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PREPARING PRESERVICE TEACHERS TO TEACH MATHEMATICAL LITERACY: A REFORM IN A TEACHER EDUCATION PROGRAM

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To meet the demand of coming school curriculum reform focusing on the competency-based model in Vietnam, this paper reports on an innovation project on developing secondary mathematics preservice teachers (PSTs) mathematical literacy and preparing them to teach mathematics contextually. Adopting a design research, we developed curriculum and researched the effectiveness of the implementation of the curriculum on secondary mathematics PST education program that integrates mathematical literacy (ML) into methods courses. The courses offer PSTs opportunities to experience ML as active learners and prepare them to teach ML. The preliminary results on a project-based modeling task show that PSTs start to develop an understanding of ML when they take real life consideration into account when solving the authentic problem. Discussion about the tension between simplifying models yet reflect closely the real problem PSTs tackle and future study is suggested.

INTRODUCTION

This paper reports on an innovation project on developing secondary mathematics preservice teachers (PSTs) mathematical literacy (ML) and prepare them to teach mathematics contextually. This initiative is to address the coming school reform curriculum to be implemented in 2019 that focusing on the competency-based model (Vietnam Ministry of Education, 2018) and emphasizes the close relationship between mathematics and real world. Teachers serve as an agent to make changes in their classrooms, and we assume that PSTs should be equipped with the skill sets to teach mathematics contextually. Therefore, our ongoing project strives to (a) investigate the process of secondary mathematics education preparation to prepare PSTs to teach mathematics contextually that meet the demand of the reform school curriculum and (b) document the influences or successes/failures of the implementation on PSTs knowledge and practice. For the scope of this paper, we will address how are PSTs' mathematical literacy understanding evident through their work on project-based tasks in this innovation mathematics teacher education program?

SCHOOL REFORM – COMPETENCE-BASED CURRICULUM

The current national school mathematics curriculum in Vietnam, starting in 2002, rarely highlights the relationship between mathematics and real world and makes no mention of mathematical modeling or mathematical literacy explicitly. In the national mathematics textbooks, some word problems exist but they are pseudo-realistic, and contexts are not an integral part of solving the problems. These are minor in the textbooks (Table 1).

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Grade	6	7	8	9	10	11	12
Tasks embedded in real-world context	80	71	46	62	32	5	0
Total Tasks	580	450	504	456	302	294	233

Table 1: Number of tasks that are embedded in real-world contexts in secondary textbooks

To meet the demand of changing society, a reform in curriculum and textbooks following a competency-based model (Vietnam Ministry of Education, 2018). In this reform curriculum, mathematical modeling is mentioned as one of the five competencies that involve communication, mathematizing, reasoning and argument, solving problems, using mathematical tools that students should develop. The curriculum indicates that it is necessary for students to use school mathematics they learn in everyday life. It underscores real world contexts in each lesson and students are required to apply mathematical knowledge they have learned to solve real world problems as well as to understand the meaning of mathematical knowledge in real world. The reformed curriculum will provide opportunities for school students to experience and apply mathematics to real life situations and build the connection between mathematics and reality. However, it also brings about challenges for teachers (including PSTs) to teach mathematics this way as they rarely have such experience as a learner and are not trained to teach mathematics contextually. Therefore, we put the efforts to reform our secondary mathematics education program, implement the innovation, and research on the effectiveness of the implementation.

CONCEPTUAL FRAMEWORKS FOR REFORMING A PRESERVICE TEACHER EDUCATION PROGRAM

Mathematical literacy

ML is individual’s abilities to understand mathematics and to use mathematics in a variety of contexts including everyday life situations, profession, and scientific settings. The mathematics serves as tools to describe, explain, and predict phenomena (OECD, 2013). In turn, individuals appreciate the role mathematics plays in the world and prepare them to be constructive citizens and make well-founded judgments and decision. In addition, OECD (2013) utilizes the mathematical modeling cycle (cf. Kaiser & Stender, 2013) to describe the actions students do when facing challenges in their lives that require mathematics to solve including individual’s capacity to formulate, employ, and interpret mathematics in a variety of contexts.

Several researchers and mathematics educators highlight the difference between mathematics and ML and argue that some people are good at mathematics, not necessarily good at ML (e.g., Orril, 2001). In addition, the focus on developing ML might be different from developing mathematical understanding. For example, the aim of developing school mathematical understanding is to help students climb the ladder of abstract structure whereas ML anchored in data that are derived from the empirical world. In addition, school mathematics tends to develop school-based knowledge whereas ML involves mathematics acting in the world. Mathematics could start with context, and then separate it later when focusing on abstraction, whereas ML often relies on context, and the reasoning is less formal, less abstract, and more intuitive (Elwell, 2001; Steen, 2001). It is noted that ML used in this context is not limited to understanding and applying arithmetic, but the abilities to use different mathematical knowledge, which might include advanced mathematics. In addition, ML includes not only the skills, knowledge but also the beliefs, dispositions, habits of mind the people need to engage effectively in quantitative situations in life and work (International Life Skills Survey, 2000). The way we conceptualize mathematical literacy here informs us as researchers to prepare PSTs to meet the demand of coming school curriculum reform in Vietnam.

Knowledge for teaching mathematics

Teacher knowledge is an important predictor of student achievement because a mathematics teacher's decision making in class is a function, among others, of her/his knowledge (Schoenfeld, 2010). Educational researchers have conceptualized knowledge for teaching to include subject matter knowledge and pedagogical content knowledge (Shulman, 1986; Ball, Thames, & Phelps, 2008). In particular, pedagogical content knowledge refers to:

> most powerful analogies, illustrations, examples, explanations, and demonstrations—[. . .] the most useful ways of representing and formulating the subject that make it comprehensible to others.... Pedagogical content knowledge also includes an understanding of what makes the learning of specific topics easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them. . . (Shulman, 1987, p. 7)

This conceptualization of teacher mathematical knowledge informs us to provide PSTs with opportunities to learn (OTL) ML and to teach ML to their future students. That is we create opportunities for PSTs to experience ML as active learners and engage in developing their knowledge/skills to teach ML as teachers such as analyzing curriculum, selecting, adopting, adapting task, and preparing how to use appropriate approach to teach students based on their understanding of students in relation to the content.

RESEARCH DESIGN

Research and Data Collection

This ongoing project is conducted in two years, from 06/2017 to 06/2019 with a cohort of 120 PSTs. The cohort started their teacher education program in 9/2015 and participated in the project starting 9/2017 when commencing their third year in the program. We have been following this cohort for two years until they finish their last placement focusing on conducting their own teaching in real classrooms.

We adopted a design research (Cobb et al, 2003) that involve continuous data collection, data analysis, and curriculum development and implementation. First, we identified gaps related to ML in the current mathematics method courses in the program. The current curriculum little indicates the opportunities for PSTs to experience ML as a learner and rarely to develop PCK for teaching ML. In the mathematics methods courses, the opportunity to learn in ML is limited (1.2 % of total training time) such as introduction about mathematical modeling and the PISA.

In 2017, we collected empirical data on PSTs' OTL ML and their beliefs about mathematics and mathematics teaching and learning. The measure of PSTs' beliefs towards mathematics and mathematics teaching focusing on if they perceive the subject as platonic or more of its utility. The data collected combining with the analysis on the curriculum inform our curriculum development focusing on their mathematics methods courses and their field experience (school placement) and how to change their disposition/attitudes towards the subject.

In addition to measure OTL and beliefs, we captured their modeling competencies as a proxy of their ML by using both a multiple-choice test and open-ended word problems. We adopted a research-based multiple-choice test (Haines et al., 2002) to measure PSTs' understanding of ML when they started the methods courses in the program. This research-based tool was developed based on different aspects of modeling competencies which were administered to PSTs individually within 60 minutes. We also got the PSTs to work in pairs on open-ended tasks focusing on four content areas, shapes, quantity, data and chance, and change. The open-ended tasks were conducted within 120 minutes. The data collected provided us with information about their current content knowledge related to ML and the weakness and strength the PSTs brought with them to the course. All the data were used to incorporate the learning OTL described next.

We have conducted interviews (task-based and stimulated recall) and classroom observations as other sources of data such as their reflection on their placement related to ML and their lesson plans. In 2018, the project will end with a post measure of their OTL ML, beliefs, and modeling competencies. Post interviews will be conducted on some cases who show different trajectories relate to developing ML to investigate the impact of the experience on their readiness to teach ML. Table 2 summarizes the timeline for data collection.

Content	**Pre**	**Curriculum Implementation and Data collection**	**Post**
	OTL ML measures – Individual Beliefs about mathematics and mathematics teaching and learning – Individual Multiple choice modeling test – Individual Open-ended modeling tasks – Pairs Stimulated recall interviews about their OTL and beliefs Stimulated recall interviews on modeling competencies	Curriculum Implementation: Mathematics methods courses School Placement Artefacts collections – Student works and presentations on ML tasks Classroom observations	OTL ML measures – Individual Beliefs about mathematics and mathematics teaching and learning – Individual Multiple choice modeling test – Individual Open-ended modeling tasks – Pairs Special-cased interviews on their experience of the program
Timeline	09/2017	09/2017-05/2019	05/2019

Table 2: Project timeline and data collection

Curriculum Development and Implementation

OTL ML and teach ML were planned to incorporate in four methods courses (two in Semester 1 of 2017-18 school year, one on Mathematics Teaching Methods and one on Assessment of Mathematics Learning, one in Semester 2 of 2017-18 on Mathematics Curriculum Development, and one in Semester 1 of their final school year on New Trends in Mathematics Teaching and Learning). In addition, PSTs were asked to reflect on ML when they are on school placements. The first placement was mainly focusing on observing real classrooms and planning mathematics lessons, but not implementing them. In this instance, the PSTs were asked to reflect on how the observed lessons offer OTL ML and nominate their one best lesson plan that incorporates ML. In the second placement when PSTs will plan and implement their lessons in real classes, they will be asked to report on how they incorporate ML into the classes as well as reflect on the challenges/success they have when teaching ML.

First, we expose PSTs to tasks that offer rich opportunities to engage in ML as active learners. ML tasks have been integrated into mathematics method courses, which range from standard applications and true (authentic) modeling problems (Tran & Dougherty, 2014). These tasks were adapted from research (e.g., PISA) to fit in the context of Vietnam such as peeling pineapple tasks (cite), relationships between gender and the use of sunscreen (xxx). Some were created based on the team' experience with the training program and understanding of the local context such as designing birthday cake boxes, designing University parking for both staff and students. We scaffold PSTs' experience with ML tasks by introducing them with increasing levels of authenticity tasks (Palm, 2009; Tran et al., 2016) that requires different time to solve such as several contextual tasks in one session (Semester 1 of 2017-18 school year), one in a session (Semester 1 of 2017-18), and project-based tasks that last for several weeks (Semester 2 of 2017-18 school year). These tasks necessitate the use of realistic considerations, not merely mathematical tools. In addition, we aimed to help PSTs to experience the revising model validating process as they went through the modeling cycle when solving the problems.

Second, we aimed to prepare PSTs with PCK to teach ML. In their third year of the program, PSTs were introduced the modeling cycle (OECD, 2013) to inform phases students generally go through when solving modeling problems and look back their process of solving ML tasks. In Semester 2 of 2017-18, PSTs were exposed to knowledge about ML and how to incorporate ML into the current curriculum. PSTs analyze current curricula to investigate how ML was mentioned in the documents and contrast with the reform curriculum. They also explore curricula from other countries that emphasize ML. PSTs were asked to plan a lesson that integrates ML into the content specified in the curriculum. In Semester 1 of their fourth year, PSTs will ask to analyze tasks based on the modeling cycle and the level of authenticity and then adopt/adapted them to incorporate into real lessons. These tasks could be used when they are on the second placement in the program.

Project-based Task

In Semester 2 of 2017-18, PSTs were asked to design a parking for the university. The task wording was "Currently, our university campus parking is messy including five different regions. Could you design a parking for the university to solve the current issue so that it looks neat" This task was similar to tasks in the literature, yet the uniqueness is vehicles in the university include cars, bikes, electric bikes, and motorbikes. PSTs were asked to work on this project for four weeks in groups (of 4-5 each) and report to the class in week 4. Weekly reports were conducted so that PSTs get feedback/questions from peers (not in their groups) and the lecturers and improve the report. In the last week, they submitted their report in a written form and present their report in front of the class. The data for this paper include their written report and their presentations.

Data Analysis

To investigate the initial success of the implementation of the project, we will focus on preliminary results on different ways PSTs approach an authentic modeling task of designing a parking lot for the university. A total of 15 written reports were collected when PST. Especially, we looked for (a) evidence PSTs took realistic concerns (data, information, technical considerations) into account when designing the university parking and (b) how they experienced different phases of modeling cycle when working on the task (cite). Especially we identified how the PSTs transferred from the real issue to mathematical problems and what variables they took into account to formulate the mathematical models. We then examined how they solved the mathematical problems and interpreted it back to the real-life issues.

PRELIMINARY RESULTS

A preliminary analysis shows that PSTs formulated two mathematical problems or a combination of them: (a) design parking lots based on the information about the number of vehicles, and (b) find the cost to build the parking lots. The analysis reveals that PSTs used a combination of arithmetic and proportions as the main tools to solve their project. Some used sampling and data collection technique to estimate the number of vehicles and used direct measurement and area formulas. Some build regression models to predict the cost.

For the scope of this paper, we will report on two samples of PSTs. The samples were chosen to (a) highlight PSTs' considerations of real life issues and collecting empirical data (measurement of the parking lot, surveying numbers of each of the vehicles) and (b) represent different mathematical tools used to solve relevant mathematical problems formulated from the real-world problems (e.g., arithmetic, advanced mathematical tools such as linear programming).

Surveying The Number of Vehicles and Designing Parking Lots to Meet the Demand of the Vehicles

Group 1 specified the real-life problem to address the issues of how to solve the messiness of parking in Hue University of Education, when more people use vehicles to come to university as a result of the increase of life standard. They tried to evaluate the quality of Hue University of Education' current parking and provide a plan for building the new facility with given funding. When attacking this problem, they found information about the number of vehicles present daily in the university as well as the areas available for parking in the university, which were the two sub-mathematical/statistical problems formulated from the real issue.

First, they searched for information about the number of staff members and students from the university website (http://www.dhsphue.edu.vn). However, the data might not reflect exactly the number of vehicles, which was the main variable to consider when solving the problem (they validate their model). The group then surveyed directly the number of vehicles of each type, on four random days during weekdays. When collecting the data from four days, on average, they found the percentages of vehicles in each of the parking lots: H (50%), DEG (40%) and GV (10%). In addition, they estimated the number of vehicles for each type as: motorbikes (60%), electric-bikes (15-17%), bikes (20-22%) and cars (2-3%). They also estimated that there are about 1500 vehicles in students' parking lot and 180 in the staffs' parking lot. Therefore, they decided to design two parking lots, one for students and one for staff. The students' parking can contain 900 motorbikes, 250 electric-bicycles, and 350 bicycles. The staff's parking lot consists of 135 motorbikes and 45 cars each day. During this process, the students used sampling and surveying as mathematical/statistical tools to collect data. In addition, they utilized knowledge about proportion and percentages to decide the capacity for parking for each type of vehicles and for staff and students.

For the second sub-problem, the PSTs measured the sizes of current parking lots applying their geometric knowledge about the area. They drew a plan with specified dimensions for the parking lots.

The PSTs then searched for dimensions of each type of vehicles to decide the appropriate space for each using a rectangular model and compared the area of the models to that of the parking lots proportionally. They found out that one-story parking lots would not be enough to meet the demands of the number of vehicles, therefore, need to look for an alternative design. The PSTs investigated parking lots in other universities and those of a supermarket within the city to look for parking designs and operations. As they found no students came to the university by cars, the students decided to create one parking lot for the staffs and two for students. After collecting all relevant data, they designed a two-story parking with one story for 45 cars and the other for motorbikes. In particular, with their survey of car dimensions and spaces between two cars (length: 5,5 m, width: 2,3-4 m and the gap between two cars: 4-6 m), they figured out the area of the parking should be about 36*30 (m^2).

For the students' parking lots, this group revamped the model of current parking lots by including specified dimensions for each row taking into account the dimension of bikes, motorbikes, or electric bikes with the length of 2m and width of 0,8m. The distance between two consecutive rows is 1.8m. Therefore, they used 2 meters square for one vehicle in these parking lots. They worked out the number of vehicles for each of the parking lots in the university and check if they meet the demands of student vehicles from their survey (Figure 1).

After solving finishing these sub-problems, they found out the cost to build such parking lots. They then submitted their project and presented their plan in front of the class.

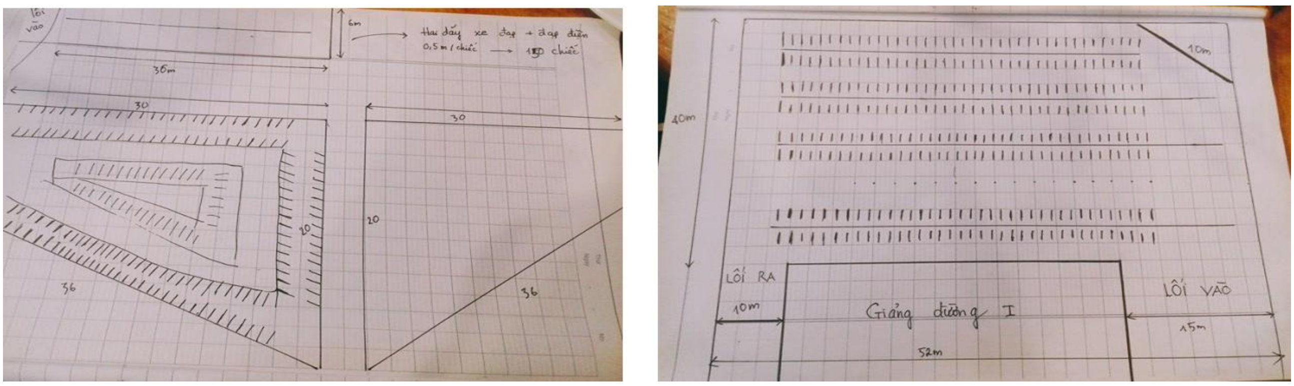

Figure 1: Layout of vehicles into roles in two parking lots

Focusing on predicting the cost of building parking lots on the number of vehicles

The group surveyed the number of vehicles on three random days to find out 1600 vehicles (all three types) for both staffs and students each day. This group also measured the sizes of parking lots and calculated their areas. They also decided that one of the parking lots needed to be two-story parking. They decided to build three parking lots including one of two-story and the other two one-story that attach to the three entrances into the University, G32, G34, G36. In addition, they formulated a mathematical problem of developing a mathematical model to predict the cost of the parking when knowing the number of vehicles.

Based on the information about the cost of materials and relevant devices to operate the parking (e.g., camera) and the cost to demolish current parking lots in the University, they recorded the data on a table. The data were based on following variables: the money to demolish the current parking lot, how much of the old infrastructure could be reused in the new one, the area of the parking lots, the number of stories, and the number of vehicles in each of the parking lots. They then graphed the data in a coordinate plane including one axis for the number of vehicles and the other the cost (in Vietnamese dong). They created a function as an approximation for the collected data to come up with a model using power functions. The coefficients were an estimation based on the data without checking if the models were good for prediction, or a regression model to minimize the total sum of square deviations (Figure xxx). The two models follow:Two-story parking lot at G34 for staff:

C = $\boldsymbol{C_{32}}$ + $\boldsymbol{C_{34}}$ + $\boldsymbol{C_{36}}$ = $0,\mathbf{918}.\boldsymbol{x_{32}}^{\mathbf{0,95}}$ + 2,05. $\boldsymbol{x_{34}}^{\mathbf{0,95}}$ + 1,22. $\boldsymbol{x_{36}}^{\mathbf{0,83}}$ (x.. is the number of vehicles in the parking .., and C.. the cost to build parking lot ..)

Two-story parking lot at G32 for students and keep the staff G34 parking lot as is:

Model 2: C = $\boldsymbol{C_{32}}$+$\boldsymbol{C_{36}}$ = 1,28. $\boldsymbol{x_{32}}^{\mathbf{0,98}}$ + 1,22. $\boldsymbol{x_{36}}^{\mathbf{0,83}}$

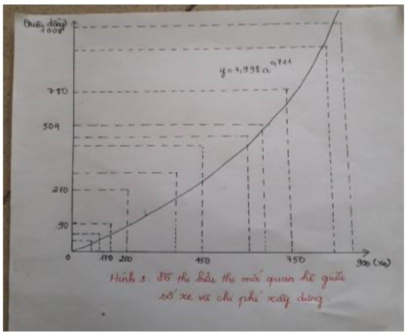

Figure 2: Power functions to predict the cost to build one parking

DISCUSSION

This is an on-going project and we are still in the process of implementing the innovative curriculum focusing on the developing PCK for PSTs to teach ML. We have not collected the post data to investigate the effectiveness of the program. However, at this stage, the data show that the PSTs start to experience problem-solving in a different way not merely using real world contexts as a cover that is easily stripped out to reveal the mathematics. In addition, the PSTs experienced the uncertainty when using mathematics to solve problems they meet in their lives. However, opportunities to discuss the difference between the estimation were not taken, which could be powerful for validation. In predicting the cost to build parking lots, the PSTs need to balance between how much they simplify the model so that they could formulate a problem that is solvable versus how to developed a model that is sophisticated enough to capture the real world yet challenging to solve with their current mathematical knowledge. The PSTs were not familiar with regression models in prediction and unsure how to evaluate how good their model is. A possible suggestion might be the collaborations between mathematics educators and mathematicians who are responsible for training their mathematics education. A question emerge is what the program likes if the mathematicians take an ML perspective when running their courses, how PSTs mathematical knowledge could be strengthened?

Within the scope of this project, we could investigate how PSTs‘ knowledge change during the implementation of the innovation. However, it is challenging to discuss the impact of the implementation on their practices. It is because the PSTs have not had opportunities to teach in real classroom yet. Future studies could build on this project and follow the PSTs in their second placement (teaching) and their first years of teaching to see how the training changes their practices.

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