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Rigorous Thinking in Mathematics Modelling for Slow Learners

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Abstract. Rigorous questions in discussion learning method plays a dominant role in the successful delivery of lessons for slow learners at higher education. This study aims to propose a framework to achieve good critical thinking for slow learners through Rigorous Mathematics computational Thinking (RMcT) model. This study used qualitative approach to describe slow learner's critical thinking by using RMcT model. The instruments used in this study were test instrument, critical thinking questionnaire, and interview guideline as supporting instrument to describe slow learner's critical thinking through RMcT model. The subjects were college students in mathematics modelling course in mathematics education department. Based on critical thinking test results, slow learners could divide variable used in mathematics modelling. Based on questionnaire results, slow learner students build their own understanding and solve the problem based on their experience while answering the given question during learning process. In addition, the interview they feel that the instructor can mediated the problem by giving analogy to the other material. In summary, RMcT could mediate slow learner's critical thinking as its characteristics (by using Rigorous questions). Findings are useful for designers, service providers and policy makers of special needs higher school when implementing teaching strategy to mediated real-life problems into mathematics modelling for slow learners.

1. Introduction

In problem-solving activities, students are required to understand the problems, develop strategies, implement strategies and evaluate the results. The problem-solving process is one of the lecturer's priority as a facilitator in the classroom in delivering the teaching material to the students. Students are expected to be able to understand, associate and apply mathematical concepts accurately, precisely, and efficiently in determining the right strategy to solve a mathematical problem. Krulik and Rudnick state that high-level thinking skills (HOTS) include basic thinking, critical thinking, and creative thinking [1]. There are eight descriptions that can be associated with critical thinking, namely testing, connecting, and evaluating all aspects of a situation or problem, focusing on a part of a situation or problem, gathering and organizing information, validating and analyzing information, remembering and analyzing information, determine whether or not an answer is reasonable, draw valid conclusions, have analytical and reflexive properties.



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Current teaching and learning strategies in undergraduate programs need to give enough attention to critical thinking. This need stems primarily from the persistent commitment to teaching methods that stress memorization. In traditional teaching, there is often an implicit assumption that learning to think critically develops naturally as students learn increasingly the complex levels of discipline content. Analytical frameworks that develop critical thinking must be taught explicitly and constructed consciously, beginning with simple operations and building toward the complexity. For most students, this means memorizing and learning to recognize key concepts, terms, issues, and methodologies, and then working with them in the context of real problems and concerns and relating them to experiences and previous learning through application, analysis, evaluation, and creation. Some skill associated with the concept of critical thinking is understanding problems, classifying information to solve problems, understanding the assumptions, formulating and deriving relevant hypotheses, drawing valid conclusions and determining the validity of the conclusions [2]. Ennis said that there are six components in critical thinking such as focus, reason, inference, situation, clarity, and overview [3]. Firstly, the focus is related to the identification of the problem. This problem should be included in the conclusion of an argument. Next, the reason must be accepted logically or not. The reason, which is accepted logically, can support the conclusion, namely inference. After that, the subject should make a correction based on the situation given. In this step, they clarify the term is used. Last, they do an overview of all result as an argument in the conclusion. Watson and Glaser made measurements through tests that included five indicators, namely recognizing assumptions, making inferences, deductions, interpretations, and evaluating arguments [2]. From the various abilities related to critical thinking presented by experts, it turns out that the measurement of critical thinking skills has been included in the five indicators as stated by Watson and Glaser.

Critical thinking is generally regarded as the main goal of learning. Besides that, critical thinking plays an important role in many types of work, especially jobs that require accuracy and analytical thinking [2]. This opinion is also in line with the purpose of mathematics learning, namely that students can use mathematics as a way of reasoning (logical thinking, critical, systematic, and objective) that can be used to solve problems, both in daily life and in learning various sciences. Critical thinking is needed in daily life because human society is always faced with problems that require a solution. To solve a problem, data is needed so that logical decisions can be made, and to make the right decision, good critical thinking skills. There are several ways to keep students actively involved in the learning process while developing critical thinking. The various elements of learning, that include self-learning, collective learning, passive learning, and active learning, have their place as part of a series of mutually reinforcing activities for a critical thinking development [4]. The teacher has a responsibility to prepare the learning strategies which is appropriate with student's cognitive level [5].

Mathematics Education Department of Universitas Ahmad Dahlan (UAD) has the vision to facilitate special need students such as slow learners to study equally in regular education. To make an equity in learning process, mathematics education of UAD implement learning model which is compatible to the slow learner students such as Rigorous Mathematics computational Thinking (RMcT) learning model. RMcT is a learning model as the combination between Rigorous Mathematics Thinking (RMT) and Computational Thinking (CT). RMcT facilitate slow learner in reasoning by rigorous question given during learning process. By giving rigorous question, the students remember the previous concepts and other subject such as carbon dating in chemical reaction. One material studied about the connection between mathematics and real-life situation is a Mathematics Modelling. Mathematics modelling is chosen because the material could be developed to invite students to learn critically about the concepts given in daily life. In addition, RMcT is expected to be based on the problem which used reasoning skills. RMcT adapt the needs of slow learner students in reflective activity. Therefore, researchers are interested to develop RMcT learning model for slow learners. Required through the development of RMcT, to stimulate critical thinking, the students can think critically offered through problems given by lecturers, develop strategies for problem-solving and are actively involved in learning process.

The development of RMcT learning model is validated based on expert and implementation in class. In order to develop a better understanding of the impact that RMcT have on learning mathematics

modelling, a qualitative investigation was carried out in the development of the learning model, especially for slow learner in inclusive class.

2. Method

This is a descriptive qualitative research. RMcT learning model is implemented in mathematics modelling course in mathematics education department. First material discussed is a first order of differential equation. The students were using a handout while learning. The data was taken in Mathematics Education Department in Universitas Ahmad Dahlan. The subjects consisted of 4 students in 5th semester of mathematics education department in Universitas Ahmad Dahlan using purposive sampling based on the condition that they are slow learner.

The validation of the data used is subject triangulation. The instruments were written test and interview. The researchers analyze the written comments from the experts. In other time researchers make an interview about the learning model experienced by the students. By using the digital module, the expert gives feedback about the learning instrument.

3. Result and Discussion

The subject is doing a CFIT test. The test was identifying the student's IQ score. To identify the slow learner, the researchers using criteria given by American Psychiatric Association. The characteristics of slow learner are immature in interpersonal relationships and show difficulty in understanding teacher instructions that have many steps, have few internal strategies, such as organizational skills. They have difficulties in learning to generalize information [6, 7]. Based on the test, the researchers get two slow learner's students in mathematics education department. The slow learners' IQ score is shown in Table 1.

Table 1. Participants

Students' Code	IQ Score
1 st Subject	85
2 nd Subject	86

After identification, the subjects are set in the same class with RMcT Model. While implementing RMcT model, the subjects are represented their own group to make an explanation related to the concept of First Order Differential Equation. They are asked the detailed concept such as the definition of dependent variables, independent variables, and the solution of differential equation. The illustration is shown in Figure 1.

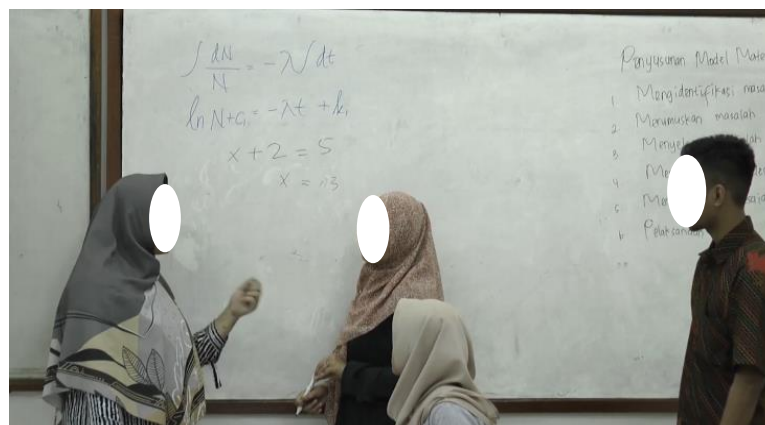


Figure 1. The lecturer start explaining the first order of differential equation using Rigorous Question

While discussion, the first subject feels unconfident while solving the problem. Besides, the subject has traumatic in solving mathematics modelling in differential equation course. It gave impact to her

low perception about her ability and own thinking. This is confirmed that slow learners have a low perception about herself dan immature in interpersonal relationship. By using RMcT learning model, the lecturer facilitated the learning process. The lecturer gave a question about what variables is in the Equation (1).

$$-\frac{dN}{dt} = \lambda N \quad (1)$$

The subject's answer about the dependent and independent variables in the Equation (1) is incorrect. She was confused to determine the dependent and independent variables. The lecturer also checks the subject's understanding in the first order of differential equation topic. By giving questions, the lecturer gave the simplest algebraic equation to construct her understanding in variables. The second subject also experienced the confusion in determining the dependent and independent variables in class. The illustration is shown in Figure 2.



Figure 2. The lecturer facilitates the students to determine the dependent and independent variables

By using RMcT learning model, the lecturer gives the steps in modelling mathematics context such as: 1) problems identification, 2) determining the mathematics model, 3) deriving the strategy in solving the problem, 4) interpreting the solution, 5) rechecking the solution. As the first step, the subject still has difficulties in identifying the variables of the Equation, determining mathematics model, and interpreting the solution. The subject's work about mathematics modelling is shown in Figure 3.

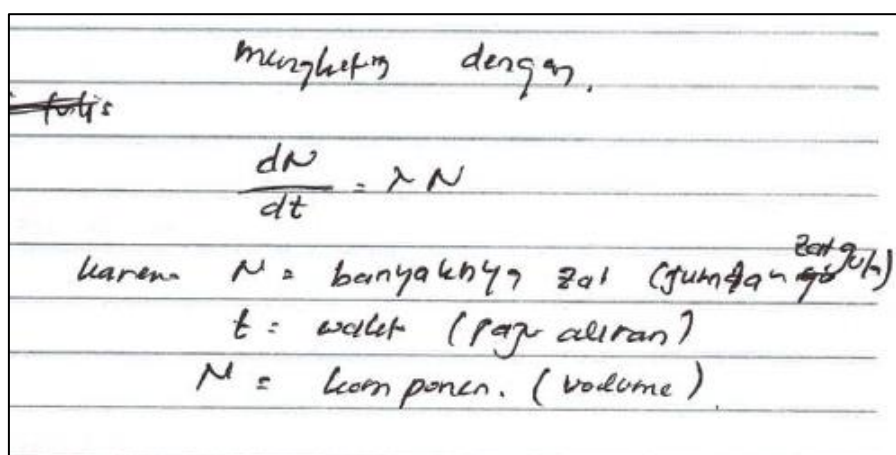


Figure 3. Subject's work in modelling the mathematics problem

Based on the Figure 3, subject made an equation using variables. However, the symbol of the number of substances is the same with the symbol of volume. The role of the lecturer as the mediator gave slow learner to express their analytic perception. Kenard said that creation of rigorous mathematical thinking and mathematical-scientific conceptual development helps you gain insight about patterns and relationships [8, 9]. Meanwhile, their calculation about the algebraic expression is well constructed. It can be seen in Figure 4.

zat gula = 10kg + 20gr \rightarrow hasil mangsan' jumlah zat gula
 * kkg = 1000 gr

$$\begin{array}{r} 20 \text{ gr} \\ + \\ 1000 \text{ gr} \\ \hline 1020 \text{ gr} \end{array}$$

 waktu keluar - waktu di alirkan \rightarrow kedua waktu.
 = 45 l/menit - 40 l/menit
 = 5 l/menit

Figure 4. Subject's works in deriving the calculation

Based on the calculation in Figure 4. The subject can calculate both in mass and flow rate. In mass, subject add different unit between kilogram and gram. In flow rate, she can calculate between the same unit. Besides that, the lecturer role to give a feedback and stimulation on how she can criticize her work. For the case the relationship between the mass and the flow rate, it seems that the subject cannot make a relationship of the given problem. the problem itself can be seen in Figure 5.

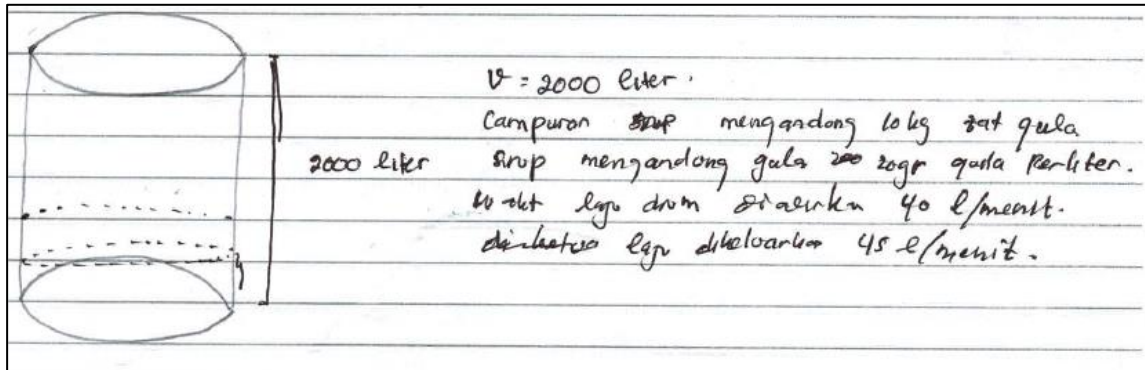


Figure 5. Mathematics modelling problem

By seeing the representation of the subject about the volume of the cylinder, the symbol of 2000 liter is written as the height of the cylinder. In this case the lecture tried to understand subject's work about the meaning of dotted line in the cylinder. The lecturer starts to give the known and unknown variables used. It allows slow learners to experience more and develop higher orders of mathematical thinking step by step. These characteristics is related with the computational thinking. From a pedagogical perspective, the thoughtful use of computational tools and skillsets can deepen learning of mathematics and science content [10-19].

However, RMcT learning model gives slow learner to express their idea by answering lecturers' rigorous question. Both slow learner students express their thought and comments not only in answering the lecturer's questions, but also a discussion in class. It happens because RMcT is a combination of rigorous mathematics thinking and computational thinking. As RMT has a synthesis and utilization of mental. Subject derived insights about patterns in solving problems. The lecturer motivated the students to try their schemes in elaborating these insights for their organization, correlation, orchestration and

abstract representation to form emerging conceptualizations and understandings. RMcT learning model gave students chance to determine a specific solution by herself in group because RMcT mediated the material transferred to the students personally. By studying a specific case can enrich one's conceptualization of the general [20]. The solution of the problem was discussed in a group so that the subject has difficulties in expressing her ideas. Comparable to normal children, classrooms for slow learners are ideally small where the student-to-teacher ratio is much smaller [21]. This will promote intense contact between teachers and students [22]. Teachers will interact better with their students and can appraise the students' social and emotional needs and academic ability levels. These unique students require one-to-one contacts to progress in their academic learning [23]. they feel that the instructor can mediated the problem by giving analogy to the other material. In summary, RMcT could mediate slow learner's critical thinking as its characteristics (by using Rigorous questions). Critical thinking as the impact of giving high order thinking question and context in question is very important [24]. Findings are useful for designers, service providers and policy makers of special needs higher school when implementing teaching strategy to mediated real-life problems into mathematics modelling for slow learners.

4. Conclusion

In order to develop a better critical thinking skill of the impact RMcT Model in mathematics modelling course, the students are given a rigorous question such that they usually use their own reasoning and ideas to solve the given problem. RMcT gave a chance of the students to think critically since it asked the student to use their own ideas. The terms of the questions should be constructed by using a step-by-step question. The students must not only organize and outline concepts and theories, but their evaluation statements will be conveyed by critiquing, checking, experimenting, judging, testing, detecting, and monitoring. Students must make judgments about the material and articulate the reasons for evaluation.

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References

- [1] Krulik, S. and Rudnick, J.A. (1995). A new sourcebook for teaching reasoning and problem solving in elementary school. Boston: Allyn and Bacon.
- [2] Watson, G.B., Glaser, E. M. (1980). Watson-Glaser critical thinking manual. San Antonio: The Psychological Corporation, Harcourt Brace & Co.
- [3] Ennis, R. H. (1996). Critical Thinking. USA: Prentice Hall. Inc.
- [4] Zapalska, A.M., Nowduri, S., Imbriale, P. Wroblewski, B., and Glinski, M. (2008). A Framework for Critical Thinking Skills Development Across Business Curriculum Using the 21st Century Bloom's Taxonomy. *Interdisciplinary Education and Psychology*. 2018; 2(2):2
- [5] Zuliana, E., Setyawan, F., & Veloo, A. (2017, December). Helping students mathematical construction on square and rectangle's area by using Sarong motive chess. In *Journal of Physics: Conference Series* (Vol. 943, No. 1, p. 012058).
- [6] Kephart, N. C. (1960). The slow learner in the classroom.
- [7] Hoffman, R. I. (1968). The Slow Learner—Changing His View of Math. *The bulletin of the National Association of Secondary School Principals*, 52(327), 86-97.
- [8] Kinard, J. T. (2006). Creating rigorous mathematical thinking: a dynamic that drives mathematics and science conceptual development. *Transsylvania Journal of Psychology-Erdély Pszichológiai Szemle, Special issue Vol. Supplement 2006, part, 2*, 251-266.
- [9] Kinard, J. T., & Kozulin, A. (2005). Rigorous mathematical thinking: Mediated learning and psychological tools. *Focus on learning problems in mathematics*, 27(3), 1.
- [10] Guzdial M (1994) Software-realized scaffolding to facilitate programming for science learning. *Interact Learn Environ* 4(1):001–044

- [11] Eisenberg M (2002) Output devices, computation, and the future of mathematical crafts. *Int J Comput Math Learn* 7(1):1–44
- [12] National Research Council (2011a) Learning science through computer games and simulations. The National Academies Press, Washington, DC
- [13] National Research Council (2011b) Report of a workshop of pedagogical aspects of computational thinking. The National Academies Press, Washington, DC
- [14] Redish EF, Wilson JM (1993) Student programming in the introductory physics course: mUPPET. *Am J Phys* 61:222–232
- [15] Repenning A, Webb D, Ioannidou A (2010) Scalable game design and the development of a checklist for getting computational thinking into public schools. In *Proceedings of the 41st ACM technical symposium on computer science education*. pp 265–269
- [16] Sengupta P, Kinnebrew JS, Basu S, Biswas G, Clark D (2013) Integrating computational thinking with K-12 science education using agent-based computation: a theoretical framework. *Educ Inf Technol* 18(2):351–380
- [17] Wilensky U (1995) Paradox, programming, and learning probability: a case study in a connected mathematics framework. *J Math Behav* 14(2):253–280
- [18] Wilensky U, Brady C, Horn M (2014) Fostering computational literacy in science classrooms. *Commun ACM* 57(8):17–21
- [19] Wilensky U, Reisman K (2006) Thinking like a wolf, a sheep, or a firefly: learning biology through constructing and testing computational theories—an embodied modeling approach. *Cogn Instr* 24(2):171–209
- [20] Setyawan, F., & Prahmana, R. C. I. (2017, December). Visualizer’s representation in functions. In *Journal of Physics: Conference Series* (Vol. 943, No. 1, p. 012004). IOP Publishing.
- [21] Lohman, A. E. (2011). Special education learning environments: Inclusion versus self-contained (Doctoral dissertation, Lindenwood University).
- [22] Firdausy, A. R., Setyaningsih, N., & Waluyo, M. (2019). The Contribution of Student Activity and Learning Facilities to Learning Independency and it’s Impact on Mathematics Learning Outcomes in Junior High School. *Indonesian Journal on Learning and Advanced Education (IJOLAE)*, 1(2), 29-37.
- [23] Webster, R., Blatchford, P., Bassett, P., Brown, P., Martin, C., & Russell, A. (2010). Double standards and first principles: Framing teaching assistant support for pupils with special educational needs. *European journal of special needs education*, 25(4), 319-336.
- [24] Himmah, W. I., Nayazik, A., & Setyawan, F. (2019, March). Revised Bloom’s taxonomy to analyze the final mathematics examination problems in Junior High School. In *Journal of Physics: Conference Series* (Vol. 1188, No. 1, p. 012028). IOP Publishing.