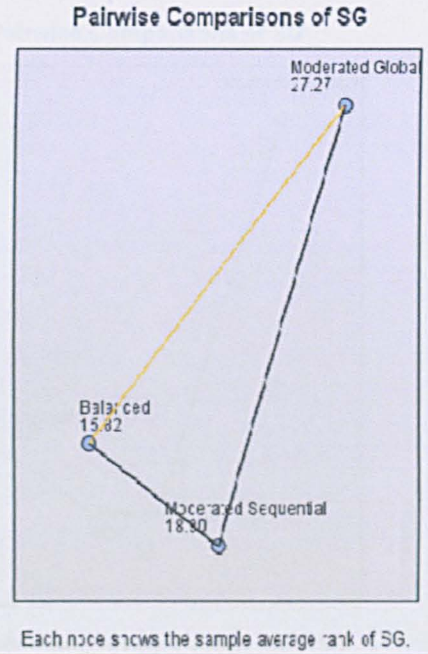
**Table 4.6 – INFO055 Sequential-Global Style. Exercise interactions Group Median Report**

| SG | | Exercises_Visits | Exercises_Answered | Exercises_Skipped | Exercises_T |
|---|---|---|---|---|---|
| Moderated Global | N | 15 | 15 | 15 | 15 |
| | Median | 12,00 | 4,00 | ,00 | 30,5886 |
| Balanced | N | 20 | 20 | 20 | 20 |
| | Median | 1,00 | ,00 | 3,50 | ,1128 |
| Moderated Sequential | N | 5 | 5 | 5 | 5 |
| | Median | 10,00 | 2,00 | ,00 | 27,8873 |
| Total | N | 40 | 40 | 40 | 40 |
| | Median | 10,00 | 2,00 | ,00 | 25,7705 |



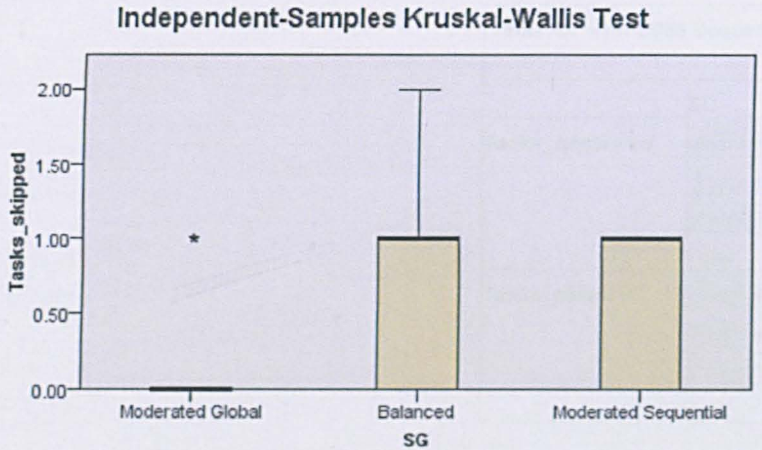

| | |
|---|---|
| **Total N** | 40 |
| **Test Statistic** | 9.430 |
| **Degrees of Freedom** | 2 |
| **Asymptotic Sig. (2-sided test)** | .009 |

Figure 4z– INFO055 Sequential-Global Style. Distribution shapes Task_Answered



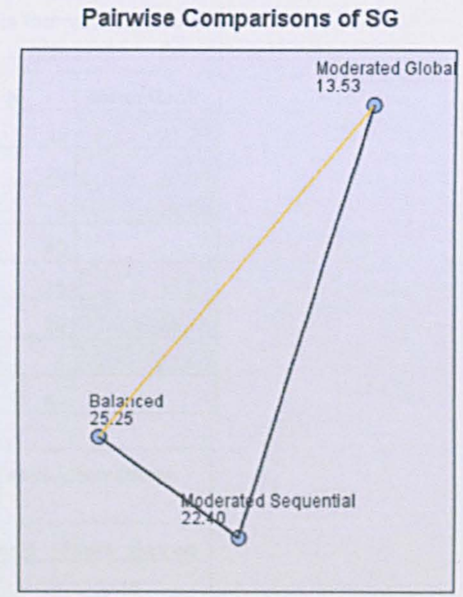

| Sample1-Sample2 | Test Statistic | Std. Error | Std. Test Statistic | Sig. | Adj.Sig. |
|---|---|---|---|---|---|
| Balanced-Moderated Sequential | -3.075 | 5.490 | -.560 | .575 | 1.000 |
| Balanced-Moderated Global | 11.442 | 3.750 | 3.051 | .002 | .007 |
| Moderated Sequential-Moderated Global | 8.367 | 5.670 | 1.475 | .140 | .420 |

Figure 4aa– INFO055 Sequential-Global Style. Post-hoc analysis Task_Answered




| | |
|---|---|
| **Total N** | 40 |
| **Test Statistic** | 11.248 |
| **Degrees of Freedom** | 2 |
| **Asymptotic Sig. (2-sided test)** | .004 |

**Figure 4ab– INFO055 Sequential-Global Style. Distribution shapes Task_Skipped**




Each node shows the sample average rank of SG.

| Sample1-Sample2 | Test Statistic | Std. Error | Std. Test Statistic | Sig. | Adj.Sig. |
|---|---|---|---|---|---|
| Moderated Global-Moderated Sequential | -8.867 | 5.328 | -1.664 | .096 | .288 |
| Moderated Global-Balanced | -11.717 | 3.524 | -3.325 | .001 | .003 |
| Moderated Sequential-Balanced | 2.850 | 5.159 | .552 | .581 | 1.000 |

**Figure 4ac– INFO055 Sequential-Global Style. Post-hoc analysis Task_Skipped**

**Table 4.7 – INFO055 Sequential-Global Style. Tasks interactions Group Mean Ranks**

| | SG | N | Mean Rank |
|---|---|---|---|
| Tasks_Answered | Moderated Global | 15 | 27,27 |
| | Balanced | 20 | 15,83 |
| | Moderated Sequential | 5 | 18,90 |
| | Total | 40 | |
| Tasks_skipped | Moderated Global | 15 | 13,53 |
| | Balanced | 20 | 25,25 |
| | Moderated Sequential | 5 | 22,40 |
| | Total | 40 | |

**Table 4.8 – INFO055 Sequential-Global Style. Tasks interactions Group Median Report**

| SG | | Tasks_Answered | Tasks_skipped |
|---|---|---|---|
| Moderated Global | N | 15 | 15 |
| | Median | 1,00 | ,00 |
| Balanced | N | 20 | 20 |
| | Median | ,00 | 1,00 |
| Moderated Sequential | N | 5 | 5 |
| | Median | ,00 | 1,00 |
| Total | N | 40 | 40 |
| | Median | 1,00 | ,00 |

# APPENDIX 5

# INFO023

# KRUSKAL–WALLIS ANALYSIS

# ACTIVE–REFLECTIVE

# LEARNING STYLE GROUPS

| | Null Hypothesis | Test | Sig. | Decision |
|---|---|---|---|---|
| 1 | The distribution of Slides_Visits is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .588 | Retain the null hypothesis. |
| 2 | The distribution of Slides_Time is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .760 | Retain the null hypothesis. |
| 3 | The distribution of InteractiveExamples_ is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .937 | Retain the null hypothesis. |
| 4 | The distribution of InteractiveExamples_T is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .904 | Retain the null hypothesis. |
| 5 | The distribution of InteractiveMaterials_Visits is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .712 | Retain the null hypothesis. |
| 6 | The distribution of InteractiveMaterials_T is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .575 | Retain the null hypothesis. |
| 7 | The distribution of Video_Visits is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .872 | Retain the null hypothesis. |

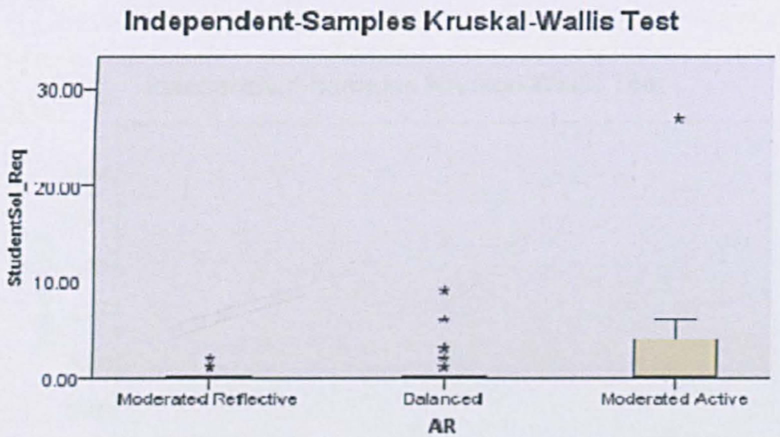
**Figure 5a – INFO023 Active-Reflective Style. Test Hypothesis Results**

| | | | | |
|---|---|---|---|---|
| 8 | The distribution of Video_Time is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .380 | Retain the null hypothesis. |
| 9 | The distribution of Quiz_Visits is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .795 | Retain the null hypothesis. |
| 10 | The distribution of Questions_Answered is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .739 | Retain the null hypothesis. |
| 11 | The distribution of Hint_Requests is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .187 | Retain the null hypothesis. |
| 12 | The distribution of Questions_Skipped is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .581 | Retain the null hypothesis. |
| 13 | The distribution of Quiz_T is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .706 | Retain the null hypothesis. |
| 14 | The distribution of Exercises_Visits is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .181 | Retain the null hypothesis. |

**Figure 5b–INFO023 Active-Reflective Style. Test Hypothesis Results**

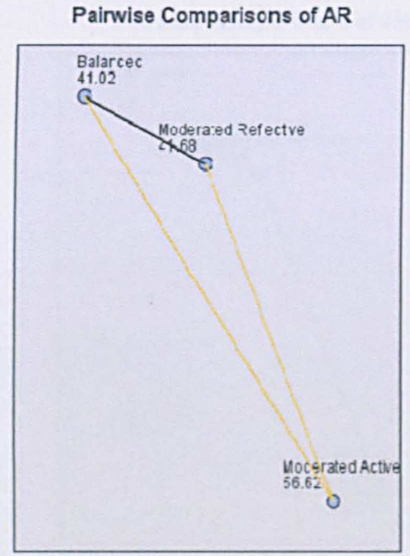
| | | | | |
|---|---|---|---|---|
| 15 | The distribution of Exercises_Answered is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .147 | Retain the null hypothesis. |
| 16 | The distribution of Exercises_Skipped is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .473 | Retain the null hypothesis. |
| 17 | The distribution of Exercises_T is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .516 | Retain the null hypothesis. |
| 18 | The distribution of StudentSol_Req is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .005 | Reject the null hypothesis. |
| 19 | The distribution of StudentSol_T is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .017 | Reject the null hypothesis. |
| 20 | The distribution of TeacherSol_Req is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .361 | Retain the null hypothesis. |
| 21 | The distribution of TeacherSol_T is the same across categories of AR. | Independent-Samples Kruskal-Wallis Test | .524 | Retain the null hypothesis. |

**Figure 5c– INFO023 Active-Reflective Style.Test Hypothesis Results**




| | |
|---|---|
| **Total N** | 90 |
| **Test Statistic** | 10.702 |
| **Degrees of Freedom** | 2 |
| **Asymptotic Sig. (2-sided test)** | .005 |

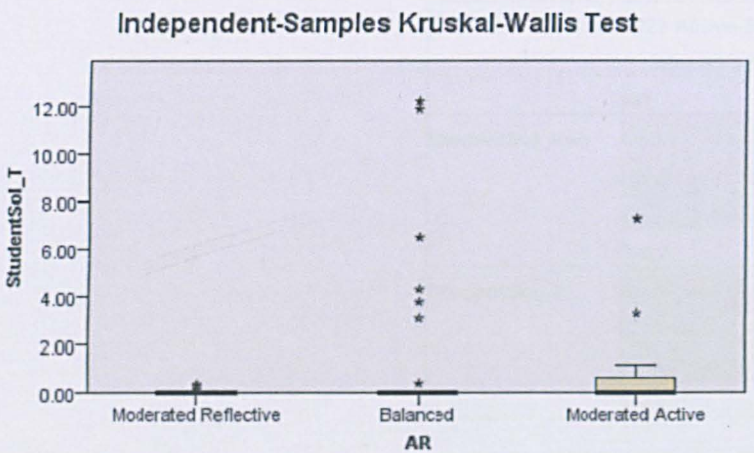
Figure 5d – INFO023 Active-Reflective Style. Distribution shape Student_Sol_Req




Each node shows the sample average rank of AR.

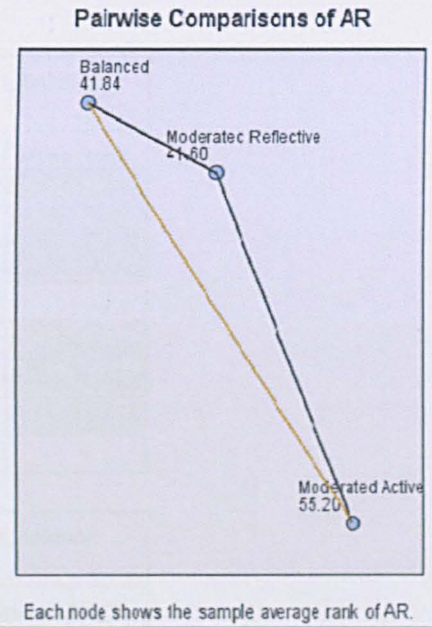
| Sample1-Sample2 | Test Statistic | Std. Error | Std. Test Statistic | Sig. | Adj.Sig. |
|---|---|---|---|---|---|
| Balanced-Moderated Reflective | .653 | 5.378 | .121 | .903 | 1.000 |
| Balanced-Moderated Active | -15.598 | 4.992 | -3.125 | .002 | .005 |
| Moderated Reflective-Moderated Active | -14.945 | 6.004 | -2.489 | .013 | .038 |

Figure 5e – INFO023 Active-Reflective Style. Post-hoc analysis Student_Sol_Req




| | |
|---|---|
| **Total N** | 90 |
| **Test Statistic** | 8.125 |
| **Degrees of Freedom** | 2 |
| **Asymptotic Sig. (2-sided test)** | .017 |

Figure 5f – INFO023 Active-Reflective Style. Distribution shape Student_Sol_Time




| Sample1-Sample2 | Test Statistic | Std. Error | Std. Test Statistic | Sig. | Adj.Sig. |
|---|---|---|---|---|---|
| Moderated Reflective-Balanced | -.244 | 5.381 | -.045 | .964 | 1.000 |
| Moderated Reflective-Moderated Active | -13.600 | 6.007 | -2.264 | .024 | .071 |
| Balanced-Moderated Active | -13.356 | 4.995 | -2.674 | .007 | .022 |

Figure 5g – INFO023 Active-Reflective Style. Post-hoc analysis Student_Sol_Time

**Table 5.1 – INFO023 Active-Reflective Style.Student_Solution Interactions Mean Ranks**

| | AR | N | Mean Rank |
|---|---|---|---|
| **StudentSol_Req** | Moderated Reflective | 20 | 41,68 |
| | Balanced | 45 | 41,02 |
| | Moderated Active | 25 | 56,62 |
| | Total | 90 | |
| **StudentSol_T** | Moderated Reflective | 20 | 41,60 |
| | Balanced | 45 | 41,84 |
| | Moderated Active | 25 | 55,20 |
| | Total | 90 | |

**Table 5.2 – INFO023 Active-Reflective Style.Student_Solution Interactions Median Report**

| AR | | StudentSol_Req | StudentSol_T |
|---|---|---|---|
| **Moderated Reflective** | N | 20 | 20 |
| | **Median** | **,00** | **,0000** |
| **Balanced** | N | 45 | 45 |
| | **Median** | **,00** | **,0000** |
| **Moderated Active** | N | 25 | 25 |
| | **Median** | **,00** | **,0000** |
| Total | N | 90 | 90 |
| | Median | ,00 | ,0000 |
| **Sig.** | | **,005** | **,017** |

# APPENDIX 6

# INFO023

# KRUSKAL–WALLIS ANALYSIS

# SENSING–INTUITVE

# LEARNING STYLE GROUPS

### Hypothesis Test Summary

| | Null Hypothesis | Test | Sig. | Decision |
|---|---|---|---|---|
| 1 | The distribution of Slides_Visits is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .697 | Retain the null hypothesis. |
| 2 | The distribution of Slides_Time is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .578 | Retain the null hypothesis. |
| 3 | The distribution of InteractiveExamples_ is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .635 | Retain the null hypothesis. |
| 4 | The distribution of InteractiveExamples_T is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .669 | Retain the null hypothesis. |
| 5 | The distribution of InteractiveMaterials_Visits is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .460 | Retain the null hypothesis. |
| 6 | The distribution of InteractiveMaterials_T is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .518 | Retain the null hypothesis. |
| 7 | The distribution of Video_Visits is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .923 | Retain the null hypothesis. |

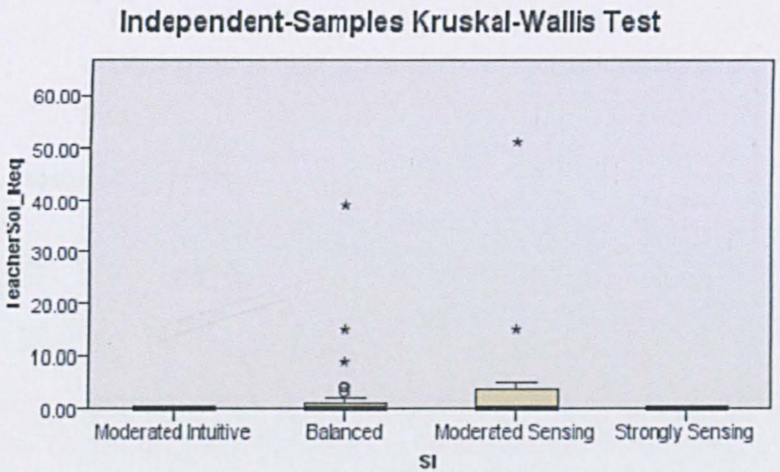
Figure 6a– INFO023 Sensing-Intuitive Style. Test Hypothesis results

| | | | | |
|---|---|---|---|---|
| 8 | The distribution of Video_Time is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .529 | Retain the null hypothesis. |
| 9 | The distribution of Quiz_Visits is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .173 | Retain the null hypothesis. |
| 10 | The distribution of Questions_Answered is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .392 | Retain the null hypothesis. |
| 11 | The distribution of Hint_Requests is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .710 | Retain the null hypothesis. |
| 12 | The distribution of Questions_Skipped is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .913 | Retain the null hypothesis. |
| 13 | The distribution of Quiz_T is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .133 | Retain the null hypothesis. |
| 14 | The distribution of Exercises_Visits is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .283 | Retain the null hypothesis. |

Figure 6b– INFO023 Sensing-Intuitive Style. Test Hypothesis Results

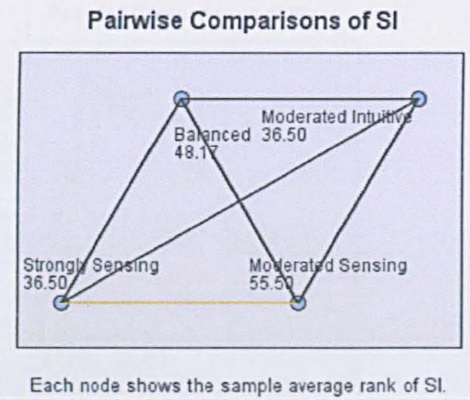
| | | | | |
|---|---|---|---|---|
| 15 | The distribution of Exercises_Answered is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .670 | Retain the null hypothesis. |
| 16 | The distribution of Exercises_Skipped is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .905 | Retain the null hypothesis. |
| 17 | The distribution of Exercises_T is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .396 | Retain the null hypothesis. |
| 18 | The distribution of StudentSol_Req is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .684 | Retain the null hypothesis. |
| 19 | The distribution of StudentSol_T is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .892 | Retain the null hypothesis. |
| 20 | The distribution of TeacherSol_Req is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .005 | Reject the null hypothesis. |
| 21 | The distribution of TeacherSol_T is the same across categories of SI. | Independent-Samples Kruskal-Wallis Test | .005 | Reject the null hypothesis. |

**Figure 6c– INFO023 Sensing-Intuitive Style. Test Hypothesis Results**



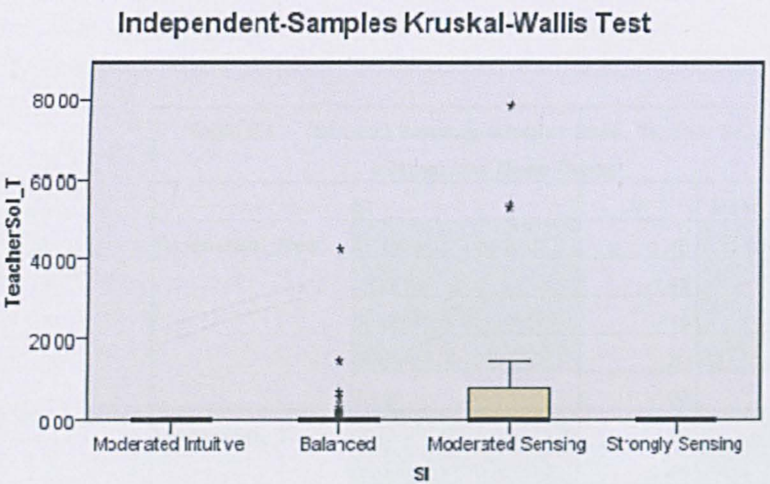

| | |
|---|---|
| **Total N** | 90 |
| **Test Statistic** | 12.764 |
| **Degrees of Freedom** | 3 |
| **Asymptotic Sig. (2-sided test)** | .005 |

Figure 6d – INFO023 Sensing-Intuitive Style. Distribution shape Teacher_Sol_Requests



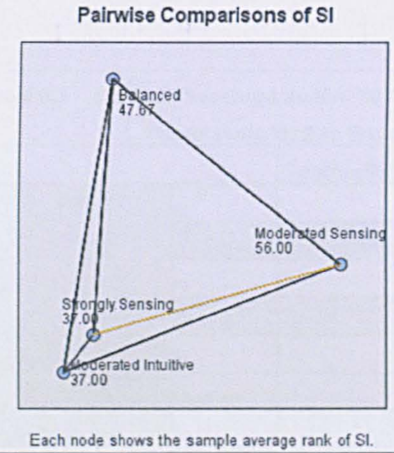

| Sample1-Sample2 | Test Statistic | Std. Error | Std. Test Statistic | Sig. | Adj.Sig. |
|---|---|---|---|---|---|
| Moderated Intuitive-Strongly Sensing | .000 | 7.067 | .000 | 1.000 | 1.000 |
| Moderated Intuitive-Balanced | -11.667 | 6.379 | -1.829 | .067 | .405 |
| Moderated Intuitive-Moderated Sensing | -19.000 | 7.450 | -2.551 | .011 | .065 |
| Strongly Sensing-Balanced | 11.667 | 4.904 | 2.379 | .017 | .104 |
| Strongly Sensing-Moderated Sensing | 19.000 | 6.233 | 3.048 | .002 | .014 |
| Balanced-Moderated Sensing | -7.333 | 5.440 | -1.348 | .178 | 1.000 |

Figure 6e – INFO023 Sensing-Intuitive Style. Post-hoc analysis Teacher_Sol_Requests




| | |
|---|---|
| **Total N** | 90 |
| **Test Statistic** | 12.668 |
| **Degrees of Freedom** | 3 |
| **Asymptotic Sig. (2-sided test)** | .005 |

Figure 6f – INFO023 Sensing-Intuitive Style. Distribution shape TeacherSol_Time




| Sample1-Sample2 | Test Statistic | Std. Error | Std. Test Statistic | Sig. | Adj.Sig. |
|---|---|---|---|---|---|
| Moderated Intuitive-Strongly Sensing | .000 | 6.910 | .000 | 1.000 | 1.000 |
| Moderated Intuitive-Balanced | -10.667 | 6.237 | -1.710 | .087 | .523 |
| Moderated Intuitive-Moderated Sensing | -19.000 | 7.284 | -2.609 | .009 | .055 |
| Strongly Sensing-Balanced | 10.667 | 4.795 | 2.225 | .026 | .157 |
| Strongly Sensing-Moderated Sensing | 19.000 | 6.094 | 3.118 | .002 | .011 |
| Balanced-Moderated Sensing | -8.333 | 5.319 | -1.567 | .117 | .703 |

Figure 6g – INFO023 Sensing-Intuitive Style. Post-hoc analysis TeacherSol_Time

| Table 6.1 – INFO023 Sensing-Intuitive Style. Teacher Solution Interactions Mean Ranks | | | |
|---|---|---|---|
| | **SI** | **N** | **Mean Rank** |
| **TeacherSol_Req** | Moderated Intuitive | 10 | 36,50 |
| | Balanced | 45 | 48,17 |
| | Moderated Sensing | 15 | 55,50 |
| | Strongly Sensing | 20 | 36,50 |
| | Total | 90 | |
| **TeacherSol_T** | Moderated Intuitive | 10 | 37,00 |
| | Balanced | 45 | 47,67 |
| | Moderated Sensing | 15 | 56,00 |
| | Strongly Sensing | 20 | 37,00 |
| | Total | 90 | |

| Table 6.2 - INFO023 Sensing-Intuitive Style. Teacher Solution Interactions Median Report | | | |
|---|---|---|---|
| SI | | TeacherSol_Req | TeacherSol_T |
| Moderated Intuitive | N | 10 | 10 |
| | Median | ,00 | ,0000 |
| Balanced | N | 45 | 45 |
| | Median | ,00 | ,0000 |
| Moderated Sensing | N | 15 | 15 |
| | Median | ,00 | ,0000 |
| Strongly Sensing | N | 20 | 20 |
| | Median | ,00 | ,0000 |
| Total | N | 90 | 90 |
| | Median | ,00 | ,0000 |
| | Sig | ,005 | ,005 |

# APPENDIX 7

# INFO023

# KRUSKAL–WALLIS ANALYSIS

# VISUAL–VERBAL

# LEARNING STYLE GROUPS

**Hypothesis Test Summary**

| | Null Hypothesis | Test | Sig. | Decision |
|---|---|---|---|---|
| 1 | The distribution of Slides_Visits is the same across categories of W. | Independent-Samples Kruskal-Wallis Test | .912 | Retain the null hypothesis. |
| 2 | The distribution of Slides_Time is the same across categories of W. | Independent-Samples Kruskal-Wallis Test | .622 | Retain the null hypothesis. |
| 3 | The distribution of InteractiveExamples_ is the same across categories of W. | Independent-Samples Kruskal-Wallis Test | .932 | Retain the null hypothesis. |
| 4 | The distribution of InteractiveExamples_T is the same across categories of W. | Independent-Samples Kruskal-Wallis Test | .665 | Retain the null hypothesis. |
| 5 | The distribution of InteractiveMaterials_Visits is the same across categories of W. | Independent-Samples Kruskal-Wallis Test | .833 | Retain the null hypothesis. |
| 6 | The distribution of InteractiveMaterials_T is the same across categories of W. | Independent-Samples Kruskal-Wallis Test | .706 | Retain the null hypothesis. |
| 7 | The distribution of Video_Visits is the same across categories of W. | Independent-Samples Kruskal-Wallis Test | .697 | Retain the null hypothesis. |

Figure 7a– INFO023 Visual-Verbal Style. Test Hypothesis Results

| | | | | |
|---|---|---|---|---|
| 8 | The distribution of Video_Time is the same across categories of W. | Independent-Samples Kruskal-Wallis Test | .491 | Retain the null hypothesis. |
| 9 | The distribution of Quiz_Visits is the same across categories of W. | Independent-Samples Kruskal-Wallis Test | .660 | Retain the null hypothesis. |
| 10 | The distribution of Questions_Answered is the same across categories of W. | Independent-Samples Kruskal-Wallis Test | .378 | Retain the null hypothesis. |
| 11 | The distribution of Hint_Requests is the same across categories of W. | Independent-Samples Kruskal-Wallis Test | .418 | Retain the null hypothesis. |
| 12 | The distribution of Questions_Skipped is the same across categories of W. | Independent-Samples Kruskal-Wallis Test | .669 | Retain the null hypothesis. |
| 13 | The distribution of Quiz_T is the same across categories of W. | Independent-Samples Kruskal-Wallis Test | .897 | Retain the null hypothesis. |
| 14 | The distribution of Exercises_Visits is the same across categories of W. | Independent-Samples Kruskal-Wallis Test | .729 | Retain the null hypothesis. |

Figure 7b– INFO023 Visual-Verbal Style. Test Hypothesis Results

| | | | | |
|---|---|---|---|---|
| 15 | The distribution of Exercises_Answered is the same across categories of VV. | Independent-Samples Kruskal-Wallis Test | .596 | Retain the null hypothesis. |
| 16 | The distribution of Exercises_Skipped is the same across categories of VV. | Independent-Samples Kruskal-Wallis Test | .878 | Retain the null hypothesis. |
| 17 | The distribution of Exercises_T is the same across categories of VV. | Independent-Samples Kruskal-Wallis Test | .955 | Retain the null hypothesis. |
| 18 | The distribution of StudentSol_Req is the same across categories of VV. | Independent-Samples Kruskal-Wallis Test | .143 | Retain the null hypothesis. |
| 19 | The distribution of StudentSol_T is the same across categories of VV. | Independent-Samples Kruskal-Wallis Test | .255 | Retain the null hypothesis. |
| 20 | The distribution of TeacherSol_Req is the same across categories of VV. | Independent-Samples Kruskal-Wallis Test | .615 | Retain the null hypothesis. |
| 21 | The distribution of TeacherSol_T is the same across categories of VV. | Independent-Samples Kruskal-Wallis Test | .457 | Retain the null hypothesis. |

**Figure 7c– INFO023 Visual-Verbal Style. Test Hypothesis Results**

# APPENDIX 8

# INFO023

# KRUSKAL–WALLIS ANALYSIS

# SEQUENTIAL–GLOBAL LEARNING STYLE GROUPS

**Hypothesis Test Summary**

| | Null Hypothesis | Test | Sig. | Decision |
|---|---|---|---|---|
| 1 | The distribution of Slides_Visits is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .088 | Retain the null hypothesis. |
| 2 | The distribution of Slides_Time is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .281 | Retain the null hypothesis. |
| 3 | The distribution of InteractiveExamples_ is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .761 | Retain the null hypothesis. |
| 4 | The distribution of InteractiveExamples_T is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .776 | Retain the null hypothesis. |
| 5 | The distribution of InteractiveMaterials_Visits is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .812 | Retain the null hypothesis. |
| 6 | The distribution of InteractiveMaterials_T is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .977 | Retain the null hypothesis. |
| 7 | The distribution of Video_Visits is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .388 | Retain the null hypothesis. |

**Figure 8a– INFO023 Sequential-Global Style. Test Hypothesis Results**

| | | | | |
|---|---|---|---|---|
| 8 | The distribution of Video_Time is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .658 | Retain the null hypothesis. |
| 9 | The distribution of Quiz_Visits is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .051 | Retain the null hypothesis. |
| 10 | The distribution of Questions_Answered is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .099 | Retain the null hypothesis. |
| 11 | The distribution of Hint_Requests is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .068 | Retain the null hypothesis. |
| 12 | The distribution of Questions_Skipped is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .419 | Retain the null hypothesis. |
| 13 | The distribution of Quiz_T is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .059 | Retain the null hypothesis. |
| 14 | The distribution of Exercises_Visits is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .409 | Retain the null hypothesis. |

**Figure 8b– INFO023 Sequential-Global Style. Test Hypothesis Results**

| | | | | |
|---|---|---|---|---|
| 15 | The distribution of Exercises Answered is the same across categories of SG | Independent-Samples Kruskal-Wallis Test | .364 | Retain the null hypothesis |
| 16 | The distribution of Exercises_Skipped is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .365 | Retain the null hypothesis. |
| 17 | The distribution of Exercises_T is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .241 | Retain the null hypothesis. |
| 18 | The distribution of StudentSol_Req is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .711 | Retain the null hypothesis. |
| 19 | The distribution of StudentSol_T is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .755 | Retain the null hypothesis. |
| 20 | The distribution of TeacherSol_Req is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .300 | Retain the null hypothesis. |
| 21 | The distribution of TeacherSol_T is the same across categories of SG. | Independent-Samples Kruskal-Wallis Test | .294 | Retain the null hypothesis. |

**Figure 8c– INFO023 Sequential-Global Style. Test Hypothesis for Results**

# APPENDIX 9

## FELDER–SILVERMAN INDEX OF LEARNING STYLE QUESTIONNAIRE[40]

**DIRECTIONS**

Enter your answers to every question. Please choose only one answer for each question. If both "a" and "b" seem to apply to you, choose the one that applies more frequently.

**1.** I understand something better after I

**a)** try it out.
**b)** think it through.

**2.** I would rather be considered

**a)** realistic.
**b)** innovative.

**3.** When I think about what I did yesterday, I am most likely to get

**a)** a picture.
**b)** words.

**4.** I tend to

**a)** understand details of a subject but may be fuzzy about its overall structure.
**b)** understand the overall structure but may be fuzzy about details.

**5.** When I am learning something new, it helps me to

**a)** talk about it.
**b)** think about it.

**6.** If I were a teacher, I would rather teach a course

**a)** that deals with facts and real life situations.
**b)** that deals with ideas and theories.

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[40] Available at https://www.engr.ncsu.edu/learningstyles/ilsweb.html

**7.** I prefer to get new information in

**a)** pictures, diagrams, graphs, or maps.
**b)** written directions or verbal information.

**8.** Once I understand

**a)** all the parts, I understand the whole thing.
**b)** the whole thing, I see how the parts fit.

**9.** In a study group working on difficult material, I am more likely to

**a)** jump in and contribute ideas.
**b)** sit back and listen.

**10.** I find it easier

**a)** to learn facts.
**b)** to learn concepts.

**11.** In a book with lots of pictures and charts, I am likely to

**a)** look over the pictures and charts carefully.
**b)** focus on the written text.

**12.** When I solve math problems

**a)** I usually work my way to the solutions one step at a time.
**b)** I often just see the solutions but then have to struggle to figure out the steps to get to them.

**13.** In classes I have taken

**a)** I have usually got to know many of the students.
**b)** I have rarely got to know many of the students.

**14.** In reading nonfiction, I prefer

**a)** something that teaches me new facts or tells me how to do something.
**b)** something that gives me new ideas to think about.

**15.** I like teachers

**a)** who put a lot of diagrams on the board.
**b)** who spend a lot of time explaining.

**16.** When I'm analysing a story or a novel

**a)** I think of the incidents and try to put them together to figure out the themes.

**b)** I just know what the themes are when I finish reading and then I have to go back and find the incidents that demonstrate them.

**17.** When I start a homework problem, I am more likely to

**a)** start working on the solution immediately.
**b)** try to fully understand the problem first.

**18.** I prefer the idea of

**a)** certainty.
**b)** theory.

**19.** I remember best

**a)** what I see.
**b)** what I hear.

**20.** It is more important to me that an instructor

**a)** lay out the material in clear sequential steps.
**b)** give me an overall picture and relate the material to other subjects.

**21.** I prefer to study

**a)** in a study group.
**b)** alone.

**22.** I am more likely to be considered

**a)** careful about the details of my work.
**b)** creative about how to do my work.

**23.** When I get directions to a new place, I prefer

**a)** a map.
**b)** written instructions.

**24.** I learn

**a)** at a fairly regular pace. If I study hard, I'll "get it".
**b)** in fits and starts. I'll be totally confused and then suddenly it all "clicks".

**25.** I would rather first

**a)** try things out.
**b)** think about how I'm going to do it.

26. When I am reading for enjoyment, I like writers to

    a) clearly say what they mean.
    b) say things in creative, interesting ways.

27. When I see a diagram or sketch in class, I am most likely to remember

    a) the picture.
    b) what the instructor said about it.

28. When considering a body of information, I am more likely to

    a) focus on details and miss the big picture.
    b) try to understand the big picture before getting into the details.

29. I more easily remember

    a) something I have done.
    b) something I have thought a lot about.

30. When I have to perform a task, I prefer to

    a) master one way of doing it.
    b) come up with new ways of doing it.

31. When someone is showing me data, I prefer

    a) charts or graphs.
    b) text summarizing the results.

32. When writing a paper, I am more likely to

    a) work on (think about or write) the beginning of the paper and progress forward.
    b) work on (think about or write) different parts of the paper and then order them.

33. When I have to work on a group project, I first want to

    a) have "group brainstorming" where everyone contributes ideas.
    b) brainstorm individually and then come together as a group to compare ideas.

34. I consider it higher praise to call someone

    a) sensible.
    b) imaginative.

35. When I meet people at a party, I am more likely to remember

    a) what they looked like.

b) what they said about themselves.

36. When I am learning a new subject, I prefer to

a) stay focused on that subject, learning as much about it as I can.
b) try to make connections between that subject and related subjects.

37. I am more likely to be considered

a) outgoing.
b) reserved.

38. I prefer courses that emphasize

a) concrete material (facts, data).
b) abstract material (concepts, theories).

39. For entertainment, I would rather

a) watch television.
b) read a book.

40. Some teachers start their lectures with an outline of what they will cover. Such outlines are

a) somewhat helpful to me.
b) very helpful to me.

41. The idea of doing homework in groups, with one grade for the entire group,

a) appeals to me.
b) does not appeal to me.

42. When I am doing long calculations,

a) I tend to repeat all my steps and check my work carefully.
b) I find checking my work tiresome and have to force myself to do it.

43. I tend to picture places I have been

a) easily and fairly accurately.
b) with difficulty and without much detail.

44. When solving problems in a group, I would be more likely to

a) think of the steps in the solution process.
b) think of possible consequences or applications of the solution in a wide range of areas

# APPENDIX 10

## Instrument for the Evaluation of Pedagogical Usability

The evaluation instrument presented in this appendix can be used to evaluate a student's perception of the usability of learning materials. The instrument has been designed in such a way that usability is evaluated through 12 statements or affirmations that a student must score using the set of values provided. Each affirmation is associated with one of the pedagogical attributes described in Section 2.5 of this thesis, and has been worded in such a way that the student understands the usability aspect that must assess.

Table 10.1 shows the mapping performed between the selected attributes of the design of a learning material and the corresponding affirmation that allows a student to assess these attributes. To achieve this mapping, each attribute's definition used in this research (briefly presented in italics) has been worded in a statement understandable by a first-year student which reflects what he or she should perceive.

**Table 10.1**. *Mapping of Pedagogical Attributes of Design and Usability Evaluation Statements for Students*

| Pedagogical Attribute of Design | Affirmation for Usability Evaluation |
|---|---|
| **Objective**<br>*What the learner should be able to accomplish after working with the resource.* | Study materials and activities have helped me to achieve the learning objectives of the course successfully. |
| **Integration**<br>*The manner in which different type of contents are integrated into the learning resource so that its overall form aligns with its function within the whole learning design, scaffolds and enhances learning* | The structure of the contents of theory and examples of issues has helped me learn according to my learning needs. |
| **Context**<br>*The degree of contextualization of the resource with regard to the learning unit topic or how specific it is to learner's level of knowledge.* | The content of the theory and exercises of topics match my knowledge in programming language (it is not too hard or too easy). |
| **Multimedia Richness**<br>*The extent to which the various media types (audio, videos, graphics, images, etc.) embedded in the resource or the learning unit facilitate learning and the achievement of objectives* | In the study materials and activities, I find the proper amount of multimedia resources to facilitate my learning (i.e., images, videos, graphics, animations, etc.). |

| | |
|---|---|
| **Previous Knowledge**<br>*The extent to which a learner is required to possess pre-requisite knowledge in order to successfully achieve the learning objective* | When I start a new topic, I have the knowledge necessary to understand new concepts and to do the exercises. |
| **Support**<br>*The level of support provided to the learner by the content author within the learning resource, e.g. in form of help menus, glossaries navigational support, on screen advice, etc.* | The study materials and activities of the course offer me all the support I need to understand the concepts and implement the activities. |
| **Feedback**<br>*The level and/or type of feedback provided to the learner whilst undertaking the interactive elements or assessments within the learning object* | The information I received when interacting with materials and completing exercises was sufficiently explanatory and suited my needs. |
| **Self-direction**<br>*The level of self-direction afforded to the learner through open navigation, optional interactivity, optional sections, etc.* | Study materials and activities in the lessons provide me with options to learn at my own pace and go into more depth in those concepts that interest me |
| **Interactivity**<br>*The amount of interactive parts contained in the resource or the extent to which the learner can engage actively with the learning object* | The study materials and activities are interactive enough to keep me engaged and attentive when learning |
| **Navigation**<br>*The extent to which the learning activity forms part of the learning design* | In general, all content materials and activities presented in the course's lessons have been useful for my progress (i.e. they are not repetitive or irrelevant for me) |
| **Assessment**<br>*The extent to and ease with which the learner can perform an effective self-assessment* | The activities provided allow me to check my progress and level of achievement of the corresponding learning objectives |
| **Alignment**<br>*The extent to which the assessment elements measure attainment of the learning objective* | The activities of the course and tests correspond to the learning objectives of the course |

The original survey was produced in Spanish. A version in the English language can be found on the following page.

## SURVEY FOR THE EVALUATION OF THE CHARACTERISTICS OF LEARNING MATERIALS AND ACTIVITIES

In your opinion, to what extent do you agree with the following statements? Use the following values:

**1- Completely disagree 2- Disagree 3- Neutral 4- Agree 5- Definitely agree**

| | Affirmation | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| 1. | Study materials and activities have helped me to achieve the learning objectives of the course successfully. | | | | | |
| 2. | The structure of the contents of theory and examples of issues has helped me learn according to my learning needs. | | | | | |
| 3. | The content of the theory and exercises of topics match my knowledge in programming language (it is not too hard or too easy). | | | | | |
| 4. | In the study materials and activities, I find the proper amount of multimedia resources to facilitate my learning (i.e., images, videos, graphics, animations, etc.). | | | | | |
| 5. | When I start a new topic, I have the knowledge necessary to understand new concepts and do the exercises. | | | | | |
| 6. | The study materials and activities of the course offer me all the support I need to understand the concepts and implement the activities. | | | | | |
| 7. | The information I received when interacting with materials and completing exercises was sufficiently explanatory and suited my needs. | | | | | |
| 8. | Study materials and activities in the lessons provide me with options to learn at my own pace and go into more depth in those concepts that interest me. | | | | | |
| 9. | The study materials and activities are interactive enough to keep me engaged and attentive when learning | | | | | |
| 10. | In general, all content materials and activities presented in the course's lessons have been useful for my progress (i.e. they are not repetitive or irrelevant for me). | | | | | |
| 11. | The activities provided allow me to check my progress and level of achievement of the corresponding learning objectives. | | | | | |
| 12. | The activities of the course and tests correspond to the learning objectives of the course. | | | | | |

Appendix 11 (pages 365-371) has not been digitised at the request of the university.