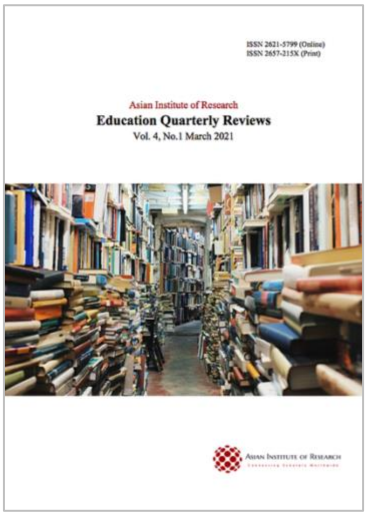

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Development of a Learning Model for Large Class Cohorts to Strengthen Learning Outcomes of Students Based on Differentiated Instruction

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Abstract
We propose a new approach to classroom learning based on sequential numeral-division. It builds on the concept of trichotomy – division of students based on creamy-level, middle-level and weaker-level students -- proposed by the present authors. A sequenced series of formative assessments can map student progress and achievement, particularly in the case of weaker students. The idea behind the development of this model is to study if weak students perform better on critical-thinking tests in a collaborative learning setting rather than when they study individually. We propose a mathematical model to measure group activity/achievement, which is a complex function of several parameters. We collect data on different parameters for validation of the model in the near future.

Keywords: Numerical Learning Model, Measurement/Quantification of Learning, Formative Assessment, Large Class Cohorts, Weaker Students, Group Learning

Introduction & Literature Survey

This study proposes a new approach based on sequential numeral-division. The concept of this classification (division and classification are used interchangeably) of the students based on their learning levels/abilities is presented in a very recent paper by the present authors, Muppala, S.P.R., and Chandramohan, B. (2020). This approach targets large class cohorts because the division is more evident. It intertwines formative and summative assessments in equal or unequal numbers that provides an excellent balance between face-to-face sessions and online learning, both self-directed and collaborative with other students (Fallows, S. and Chandramohan, B., 2010) (Muppala, S.P.R., and Chandramohan, B., 2019). Brookfield, S.D. (2017) argues that online learning has a greater advantage as detailed feedback can be given to individual student more than in face-to-face learning. It also helps to identify and offer more support to weaker students. This division in a group learning/flipped classroom was used to create student groups, whose sizes varied from an individual learner to a flexible grouping of no more than six in a cooperative activity. Such an activity, ideally, allows the students to take responsibility by themselves and builds skills that would enable them to investigate and critically reflect on the given tasks.

A sequence of formative assessments demonstrates progressive achievement, particularly for weaker students to help improve their technical proficiency and improve their module marks. Therefore, development of a flipped learning template is an ideal way to plan, deliver and evaluate this approach. Or, an alternative and effective option is the development of a sequential empirical mathematical model to generate quantitative data to assess the knowledge gains of a student involved in the collaborative learning (Das, B.M., and Sartore-Baldwin, M. L. 2019) (Munir, M.T., Baroutiana, S., Young, B.R. Carter, S., 2018) (Appiah-Twumasi, E., Antwi, V., Anderson, I.E., Sakyi-Hagan, N., 2020), . In this paper, we only present the details of the model and its validation is for a future study. The idea behind the development of this model is to study if the students in a collaborative learning perform better on critical-thinking tests than students who do individually. In other words, it is to map the weaker students' self-knowledge of the academic learning, and to measure it. Literature shows that very little work on this problem. For example, Richardson, J. (2015) says there is no evidence why there is attainment gap between BME (Black and Minority Ethnic) and white students in the UK. To partly answer this question, in an internally funded interdisciplinary project at Kingston University. Hill N. et al. (2016) in their comparative studies based on three module Levels 4 to 6 conclude that understanding attainment gaps is achieved more effectively in large class cohorts and through better inclusive assessment methods; one of them is group assessment. Brookfield, S.D. (2017), p137 says that *working in teams is the norm, so it makes perfect sense for the pedagogy to mirror* working life.

Modelling

We propose a design to measure this group activity that is a complex function of several parameters, see Eq. (1). We will carry out this study at a future date collecting parametric data through a series of questionnaires in term time, during the running of the modules. The first step is to formatively assesses the prior knowledge, ending with the module feedback. This approach is based on research in another area, Combustion, where a flame model **is** proposed, and discussed in Muppala S.P.R. (2005)**:**

$$S_T = S_{L0} + a\ f\left(S_{L0}^{\alpha} \cdot (u')^{\beta} \cdot \alpha^{\gamma}\right)\left(\frac{p}{p_0}\right)^{\delta} \qquad \text{Eq.1}$$

where the turbulent flame speed S_T, or equivalently combustion heat release, is a strong function of flame and turbulent flow quantities.

Here the first term is laminar flame speed S_{L0} that is equivalent to pre-knowledge of the student, K_0 in Eq. (2a). For zero turbulence, the turbulent flame speed S_T is equal to laminar flame speed S_{L0}. Here, S_T is $\equiv$ of learning outcomes (LOs) in group learning (the triple bar notation is equivalent ($\equiv$). It is interesting to note that assuming that the student does not gain any knowledge (because of his/her no contribution or learning or also if the group size is infinite) in the module, s/he still holds her/his pre-knowledge, K_0.

$$K_c = K_0 + a\ f\left(K_0^{\alpha} \cdot e^{\beta} \cdot l^{\gamma}\right)\left(\frac{1}{N-1}\right)^{\delta}\ where 1 < N \leq 5 \qquad \text{Eq.2a}$$

where *f* denotes mathematical function. Here, the pre-constant *a* is an adjusting factor as a function of learning environmental constraints. Higher level of degrees of freedom means higher the learning (Liebermann, A., and Miller, L. 2004). Here, K_0 is the previous knowledge of the learner, *e* is a measure of the environment conducive to learning, *l* is the level or amount of information communicated which is given as the product of duration of exposure or communication and rate of communication, among the students in that particular group. *N* is the number of students not exceeding four in a group. The exponential constants come from measured data. Further, these quantities are the inputs to evaluate the quantity K_c ; K_c is a measure of the level of attainment by a learner through problem-based learning (PBL). The maximum value the learner can attain is set to unity. In the modelling, we assume that the knowledge gained by the learner within the group-learning environment cannot exceed the defined cognizance of the leading student (whose K_c is value unity).

In this sequel Eq. (2a), the analytical model is expected to estimate the levels of learning achievements – such as test scores. N=5 is seen 'traditionally' as the optimal value for conducive learning. Hunt, C. (2011), page 52, promotes the advantages of problem-based learning and collaborative projects, Twyman, J.S. and Heward, W.L. (2018) list twelve low-level technology strategies that work in any classroom, especially for group working. Our classroom experience shows N>5 lowers the learning levels. The learning characteristics captured in an abstract way, and the exponents of parameters in Eq. (1a) are evaluated ad hoc firstly from experiments. These parameters are student's previous knowledge in the appropriate subject, learning environment, duration of contact or discussion and level of communication with peers, workload under which s/he works in a particular group and number of students involved. The mathematical relation in the problem-based learning is

$$K_c = K_0 + a\ f\left(K_0^{\alpha} \cdot e^{\beta} \cdot l^{\gamma}\right)\left(\frac{1}{N-1}\right)^{\delta}\ where 1 < N \le 5 \qquad \text{Eq. (2b)}$$

By dividing Eq. 1 by K_o yields

$$\frac{K_c}{K_0} = 1 + a\ f\left(K_0^{\alpha-1} \cdot e^{\beta} \cdot l^{\gamma}\right)\left(\frac{1}{N-1}\right)^{\delta}\quad 1 < N \le 5 \qquad \text{Eq. (2c)}$$

The conditions/limits of Eq.2a (or 2b) of the model:

1. It is devised for group learning, and not applicable to an independent learner. That is, for N equals unity, the equation becomes invalid.
2. We believe the model yields more promising results for 1<N ≤ 5, and the optimistic for the whole number, N=5 Muppala, S.P.R., and Chandramohan, B. (2020).
3. Mathematically, although the equation Eq.(2a) is still valid for any N value, practically, the quality of learning diminishes for N>5 and thus the equation has little significance for higher N value.
4. From above point, for a hypothetical case N = ∞ (infinity), the second complex term becomes zero i.e., K_c becomes 1/ (N – 1) ~ 1/∞ ~ 0; i.e. state of no learning.
5. Overall, the intended purpose of this model is to measure the Learning Outcomes (LOs) for all students with transparency, make the quantitative data available to the wider community for future validation purposes (see Twyman, J.S. and Heward, W.L.(2018) for extensive discussion on the policies to address challenges in achieving standardized LOs for all students of all – varied – cognitive skills).

The other basic assumption that governs the development of this model is that the students who participate in collaborative learning perform better on the critical-thinking test than students who do individually.
Normalization of the above relation Eq. (2c) is

$$\frac{K_c}{K_0} = 1 + a\ f\left(K_0^{\alpha-1} \cdot e^{\beta} \cdot t^{\gamma}\right)\left(\frac{1}{N-1}\right)^{\delta} \qquad \text{Eq. (2d)}$$

The normalization of all quantities satisfies dimensional homogeneity of an equation.

Discussion

In the design of this model, we assume that the students are deeply engaged in learning activities and show their dedicated involvement in interacting with the group members. Also, we assume that the learner that is much weaker, in relative terms, to the leading student (LS) benefits more than other students in the group learning. The learner is supposed to have appropriate basic subject knowledge from the pre-university studies. This influence on the learner may be accounted in the exponent δ that is taken to be equal to unity for a group not exceeding five students. We assume that that there is only one leading student within a group who demonstrates a thorough knowledge and understanding of conceptual and applied aspects of that subject. The exponent β varies between 1/4 and 1/3, adopting from the original formulation Eq. (1). This rise in the exponent indicates lowering of the level of connectivity among the group members and hence, the learning outcomes. To obtain comprehensive results, the parameters and exponents in equation 1 should be derivable following detailed interpretation of the data by Hill N. et al. (2016) collected from diverse student cohorts and compared with literature based on BME/non-BME, UK-EU/international, disability/dyslexic students and genders. This interpretation will form the basis of a future study by the authors.

Conclusions

The validation of the proposed model is a challenge for several reasons:
i) It is a novel mathematical approach, and thus requires definite data of various dynamic quantities, pre- and exponential constants to make it a workable model
ii) To the best of the authors' knowledge, there is very little quantitative data available in the literature.

However, on the positive side:
a) the workability in one classroom setting can be extended to a different classroom, or another subject because all measurable quantities are normalized.
b) the findings can be used as a reference for comparative study of new data.

Work in progress: We are currently collecting data for evaluating the proposed model.

We welcome comments and suggestions for improving the model and will gratefully acknowledge such help in future publications.

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