Virtualmatriks: A Conceptual Mathematization Process in Virtual Learning Environment

Adi Nur Cahyono

Mathematics Department, Semarang State University, Indonesia
adinegara@staff.unnes.ac.id

Abstract: In the Virtual Learning Environment, students interact with the teacher and the other students. By interacting, students can enhance the understanding of mathematical concepts and its application in the real life. This study aims to develop a model of virtual learning environment based on Realistic Mathematics Education. The research questions are how to develop and implement this model and its effect on the learning outcomes. The results of development in this study are the model and device of VirtualMATRiKS. Students simulate the conceptual mathematization process by create the movie about problem solving. Then students share and discuss it through virtual-learning device. After validated by experts, the model and device were implemented in Semarang Senior High School. And the result is the model and devices qualify the effectiveness and practicality. This model gives a positive impact on student learning outcomes, and students can reach the Upper Limit of Zone of Proximal Development. This model can be applied and developed further in learning mathematics by considering into environment, conditions and students interest.

Key words: RME ,Virtual-Learning Environment, Educational Movie, Conceptual Mathematization

Introduction

Teaching and learning mathematics are complex tasks. According to Freudenthal (1991), mathematics as human activity and mathematics must be connected to reality. Therefore, students should be able to understand the concepts of mathematics and and its application in the real world. But in fact, there are some problems in learning mathematics, such as some students are difficult to understand the concepts and problem solving, some students have low motivation in learning mathematics, and some students do not understand the application of mathematics in real life. By considering the expectations and problems, it is necessary to develop a model of learning environment that makes the learning activities become easier and more enjoyable so the students can reach the optimal learning outcomes. When referring to the Vygotskian perspective, learning outcomes and students' understanding can be increased as a result of interaction in learning. The interaction between teacher-student and student-student in learning, illustrates that social interaction in the form of discussion is able to provide students with opportunities to optimize the learning process. This interaction allows teachers and students to share and modify their ways of thinking. There is also a possibility for some students to showcase their own arguments as well as for other students the opportunity to try to capture the thought patterns of other students.

Activity is believed to be able to increase knowledge and understanding of the object was learned from the previous stage to a higher stage. Students can interact around the difficult task and share their effective problem-solving strategies, if there is an arrangement of classes and a form of learning environment. There are two forms of learning environment, namely physical learning environments and virtual learning environments. Virtual learning environment (VLE) developed by making the design of information spaces as learning environments. In the VLE, students interact with teacher and the other students, wherever and whenever. Teachers and students are familiar with the use of the system. Hardware and software that supports this system has been available. However, to achieve the purpose of learning mathematics, the development of the learning environment must be based on the characteristics and principles of mathematics and learning mathematics.

Theoretical Background

Vygotskian Perspective

According to Vygotsky (1978), there are two important concepts in the sociocultural theory, the Zone of Proximal Development (ZPD) and scaffolding. ZPD is the distance between the actual developmental level as determined by independent problem-solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers (Vygotsky, 1978). It is a dynamic developmental state. At the lower limit of the zone are the tasks that children can accomplish independently, while at the upper limit is the space where more complex tasks can be realized by children through interactions with more knowledgeable others. Learning can evoke a variety of mental processes that can only be operated stored when a person interacts with an adult or collaborate with their peers. With these interactions, students can complete a complex task that can only be solved if students are given assistance by adults or collaborate with peers, the level is referred to as the upper limit of the ZPD. The process of giving assistance in this process is called scaffolding.

Scaffolding means providing large amounts of aid to students during the early stages of learning and then reducing the assistance and provide opportunities for children is to take over greater responsibility as soon as he can do it (Slavin, 1994). Vygotsky (in John and Thornton, 1993) explains that learning occurs in two stages: first stage occurs when collaborating with others, and the next phase done on an individual basis in which occurs the internalization process. During the process of interaction occurs (teacher-student and student-student), the following capabilities should be developed: mutual respect, to test the truth of the statement of others, negotiate, and adopt the other opinion.

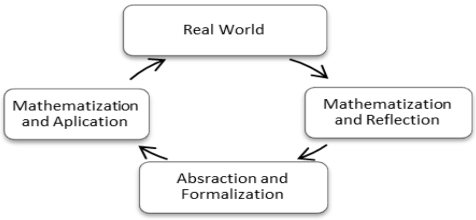
Virtual Learning Environment

A Virtual Learning Environment is a collection of integrated tools enabling the management of online learning, providing a delivery mechanism, student tracking, assessment and access to resources (Dillenbour & al, 1999). In a virtual learning environment, students and teacher can interact anywhere, anytime and easy to find and share informations. Interaction can take many forms, including synchronous or asynchronous communication, one-to-one or one-to-many or many-to-many, text-based or audio and video, or even indirect communication such as sharing objects. Researchers have introduced the notion of "place" (Dourish & Chalmers in Dillenbour & al, 1999) to emphasize that space has a social impact. Places are settings in which people interact. (Munro, Höök & Benyon in Dillenbour & al, 1999). The representation of the learning environment ranges from text-based interfaces to the most complex 3D graphical output. 3D graphical representation is often used, because it can increase motivation, and triggering a positive attitude towards the environment. Dillenbour & al (1999) observed that virtual space imparts on users behaviour even when space is only described by text. In virtual environments, learning activities ranging from multiple-choice questionnaire for simulation and problem solving. The idea of learning activities in a virtual learning environment refers to something richer than the individual, closer to the idea of the project.

The difference between other constructivist environments and what virtual environments potentially offer can be described as making students not only active, but also actors, i.e. members and contributors of the social and information space. (Dillenbour & al, 1999). A virtual learning environment integrates a variety of tools supporting multiple functions: information, communication, collaboration, learning and management (Peraya & al. in Dillenbour & al, 1999). Virtual learning environments do not only integrate a variety of software tools but also integrate all the physical tools that can be found in a classroom. According Carabaneanu (2006), a learning environment is considered adaptive if it is capable of: monitoring the activities of its users; interpreting these on the basis of domain-specific models; inferring user requirements and preferences out of the interpreted activities, appropriately representing these in associated models; and, finally, acting upon the available knowledge on its users and the subject matter at hand, to dynamically facilitate the learning process.

Realistic Mathematics Education

Mathematics as human activity and mathematics must be connected to reality. These statements are the root of the Realistic Mathematics Education (RME). RME refers to the mathematics education approach which has been developed and applied in the Netherlands since 1971. Mathematics should be undertaken as an activity in the students experience mathematics as a meaningful subject and can better understand it (Freudenthal, 1991). Freudenthal emphasizes real activity in mathematical activities. Activities under consideration should consist largely of organizing or mathematization of subject matter and is taken from reality. Learners must learn mathematics with mathematization of subject matter from the real context and activity of mathematics, not learning from the traditional presentation of mathematics to the students as a ready-use system that is generalized. Real situations can include contextual problems or authentic Mathematically Contexts for students where they're having problems which are presented in relevant and real. The process of developing mathematical concepts and ideas that started from the real world called conceptual mathematization (de Lange, 1993). Schematic model of learning is described as follows.



Picture 1. Conceptual Mathematization (de Lange, 1993)

Through a process of progressive matematization, learners are given the opportunity to rediscover the insight, knowledge and mathematical procedures. Thus learners do the stages which in RME called horizontal and vertical mathematization. Gravemeijer (in Sembiring & al., 2008), suggests that there are three main principles of RME, namely: (a) Guided reinvention / progressive mathematizing, (b) the didactical phenomenology and (c) self-developed models. For the operationalization of the three main principles of RME, according Panhuizen (in Gravemeijer, 1994: 114-115), RME has five characteristics, namely: a) The use of contextual problems, b) The use of various models, c) Student contributions, d) interactivity, and e) intertwining (integrated). Strategy, which could be applied in the implementation of RME by Loucks-Horsley (1998): (1) a short learning process, (2) curriculum development, and (3) the use of technology. The results of research in the Netherlands showed that the RME has shown satisfactory results. RME has the potential to improve students' understanding of mathematics (Streefland, 1991).

Activity Theory

All human actions are called activities. An activity involves an object. The object is to be transferred to the output of the activity. A subject performs an activity using a tool. The tool can be a physical or an abstract tool. The interactions between subject, object and community can all be mediated. Rules mediate the activity between the community and a subject. The activity may be collaborative, i.e. several subjects jointly do the activity using tools and dividing the work between each subject (Multisilta, 2008). In general, tools, rules and division of work mediate the relationship between the subject, community and object. Tools, rules and division of work are artefacts that are used to achieve the outcome. Experiences and attitudes that influence one another (Uden, 2007). Activity can furthermore be divided into actions and an action on operations. In general, activities are based on high-level goals (for example, documenting a work process with images and video clips). The Shared Activities and Experiences framework originates from a need to describe sharing and experiences in social media in theoretical terms (Multisilta, 2008).

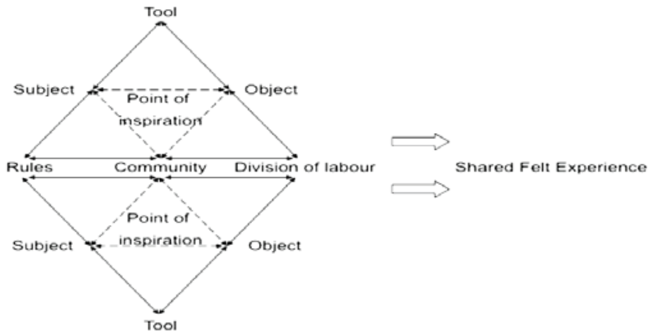


Figure 2. The Shared Experience and Activities Framework (Multisilta, J., 2008)

Figure 3: The Shared Experience and Activities (SEA) framework

Conceptual Framework and Research Question

Mathematics as human activity and mathematics must be connected to reality. Therefore, students shoud be able to understand mathematics concepts and its application in the real world. Students' understanding can be optimized through social interaction in the learning environment. There are two forms of learning environment, namely physical learning environments and virtual learning environments. In a Virtual Learning Environment (VLE), students can interact with the other wherever and whenever. In this learning environment, students do activities to learn and gain new knowledge and experience with solving problems, sharing information, and discuss. Thus, students are expected to reach the upper limit of the zone of proximal development (ZPD). Activities should be adapted to the characteristics of mathematics. Mathematical activity of solving contextual problem starts from the real world problem, mathematizing and reflecting the problem, abstraction and formalization, mathematizing in application and then bring back to the real world at the end process. In Realistic Mathematics Education (RME) approach, this process is called Conceptual Mathematization

This research questions are (1) how to develop and implement the model of VLE based on RME in Semarang Senior High Schools? and (2) Is the implementation of the model has a positive effect on student learning outcomes?

Research Method and Procedures

This research is a development research that continued from previous research, MATRiKSMovie: building the nation character through movie-based RME (See also Cahyono, 2011). The purposes of this research is to develop the model of VLE based on RME in Semarang Senior High School. According to Cahyono (2006), model is defined as a conceptual framework used as guidance to do certain activity. Pouwer (1974: 243) explain about model as assumption like metaphor formulized explicitly containing unsures which depends each other. As a metaphor, model has never been seen as part of data represented. Model explains phenomena in a form which is not usual. Every model is needed to explain something more or different from data. This requirement is fulfilled by presenting data in forms of summary (type, diagram), configuration (structure), correlation (pattern), idealization and the combination of the four. Thus, model is metaphor which is solid and useful for the comparation of relation between the choosen data and the relation among the choosen unsures of a logical construction.

In this study, validity, practicality and effectiveness criteria are defined as follows: validity refers to the extent that the design of the intervention should include "state of the art knowledge" (content validity) and the various components of the intervention are consistently linked to each other (construct validity), practicality refers to the extent that users (teachers and pupils) and other experts consider the intervention as appealing and usable in normal conditions, effectiveness refers to the extent that the experiences and outcomes from the intervention are consistent with the intended aims.

Following the work of Nieveen (1997) and Ottevanger (2001), the development and research activities in this research were conducted in three stages. The first stage is called the front-end analysis, the current situation of mathematics learning in Semarang Senior High School were analyzed. The second stage of the study is called the prototyping stage. This stage consisted to develop and validate the prototype, namely virtual-learning device, the lesson kit and formative evaluation. The third stage of the research is called the assessment stage. In this stage the final version of the model and device are implemented in Senior High School, and then the learning process and result are reflected and evaluated with the instrument.

Results and Discussion

The first stage is called preliminary stage or front-end analysis, that the current situation of mathematics learning in Semarang senior high schools was analyzed. Result of the analysis in this stage are used as the basic for the development of model with valid, practical, and effective criteria. There are some problems in learning mathematics, such as some students are difficult to understand the concepts and problem solving, some students have low motivation in learning mathematics, and some students do not understand the application of mathematics in real life. Students and teachers need a medium to interact with easier, more enjoyable, and adjust to the development of information and communication technology. The results of the analysis indicate that some of the high school students still require visualization of abstract concepts and application of concepts in the real world. One material that is considered difficult by students is a matter of trigonometry. Student difficulties understanding the concepts and solving problems related to trigonometry, including equations and trigonometric functions and applications of trigonometry in real life. Students at this age also tend to be less motivated in carrying out learning activities in mathematics and more interested in the entertainment and and social networking because of the influence of age, social, environmental, facilities, and technology. Technological development encourages innovation in teaching and learning of mathematics by adjusting to conditions. By considering the expectations and problems, it is necessary to develop a model of learning environment that makes the learning activities become easier and more enjoyable so the students can reach the optimal learning outcomes. Learning outcomes and students' understanding can be increased as a result of interaction in learning.

In the second phase (prototyping stage), the result of analysis in first stage used to develop the prototype. Based on the preliminary analysis, the prototype being developed is a model and device of virtual learning mathematics based on RME, called VirtualMATRiKS. The prototype that need to develop, i.e virtual-learning device, lesson plan, teachers guide, students workbook, and the evaluation sheet. Preliminary description of the learning process is the students simulate of the conceptual mathematization process by creating the movie about problem solving. Then students experiencing by share and discuss the movie with other through virtual-learning device. It is based on the fact that mathematical activity of solving contextual problem starts from the real world problem, mathematizing and reflecting the problem, abstraction and formalization, mathematizing in application and then bring back to the real world at the end process. The activities of students in these activities is to demonstrate the process of solving problems related to the rediscovery of the mathematical concepts and applications of mathematical concepts in real life. Process in the production of educational films starting from a given theme as a problem (in the form of the rediscovery of the concept of mathematics, or mathematical applications), then the students discuss in a production team to develop problem-solving scenarios to be presented in the drama of human activity in problem solving, setting up properties which is needed in problem solving and presentation, to present the steps solving the problem by acting in front of the camera (as actrist or as a presenter), the product is presented in real video and/ or graphic animation according to student creativity and made simple with simple tools, so implementation of these activities in accordance with the allocation of time that has been planned in the lesson plan. The results of this learning process are portofolios and movie. Each team share the learning experience by uploading the movie in the Virtual Learning Environment device, then students discuss together about material with the guidance of teachers in the virtual learning environment. This activity can be done anywhere and anytime, with rules specified by the teacher.

Draft of prototype validated by experts (education, mathematics, media, evaluation) to obtain a valid prototype and ready to be implemented in learning process on the third stage. After validated, the prototype is corrected based on the suggestions given by experts, so getting a second prototype that is better than ever. Then the second prototype was simulated in the learning process. Simulation is used to obtain data on the implementation of models and tools in learning. The data come from teachers, students, and the observer. Simulation concludes with discussion and reflection to obtain feedback and know the lack of model and device as the basis for subsequent improvement. After repair and produce the final version of the prototype, and ready for use, then executed the third stage. The result of prototyping are the model of virtual learning environment and device of VLE. Learning environment that developed through this research is a hybrid learning environment (face-to-face learning and learning through elearning devices). Learning processes and devices were developed based on the philosophy, principles, and characteristics of RME and using IT-tools in the form of e-learning device that focus on providing support for teacher(s) and students in the learning process. E-learning device was developed with the software and computer networks. Syntax of the model are (1) Teachers provide instruction, convey learning goals, students in the class divides into groups, distribute the student activity sheet, (2) The teacher gives problems to be solved by the students, so students are able to construct the concept of matter being studied and/ or apply the concepts in real life, (3) Students discussing with his team to share tasks and create problem-solving scenarios in accordance with the creativity of each. (with teacher guidance). (4) Accordance with their respective duties, students creating a simple short film production process of solving the problem (the construction of concepts and/ or application of concepts). (5) Each team sharing the learning experience by uploading a movie in the VLE device (6) Students discuss their work together with the guidance of teachers in the virtual learning environment. This activity can be done anywhere and anytime, with rules specified by the teacher, (7) Each student gives a conclusion. (8) Teachers give clear, straighten the concept (if there is a less precise), and give final task of learning (projects, pop quizzes and/ or homework) using VLE device. Virtual learning device was developed and implemented by using software, hardware, and computer network, that supports text files, images, interactive media, mathematical formulas and video. The device also provides both synchronization and asynchronization communication feature.

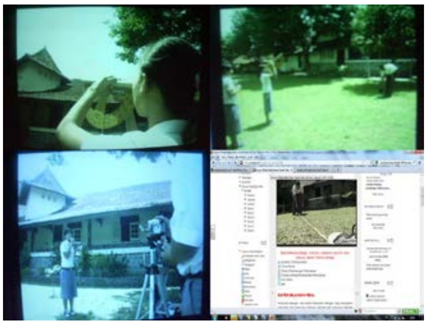


Figure 3. Practice problem solving in the real world, simple movie production, share and discuss in VLE device

The third stage of the research is called the assessment stage. In this stage the final version of the VirtualMATRiKS model and device are implemented in Senior High School, and then the learning process and result are reflected and evaluated with the instrument.VirtualMATRiKS was implemented in a Semarang Senior High School class 10 in 2008 in the subject matter of Trigonometry.

The research result suggest that the average of reliability of learning equipment (virtual-learning device, lesson plan, teachers guide, students workbook, and the evaluation sheet) is 95,30%, that is a high reliability category, the capability of teacher in organizing the learning could be categorized as very good, with average score 3,52. The average of teacher's activities in the learning process is 3,54 or it reaches 88,48 % (category of very good). The average of students' activities in the learning process is 3,54 or it reaches 88,57 % (category of very good). Seeing the average of students' involvement of each meeting, it shows that there is an increase of students' involvement from 3.45 to 3.54 at the last meeting. The average of students' skill of process in the learning is 3.57 or it reaches 89.26% (category of very good).

According the calculation, $\chi^2_{calculation}$ = 1,296 which is significant at 0,069 > 0,05 , thus, Ho is accepted which means the data has normal distribution. Therefore, the statistic used is statistic of parametric. The result shows that the mathematics learning result data coming from upper, middle and lower groups in the experiment class and control class are normally distributed and are homogenous. By using *Univariate One Way Anova* to test the difference of averages between the upper, middle and lower groups. Based on the calculation, at the row group, the significant value is 0,020 < 5%, it means that the learning outcomes between experiment class and control class is different. At the column group, the significant value is 0,000 < 5%, it means that there is no difference of the learning outcomes among the three groups (upper, middle, lower). Then, there is no interaction because the value of significant is 0,091 > 5%.

By using *Regression Analysis*, $F_{calculation}$ = 25,643 with significant rate is 0,000. It shows that there is strong effect of skill of process toward the learning outcomes or Ho is rejected which means there is influence between skill of process and learning outcomes. From the calculation, the correlation between skill of process and learning outcomes is 63,5 % and the skill of process gives contribution toward learning outcomes 40,3%. Therefore, the skill of process strongly correlates with the learning outcomes. The regression equation between skill of process and learning outcomes is $\hat{Y}$ = 32,371 + 2,657 X , where Y = learning outcomes, and X = skill of process. From the calculation, $F_{calculation}$ = 27,616 with significant rate is. It shows that there is strong effect of students' activity toward the learning outcomes or Ho is rejected which means there is influence between students' activity and learning outcomes. The correlation between students' activity and learning outcomes is 64,9 % and the students' activity gives contribution toward learning outcomes 42,1%. Therefore, the students' activity strongly correlates with the learning outcomes. The regression equation between students' activity and learning outcomes is $\hat{Y}$ = 13,968 + 1,987 X , where Y = learning outcomes, dan X = students' activity.

From *Compare Mean One Sample t Test* , we find that $t_{calculation}$ = 2,963. By using right side test, for α = 5% and df = n – 1 = 39–1 = 38 we gain $t_{(1-\alpha)(n-1)}$ = 2,021. Because $t_{calculation} > t_{table}$, then Ho is rejected. Therefore, it can be concluded that the average of learning outcomes $\geq$ 65,0, thus, the students have mastered the material because they reach material comprehension. Therefore, learning process using this model can reach the purposes of learning (reach the material comprehension) with the average of learning result is 80,57.

The results of implementation show that the learning of mathematics through VirtualMATRIKS showed the good results. Activities and process skills of students in this learning is making a positive impact on student learning outcomes. The learning outcomes in this study referred to three aspects: cognitive, affective, and psychomotor. The cognitive aspect included pupils' achievement and reasoning, the affective aspect involved pupils' motivation, activity, and creativity, while the psychomotor included skills in problem-solving process. Scaffolding for students to reach the ZPD occurs when students interact with each other in processing of problem solving.

In the activities, students are trained to be creative and caring in problems solving, both social and environmental problems. Students work together in solving the problem. Students are able to communicate their ideas and dare to be responsible. This learning can build motivation, appreciation, contribution, interest, beliefs, creativity, confidence and perseverance and a sense of responsibility and communication skills. RME approach can build self-reliance, democracy, tolerance, humanism and honesty. Mathematical learning occurs during the film production process and during the discussion and interact with teacher or the others using VLE device. Activities and process skills of students in mathematics learning through VirtualMATRiKS in the high school has provided a positive effect on the results student learning (cognitive, affective, and psychomotor). Students learning outcomes in this learning environment are better than students learning outcomes in the conventional leaqrning environment. There is a difference between understanding and student learning outcomes between before and after the learning process in that environment. After interacting via the VLE devices, understanding and student learning outcomes are higher than ever. Students can reach the upper limit of the ZPD.

Conclusion and Suggestion

Based on the results from the three stages of this study, it has been concluded that: The result of this research is a VLE model based on RME, namely VirtualMATRiKS. In this learning environment, the students simulate of the conceptual mathematization process by creating the movie about problem solving. Then students experiencing by share and discuss the movie with other through virtual-learning device.Model and device are effectively implemented in mathematics learning in Senior High School, and this model gives a positive impact on student learning outcomes (cognitive, affective, and psychomotor). Students can reach the Upper Limit of Zone of Proximal Development.

Based on the conclusions of this study, it can be suggested that this model can be applied and developed further in learning mathematics by considering into environment, conditions and students interest.

References

Cahyono, A.N. (2006). Development of Technology-based Creative Problem Solving in Mathematics Learning of Senior High School. Magister Thesis. Semarang: Semarang State University.

Cahyono, A.N. (2011). MATRiKSMovie: Building the Nation Character through Movie-based RME. Paper presented in International Seminar and the Fourth National Conference on Mathematics Education. Department of Mathematics Education, UNY.

Carabaneanu,L., Trandafir, R. and Mierlus-Mazilu, I. (2006). Trends in E-learning, Department of Mathematics and Computer Science Technical University of Civil Engineering Bucharest, Romania.

de Lange, J. (1996). Using and applying mathematics in education. In A.J. Bishop et al. (Eds.), International Handbook of Mathematics Education, 49 – 97. The Netherlands: Kluwer Academic Publishers.

Freudenthal, H. (1991). Revisiting mathematics education. The Netherlands, Dordrecht: Kluwer Academic.

Gravemeijer, K.P.E. (1994). Developing realistic mathematics education. The Nederlands, Utrecht: Freudenthal Institute.

John, G.A., dan Thornton, C.A. (1993). Vygotsky Revisited: Nurturing Young Children's Undersanding of Number. *Focus on Learning Problems in Mathematics, 15,* 18-28.

Multisilta, J. (2008). Designing for mobile social media. In A. Karahasanovic & A. Følstad (Eds.), Proceedings of The NordiCHI'08 Workshops New Approaches to Requirements Elicitation & How Can HCI Improve Social Media Development? (pp. 72-79). Tapir, Trondheim.

Nieveen, N.M. (1997). Computer support for curriculum developer: A study on the potential of computer support in the domain of formative curriculum evaluation. Doctoral dissertation. The Netherlands, Enschede: University of Twente.

Ottevanger, W. (2001). Teacher Support Materials as a Catalyst for Science Curriculum Implementation in Namibia. Doctoral dissertation. The Netherlands, Enschede: University of Twente.

Pouwer, J. (1974). The Structural Confdigurational Approach a Methodological Outline on The Unconscious in Culture. New York: Dutton & Co.

Sembiring R.K., Hadi, S., & Dolk, M. (2008). Reforming mathematics learning in Indonesian classrooms through RME. ZDM Mathematics Education (2008) 40:927–939

Slavin, R. (1994). Educational Psychology: Theories and Practice Fourth Edition Masschusetts: Allyn andBacon Publishers.

Streefland, L. (1991). Realistic Mathematics Education in Primary Schools. Utrecht: Freudenthal Institute.

Uden, L. (2007). Activity theory for designing mobile learning. International Journal of Mobile Learning and Organisation, 1(1), 81–102.

Vygotsky, L.S. (1978). *Mind in society*. Cambridge, MA: Harvard University Press.