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USING THE HISTORY OF MATHEMATICS AS A MOTIVATIONAL FACTOR IN TEACHING MATH

Abstract: Several studies have explored the importance and benefits of teaching the history of mathematics as part of regular math classes. Some of these studies addressed the question of using the history of mathematics as a motivational factor. For instance, some found that teaching or using the history of mathematics boosted students' interest in the topics, lowered mathematical anxiety, and increased motivation, as well as supporting student learning and increasing the understanding of mathematical concepts. In the present paper, we analyze the positive effects that integrating elements of the history of mathematics into regular math classes could have on student motivation. We argue that students could greatly benefit from the inclusion of topics from the history of mathematics in regular classes.

Keywords: *history of mathematics, motivation, mathematics, teaching.*

INTRODUCTION

The question of whether the history of mathematics should be taught during regular mathematics lessons is not new (Liu, 2003; Clark, 2012; Fried, 2001; Jankvist, 2009; cf. Arcavi et al., 1982; Fauvel, 1991). For instance, John Fauvel found that using history in mathematics classes helped to increase motivation for learning, give mathematics a human face, present the topics in the curriculum in a logical order, change students' perceptions of mathematics, and explain the role of mathematics in society (Fauvel, 1991). He also suggested ways to use history in the mathematics classroom, such as providing anecdotes and historical background when introducing new concepts, helping students to understand the major problems in the history of mathematics, and exploring historical errors. However, he indicates that that using the history of mathematics in class is not easy for teachers who are not used to addressing the subject.

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Mosvold and colleagues (2014) consider the history of mathematics an essential part of themathematical knowledge necessary for teaching, arguing that understanding the development of mathematics ideas helps both pre-service and in-service math teachers avoid misconceptions and get rid of possible errors related to various mathematical concepts and ideas. Clark (2012) conducted an experiment involving prospective mathematics teachers, enriching their mathematics classes with historical content. The prospective teachers who participated in the study indicated that learning procedures and algorithms by heart prevented them from gaining a full understanding of some elements of mathematics. Overall, the literature on teaching the history of mathematics indicates that it can benefit learners on both the cognitive and conative levels (Lim& Chapman, 2015; Fauvel & Maanen, 1997; Ponza, 1998; Bütüner & Baki, 2020; Şahin & Danaci, 2020; Lit et al., 2001; Ng, 2006). Learners understand math topics more deeply and are more motivated to study mathematics.

In the present study, we describe why and how primary and secondary school mathematics teachers could use the history of mathematics as a motivational factor. We argue that mathematics education programs at the faculties for teacher education should include a course on the history of mathematics to ensure that pre-service teachers obtain the necessary knowledge of and competencies in the subject.

HISTORY OF MATHEMATICS AT SCHOOL

Which history?

Addressing the questionof whether to teach the history of mathematics and why it should have a place in school mathematics is not easy as it seems (Liu, 2003). Heiede (1992) argued that there can only be personal answers to the question of whether to teach the history of mathematicsand that history enters into mathematics just as it does into every other field because humans have by nature a sense of history. According to Gazit (2013), "mathematics reached fantastic intellectual achievements by way of human processes that included mistakes, obstacles, personal conflicts, rises and falls" (Gazit, 2013: 501), thus making the study of its development an important factor in teaching it. Jankvist (2009) considered that the arguments found in the literature for teaching the history of mathematics as part of mathematics education were often blurry because the relevant research had been conducted by experts in multiple fields – for instance, mathematics, history, and education – who used their education and background to pursue specific aims. Although these scholars have offered multiple perspectives on the topic, Jankvistfelt that their research did not necessarily address the main issues in the field. In particular, the literature is scarce in works that empirically analyze the possible benefits of teaching the history of mathematics at school.

Fried (2001) also commented that little effort has been made to bring the history of mathematics into schools, although the subject is not completely absent from the classroom.

Jankvist (2009) reviewed the literature on how and why to include the history of mathematics in regular classes.

Jankvist identified two main themes:

(1) History as a tool. Some of the studies (e.g., Farmaki & Paschos, 2007; Taimina, 2004; Tattersall & McMurran, 2004) treated history as a tool, investigating how it helped students to learn mathematics. History can be a motivating factor, helping to increase students' interest in and excitement about mathematics. It can give mathematics a more human and thus less frightening face. The history of mathematics can also be used as a cognitive tool to support the learning of mathematics. It can be used to teach mathematics from a different perspective, employing different teaching methods.

(2) History as a goal. Other studies (e.g., Tzanakis & Thomaidis, 2000; Barabash & Guberman-Glebov, 2004) worked from the assumption that learning the history of mathematics was important in its own right. They focused "on the developmental and evolutionary aspects of mathematics as a discipline" (Jankvinst, 2009: 239), that is, showing students that mathematics evolves in time and space and didn't come out of the blue; instead, humans played an important role in its evolution. Different cultures shaped mathematics differently and different problems have been studied.

WHY TEACH THE HISTORY OF MATHEMATICS?

Furinghetti (2020) argued that the history of mathematics should be taught to improve student learning and teachers' ability to teach mathematics. Fauvel (1991) offered more detail, listing fifteen reasons to teach the history of mathematics during regular classes. Liu (2003), building on Fauvel's research, focused on five elements that made the teaching of the history of mathematics necessary at the school level:

(1) Incorporating the history of mathematics into instruction can help to increase students' motivation and foster a positive attitude toward learning mathematics.

(2) Making students aware of problems and obstacles that occurred during the development of the discipline can help them understand why some topics are more difficult than others.

(3) Analyzing historical problems can help students to improve their mathematical reasoning and thinking.

(4) History connects mathematics to human concerns.

(5) History helps teachers to structure their lesson plans.

Fried (2001) categorizes Fauvel's (1991) fifteen reasons for teaching the history of mathematics under three broad themes:

(1) Teaching the history of mathematics humanizes mathematics. It encourages the inclusion of multicultural approaches, gives students role models, and integrates emotions and motivation into learning.

(2) Including history makes mathematics more interesting, understandable, and approachable. It decreases student fears of mathematics, adds variety to teaching, and gives students a sense of the place of mathematics in society.

(3) Teaching the history of mathematics provides insights into concepts, problems, and problem-solving techniques. History provides a context for the study of mathematical concepts and ideas. It offers students alternative approaches to problem-solving and demonstrates the relationship between definitions and ideas.

Teaching topics from the history of mathematics also has a positive effect on attitudes (Fauvel & Maanen, 1997; Ponza, 1998), increasing students' willingness to study and master math. Thus, the teaching of the history of mathematics is an important motivational factor in math learning. Students also find the history of mathematics fun and interesting (Bütüner & Baki, 2020).

Liu (2003) was convinced that students would benefit greatly from the inclusion of the history of mathematics in regular classes but noted that there had been no empirical study up to that time of the impact of the practice on student performance. Since then, Şahin and Danaci (2020) found that incorporating the history of mathematics into the curriculum improved students' computational skills. Additionally, preliminary results are available from the work of Lit and colleagues (2001) on the efficacy of including the history of mathematics in regular classes. An experimental group was given more hours of instruction in the history of mathematics than a control group. In the experimental group, some students became more motivated to learn mathematics, whereas others considered mathematics more boring than before the intervention. The authors noted that students with higher language anxiety had worse results in math and more negative opinions about the instruction in the history of mathematics, which was more colloquial and less formal than regular math teaching. Students were also expected to read additional material outside of class. Although test scores in the experimental group were lower than those in the control group, some students in the experimental group enjoyed the new content, and this increased their appreciation of mathematics. In reflecting on the lower test scores in the experimental group, the authors hypothesized that the students needed to consolidate their skills in mathematics and that because they were

more motivated to learn, their test results would improve gradually. The authors added that the effectiveness of incorporating the history of mathematics into lessons largely depends on the way the subject is introduced. Several teaching methods can be used, and additional research is needed to understand their strengths and limitations.

Ng (2006) found that eighth-grade students from Singapore who participated in an Ancient Chinese Mathematics Enrichment Program achieved significantly higher scores on math tests than students in a control group. Also in Singapore, Weng Kin (2008) gave participants assigned to intervention group lessons in the history of algebra. Students in the experimental group valued mathematics more than those in a control group and outperformed the controls in their perseverance when dealing with challenging math problems.

THE HISTORY OF MATHEMATICS AS A MOTIVATIONAL FACTOR

Teaching the history of mathematics during regular math lessons increases students' motivation to learn mathematics (Fauvel, 1991). Sen (2017) affirmed that the "history of mathematics plays an important role in learning mathematics because it creates interest, positive attitude and respect for the subject which are finally strengthen the cognitive and affective domains of the learners" (Sen, 2017: 18). Thus, Sen believes that the history of mathematics might play a key role in the conative aspects of learning mathematics. Lit and colleagues (2001) experimentally found that some students in their experimental group felt that the history of mathematics increased their interest in learning mathematics, although others had an opposite reaction. Those who viewed the inclusion of history positively felt that it changed the way that math was taught, making it more interesting and helping them to learn more.

More recently, Lim and Chapman (2015) studied 51 students assigned toan experimental group and 52 students in a control group to investigate the affective factors that are involved in integrating the history of mathematics into classrooms. The aim was to study the effects of the teaching of the history of mathematics on attitudes towards math, math anxiety, motivation to study math, and math achievement. Authors used internationally verified and reliable scales to measure these affective and cognitive factors.

Students in the experimental group reported significantly more positive attitudes towards mathematics than those in the control group, but the observed effects were short-lived. No statistically significant differences were observed in math anxiety, leading the authors to conclude that teaching the history of mathematics did not significantly affect the anxiety that students may feel in studying math. Students in the experimental group felt more motivated to learn

mathematics than those in the control group, but, like the improved attitudes toward mathematics, the post-test indicated that this effect was time-limited. Lastly, there was a statistically significant difference in mathematics achievement between the experimental and control groups that favored the experimental group. Further analysis showed that approximately 13% of the variance in achievement on the post-test could be ascribed to the intervention. Four months after the intervention, there were similar statistically significant differences between the groups in favor of the experimental group. At one year after the intervention, achievement was still significantly higher in the experimental group.

The results of Lim's and Chapman's (2015) work suggest that including the history of mathematics in regular math classes has some beneficial effects, mostly in the cognitive sphere. Overall, achievement in the experimental group was better even a year after the intervention, suggesting that teaching the history of mathematics could help students to perform better in mathematics. However, the intervention did not affect math anxiety. This result was surprisingbecauseit would seem that more discursive lessons might help students to control their anxiety. Furthermore, the study found that the positive effects of teaching the history of mathematics on student attitudes and motivation were mostly short-lived. Those results were consistent with the literature and understandable because the intervention lasted only about one month. To influence students' motivation and attitudes more permanently, we suggest integrating the history of mathematics into lessons during the entire school year and throughout students' academic careers so that they might be constantly exposed to the positive effects of such teaching.Time is needed to motivate students properly and consolidate their mathematics skills (Lit et al., 2001).

Lim and Chapman (2015) solicited follow-up qualitative feedback from the students in their study. The positive feedback that they received could be categorized under three main themes:

(1) Students enjoyed the lessons in the history of mathematics and found them interesting. They reported that the lessons were fun and that the stories about mathematicians enlivened the regular lessons. Moreover, the history lessons made them appreciate math more and kept them awake during math class.

(2) Students recognized some applications of mathematics. They reported that they could see how mathematics has been used to solve real-life problems in the past, thus giving them a greater appreciation for math.

(3) Students had a better understanding of how formulae and concepts developed. Before the intervention, they thought that mathematics was just about the application of formulae. Learning about the history of mathematics helped them to understand where the formulae came from.

Some students, however, expressed negative opinions about the inclusion of the history of mathematics in regular classes. These opinions fell into three categories:

(1) The lessons were a waste of time. Students found the interjections on the history of mathematics time-consuming and would have preferred to concentrate on exam-related materials (their standardized exams did not include the history of mathematics).

(2) They could not understand the historical components of the lessons. Students felt that the lessons that included the history of mathematics were difficult to understand and taught at too high a level.

(3) They found the lessons that included the history of mathematics boring.

Overall, the feedback suggested that the intervention had positive effects on student motivation, expressed through student interest in and understanding of the topics that were studied. From a negative standpoint, some students were worried that the topics covered during the intervention were not related to their exam curriculum; this impression might have increased their mathematical anxiety. Thus, a great limitation of introducing the history of mathematics into math teaching is that it appears to relate poorly to state curricula; its inclusion appears to be a waste of time. The problem, as we see it, goes to the essence of teaching mathematics: do students learn mathematics only to pass high-stakes examinations? Should teachers teach only the mathematical principles that are assessed by standardized tests? We suggest that policymakers and educators decrease the pressure on both students and teachers in teaching mathematics and give instructors more teaching freedom. Furthermore, we suggest that legislators include the history of mathematics as an organic part of the learning and teaching of mathematics so that it is not an exception but rather a part of the cultural heritage of mankind that is regularly taught in schools.

EXAMPLES

Mathematics teachers might decide to use real historical texts or tasks throughout the different steps in the teaching and learning process, for instance to introduce a new mathematical concept, to explore deeply ad argument or to motivate students to study a particular type of problem (Massa Esteve, 2014). Some examples might include:

(1) Caclulating on the lines with the roman numerals (Faustmann, 2010): this activity might be carried out with 10-year-old students in order to explore the four basic arithmetical operations with natural numbers, such as CCCVII + DCLXXVIII. Such operations are carried out on the lines, which helps students to reason about how does addition work. Students can then prepare some poster exibitions and short talks.

(2) For instance, taking a closer look at the abovepresented calculation, students might try to sum firstly the "I" numerals, obtaining II + III = V, thus having three "V" (2 in the original number and one from the latter sum) etc. The activity could take just some minutes, but work on original documents can further enrich the classroom activity.

This activity might be integrated with the study of ancient numeral systems (Ernest, 1998): students learn the decimal number system by taking a closer look to the Egyptian or Mayan system.

(1) The life and work of Leonhard Euler (Faustmann, 2010): older students (e.g., 16-year-olds) might work together in small groups to write a short biography of the mathematician Leonhard Euler. Primary resources are welcome as well: students can work in small groups to translate some Euler's works and problems, such as the original "Seven bridges of Königsberg" problem (see also Ernest, 1998) and the "Euler's line" that passes through the ortocenter, the circumcenter and the centroid of any non-equilateral triangle. To this end, we suggest using a software for dynamic geometry, such as GeoGebra, in order to construct the Euler's line. Through observation, Faustmann (2010) foundthat this kind of activity helped students to abtain a historically sensitive picture of Euler's work and increased their understanding and appreciation of functions, variables and constants. Moreover, this kind of work motivated the students to do further projects.

(2) Euclidean geometry (Faustmann, 2010): using some translations of the Euclid's "Elements" (or translating them from ancient Greek, if students learn it at school), students prove some elementary theorems and do the drawings with some geometry software. The author found that despite Euclid's work not being entirely new to the students, they seemed to appreciate geometry and "falling in love" with it. Students' work might be extendend to a project work, both individual or group.To this end, we suggest a collaborative learning method, which might enhance students' knowledge and motivation towards the subject. A deeper analysis of Euclid's postulates might give the teacher and students the opportunity to explore non-euclidean geometries, both from a historic and mathematics perspective.

(3) The square root (Rogers & Pope, 2019; Fowler & Robson, 1998): students studying square roots and their properties might face firstly the inscriptions on the Tablet YBC 7289, a Babylonian tables which contains a good approximation of the number $\sqrt{2}$ in the sexagesimal number system. The authors proposed making a concept map, which might help students to study the history of square roots. We suggest teachers not only to focus on making a concept map, but rather to compare the Babylonian approximation of the square root (1.4142196…) with the value which is given by calculators (1.41421356…). Since the Babylonian approximation of the $\sqrt{2}$ is written in sexagesimal number system, we recommend teachers also to spend some words about it and about how Babylonians wrote fractions. In particular,

from the Tablet YBC 7289 it might be noticed that Babylonians used the base 60 also for fractions, writing the numer as 1 24 51 10, which means:

$$\sqrt{2} \approx 1 + \frac{24}{60} + \frac{51}{60^2} + \frac{10}{60^3}.$$

The Tablet provides also an example of calculation of the diagonal of a square with side equal 30 (and diagonal 42 25 35, i.e., 42.424…). Starting from this topic, students might develop even further the concept of square roots, for instance by proving the irrationality of$\sqrt{2}$ as Euclid did. In this case, two different concepts from the history of mathematics converge in a single lesson unit.

Massa Esteve (2014) states that teachers are required to present historical figures in context, both from an objectives' and a period's point of view. Thus the author suggests to situate mathematicians and mathematics problems chronologically. It is however important not to use only some amusing anecdotes or biographical details, but rather focus on some mathematical contents, methods and problems that originated in the past. It is furthermore of great importance to show students the mathematical reasoning behind the proofs and methods that are studied, which helps to contextualize the topc within the mathematical syllabus.

CONCLUSIONS

The implementation of the history of mathematics in classrooms is a hot topic in mathematics education. Despite the increasing inclusion of the history of mathematics in classes and its possible beneficial effects on motivation, Radford (1997) believes that the subject is still taught on a superficial level. Moreover, there is a need for further research in the area, despite the promising results presented in several studies (Lim & Chapman, 2015).

In the present work, we addressed the question of using the history of mathematics to motivate students. Based on our analysis, teaching the history of mathematics could have positive effects on students' motivation to learn mathematics and their attitudes towards the subject. However, these effects do not seem to be sustained on a long-term basis (Lim & Chapman, 2015), so it would be necessary to reinforce them by incorporating the history of mathematics more consistently into curricula.

Based on the literature summarized here, we suggest that universities and policymakers provide more training in the history of mathematics to preservice teachers to give them the knowledge and competencies to feel comfortable teaching math history. Furthermore, we argue that university courses in the history of mathematics should not focus merely on historical content but rather encompass the pedagogical and psychological spheres (Massa Esteve, 2014). Prospective teachers

should study not only the historical and cultural development of mathematical concepts and procedures but also the use of the history of mathematics to enrich lessons, modify student attitudes, and increase students' motivation to learn mathematics.

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КОРИШЋЕЊЕ ИСТОРИЈЕ МАТЕМАТИКЕ КАО МОТИВАЦИОНОГ ФАКТОРА У НАСТАВИ МАТЕМАТИКЕ

Резиме

Неколико студија истраживала су значај и користи наставе историје математике у оквиру редовних часова математике. Неке од ових студија бавиле су се питањем коришћења историје математике као мотивационог фактора. На пример, неки су открили да је предавање или коришћење историје математике појачало интересовање ученика за теме, смањило математичку анксиозност, повећало мотивацију, подржало учење ученика и повећало разумевање математичких појмова. У овом раду анализирамо позитивне ефекте које би интегрисање елемената историје математике у редовне часове математике могло имати на мотивацију ученика. Тврдимо да би ученици могли имати велике користи од укључивања тема из историје математике у редовну наставу.

Кључне речи: *историја математике, мотивација, математика, настава.*