MATHEMATICS INNOVATIVE GAMIFICATION FOR AT-RISK STUDENTS

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ABSTRACT

Many researches emphasize the importance of developing students’ ability to solve problems related to number or algebraic equations. As at-risk students’ understandings of the algebraic concepts are in need of guidance, this study intends to innovative gamification for at-risk students to solve number equations through the use of Flexi-EQ Solver. In this quantitative study, a randomly selected 161 at-risk students answered the test questions. From the test answers, students’ difficulties in learning mathematics concepts were analyzed. On the other hand, another 56 randomly selected at-risk students answered a questionnaire. From the test analysis, the students face major difficulties in factorization on algebraic expression, linear equations in one variable, transformation of formula and solving logarithmic equations. An innovative gamification framework embedded in Flexi-EQ Solver was then proposed for at-risk students. Flexi-EQ Solver which also called as Flexible-Equations Solver is a flexible interface featuring step-by-step exploration solutions for exponential, logarithmic, square and square root, inequality, decimal, percentage, fraction and trigonometric equations. Flexi-EQ Solver helps at-risk students to visualize number equations by seeing, touching, hands-on and manipulating it. On the average, the respondents agreed on the use of Flexi-EQ Solver for learning mathematics. With respect to the usage of Flexi-EQ Solver, 57.1% of the respondents highly recommended the use of Flexi-EQ Solver. Majority of at-risk students proposed the incorporation of visual learning theory and multiple representations as an innovative gamification framework in learning mathematical skills.

Keywords: Number Equations; Visual Learning; Design; Innovative Gamification; At-Risk Students

INTRODUCTION

Number system can be used in calculating all sorts of equations ranging from displacement of bus, velocity of car, acceleration of aircraft, momentum of objects and many more. The ability to solve number and linear equations is the
foundation for mastering many concepts in Algebra, but there is evidence that user’s understanding of the concept is often minimal [1]. Many studies emphasize urgent need to develop a broader and deeper view of algebra learning among students [2, 3], as well as arithmetic learning. Thus, number equations and algebraic equations solving skills are critical predictor to the success in mathematics.

Karina [4] investigated 12 to 13 years old students’ algebraic thinking in a hybrid environment of functional and equation-based approaches to learn algebra. The study examined 102 students relating to their generalization ability and knowledge of multiple representations and variables prior to formal study of algebraic expressions and equations at secondary school. The results showed that nearly half of the students demonstrated the ability to generalize explicitly. One fifth of the students able to construct a symbolic.

Cartesian connection as moving between algebraic equations and graphs within a process of a function is seen as foundational to enable students to develop the flexibility and fluency interacting with multiple representations [5]. There is an urgent need to equip students with the ability to connect to multiple representations for arithmetic and algebraic learning. Besides, Duval [6] emphasized that in order to understand different facets of the corresponding mathematical object and to develop an appropriate concept image, several of such representations have to be integrated.

Various content domains emphasize different representations to be used by the students. Multiple representations in the content domain of fractions for example highlight different concepts of fractions such as part-whole, ratio, operator and quotient [7]. Fostering students’ abilities to match symbolic-numerical representations with appropriate diagrams or illustrations play a key role for sustainable learning of operations with fractions [8].

Researchers have reviewed various indicators to identify at-risk students. Generally, most researchers agreed that the key indicator of at-risk student is the socioeconomic status of a student. According to Spring [9] and Gray [10], at-risk students are students who are at a higher risk of academic failure due to a low socioeconomic status, being academically disadvantaged or achieving poor grades. Other indicator included minority group having a sibling that dropped out of school and changing schools multiple times in the elementary grades. According to Cummings [11], at-risk students are identified as students who are at risk of school failure, including academic, personal, and environmental influences. At-risk students may experience more difficulties at school than their peers [12]. However, students who run the highest risk of having difficulty in school are those who are economically disadvantaged [13]. According to Spring [9] and Gray [10], at-risk students are students who are at a higher risk of academic failure due to a low socioeconomic status, being academically disadvantaged or achieving poor grades. Recent literature has defined the at-risk
as students who are not perceived to succeed in school due to variables beyond their control, such as socioeconomic status and family dynamics [10].

It has been advocated that user should explore many aspects of each concept through multiple representations, especially when solving problems. Many researches stress the importance of developing at-risk students’ ability to solve problems that can be modelled by means of linear equations of a variety of representational modes. Thus, this study aims to develop Flexible-Equations Solver (Flexi-EQ Solver) which aims to engage at-risk students through multiple representations to solve number equations. Further, it also aims to propose a mathematics innovative gamification framework for at-risk students.

In this study, at-risk students are operationally defined as students who are at risk of school failure due to a low socioeconomic status, specifically called as Bottom 40% (B40) family income group. These at-risk students obtained minimum 3 credits in their SPM (Sijil Pelajaran Malaysia) subjects with Malay Language credit, either History, English Language or Mathematics with a pass.

**METHODOLOGY**

This quantitative study aims to develop the mathematics innovative gamification for at-risk students in which test and survey data are used to develop and evaluate the feedback of the proposed innovative gamification. A randomly selected 161 at-risk students answered the test questions whereas another randomly selected 56 at-risk students answered the questionnaire.

The age interval for the at-risk student was 18 to 20 years old. They were students who are at risk of school failure due to low SPM achievement and low family income. The randomly selected 161 at-risk students were asked to answer to the test questions within 60 minutes in a spacious examination hall. Another 56 at-risk students answered the questionnaire within 15 minutes in a lecture hall after they had been exposed to Flexi-EQ Solver for two months. During their treatment period, they use Flexi-EQ Solver for 2 hours every week to solve number equations. A test and a survey questionnaire were given to the at-risk students. The test consisted of 11 questions aimed to identify the difficulty index of the test questions for the randomly selected 161 at-risk students. The survey consisted of 22 items, aimed to elicit feedback on the usage of Flexi-EQ Solver from the randomly selected 56 at-risk students. The questionnaire was adapted from MicroSIFT [14] to evaluate on the usage of Flexi-EQ Solver in the at-risk students’ learning. From the data analysis, the innovative gamification framework was finally proposed for the at-risk students.
RESULTS AND DISCUSSIONS

Difficulty Index

According to Kennedy and Ato [15], the item difficulty index is calculated as a percentage of the total number of correct responses to the test items. It is calculated using the formula \( \rho = \frac{R}{T} \), where \( \rho \) is the item difficulty index, \( R \) is the number of correct responses and \( T \) is the total number of responses (which includes both correct and incorrect responses). Difficulty is defined as the relative frequency with which those taking the test choose the correct response [16].

All the test questions are from standard examination format with each question given 3 marks respectively. Hence the validity and reliability are strong. From the 161 at-risk students, they face difficulties in factorization on algebraic expression (0.32), linear equations in one variable (0.20), transformation of formula (0.36) and solving logarithmic equations (0.33). The respondents generally were not well mastered and understood all the contents as illustrated in Table I.

As an alternative way to assist this group of students, Flexi-EQ Solver was developed to train and master the problematic contents, for example solving different equations, expressions and handling various formulas.

### TABLE I. DIFFICULTY INDEX ON TEST QUESTIONS

| Content                                      | N   | Mean | Std Dev | Difficulty Index |
|----------------------------------------------|-----|------|---------|------------------|
| Operations Expressions on BODMAS             | 161 | 2.09 | 0.94    | 0.70             |
| Factorization on Algebraic Expression        | 161 | 0.96 | 0.71    | 0.32             |
| Perform Operation on Algebraic Expression   | 161 | 1.76 | 1.02    | 0.59             |
| Linear Equations in One Variable             | 161 | 0.60 | 0.63    | 0.20             |
| Quadratic Equations in One Variable          | 161 | 2.07 | 1.20    | 0.69             |
| Simultaneous Equations in Two Variables      | 161 | 2.24 | 0.98    | 0.75             |
| Transformation of Formula                    | 161 | 1.07 | 0.72    | 0.36             |
| Rules of Indices                             | 161 | 1.70 | 0.73    | 0.57             |
| Solve Exponential Equations                  | 161 | 1.54 | 1.21    | 0.51             |
| Rules of Logarithm                            | 161 | 1.61 | 0.66    | 0.54             |
| Solve Logarithmic Equations                   | 161 | 1.00 | 1.22    | 0.33             |

Flexi-EQ Solver

Flexi-EQ Solver which also called as Flexible-Equations Solver is a flexible interface featuring step-by-step exploration solutions to exponential, logarithmic, square and square root and fraction equations. It engages users in algebraic ways of thinking to solve any form of linear systems of equations. Through Flexi-EQ Solver, user could manipulate different forms of number equations to understand
multiple expressions of equations, solve multiple equations, reset the equations, try again and see where they tend to make mistake. It gives chance to users to gain hands-on approach as the users can manipulate and make flexible experience on equations by themselves.

Flexi-EQ Solver used visual learning theory to visualize number equation idea, understand number equation by seeing, touching, hands on and manipulating it. Research has shown that visual learning theory is especially appropriate to the attainment of mathematics skills. Flexi-EQ Solver enables users to have the ability to see how concepts work and visualize an equation as a set of images. By creating models, they interact with mathematical concepts, process information, observe changes, reflect on their experience, modify their thinking and draw conclusions. Flexi-EQ Solver offers flexible continued practice and elevating experience to the user when trying to recognize number sense as well as dealing with mathematics equations and symbols. Its novelty lies in the active participation from all users to be able to improve their calculation skills while boosting confidence in mathematics. Examples of the interfaces of Flexi-EQ Solver are shown in the Figure 1 to Figure 4.

Figure 1. Trigonometric Equation
Figure 2. Logarithmic Equation
Figure 3. Equation with Fraction
Figure 4. Equation with Square Root
Feedback on Flexi-EQ Solver

Overall mean rating of Flexi-EQ Solver was 3.91 (n=56). On the average, the respondents agreed on the use of Flexi-EQ Solver. The questionnaire rating for Flexi-EQ Solver ranging from 1-Strongly Disagree; 2-Disagree; 3-Neutral; 4-Agree and 5-Strongly Agree. The respondents agreed that the graphics or colour are used for appropriate instructional reasons. It is also effective in terms of clear, readable and attractive display. Generally, they agreed that visual learning theory is important in the attainment of mathematical skills (mean=4.02). On the other hand, the respondents also agreed that Flexi-Eq Solver assisted them to practise Mathematics equations and they could control the rate and sequence accordingly. They were satisfied with the multiple representations illustrated in Flexi-EQ Solver (mean=4.15).

Questionnaire output concerning recommendation for Flexi-EQ Solver shows the following results. With respect to the rating on the use of Flexi-EQ Solver, 32 (57.1%) out of a total of 56 students would highly recommend the use of Flexi-EQ Solver. Further, 21 (37.5%) of the students would use or recommend the use of Flexi-EQ Solver with little or no change. 3 of the students would use or recommend the use if certain changes are made. Finally, none of them would not use or recommend the use of Flexi-EQ Solver.

Further, the respondents provide their feedback concerning the elements of innovative gamification framework for at-risk students. The respondents expressed difficulties in solving different equations (eg: linear equations and logarithmic equations), solving expressions (eg: algebraic expression) and handling various formulas (eg: transformation of formula). Generally, they agreed that visual learning theory and multiple representations are important in the attainment of mathematical skills. The proposed innovative gamification framework for at-risk students is shown in Figure 5.

Figure 5. Innovative Gamification Framework for At-Risk Students
CONCLUSIONS

In conclusion, on the average, the at-risk students agreed and highly recommended the use of Flexi-EQ Solver to assist them in solving systems of equations. Generally, they agreed that visual learning theory and multiple representations are important in the attainment of mathematical skills. Persistence is essential, together with a realization that at-risk students' difficulties may well be reasonable ones. There are some crucial investigations that have not been addressed in this study. In future study, the effectiveness of the use of Flexi-EQ Solver for at-risk students could be studied further. Pre-test and post-test setting could be used to study the attainment of mathematical skills for at-risk students with Flexi-EQ Solver as a treatment tool.

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