The review of undergraduate courses aimed at developing subject matter knowledge by mathematics student teachers

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Abstract

The aim of this study is to determine the views and evaluations of secondary school mathematics student teachers regarding the undergraduate courses aimed at developing mathematical subject matter knowledge, and to reveal their suggestions as to improve those courses. From four different state universities, in total 36 secondary school mathematics student teachers in their last year of preparation participated in this study. The data were collected through four open-ended questions asked to student teachers. Student teachers’ responses were analyzed by means of content analysis. It is determined that student teachers largely hold a negative opinion with respect to undergraduate courses aimed at developing SMK. Especially, the student teachers rated their sufficiency in mathematics, geometry, and history of mathematics knowledge as low. We hope that the study will contribute to the revision of courses aimed at developing subject matter knowledge in Turkey.

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1. Introduction

‘Subject Matter Knowledge (SMK)’ is considered as a highly important knowledge base in mathematics student teachers’ training. It is defined as understanding mathematical concepts, processes and operations; distinguishing the relations between concepts; relating mathematical concepts with operations, and real world applications of mathematical concepts (Fenema ve Franke, 1992). Studies have shown that deficiency in SMK diminishes the quality and effectiveness of teaching (McDiarmid et al., 1989; Mossenthal and Ball, 1992; Even et al., 1993; Llyod and Wilson, 1998; Hashweh, 1987; Thompson, 1992). Some of the consequences of shortage in SMK are identified as follows: discomfort in asking conceptual questions, strong fidelity to the textbook, being unable to evaluate alternative ideas and students’ solution approaches, authoritative teaching, and being unable to relate the topic being taught to the succeeding topics, to other mathematical topics, and to the students’ prior knowledge. Thus, it is
essential to place emphasis on developing SMK during the training of mathematics student teachers. The quality of undergraduate courses meant to develop SMK in student teachers is an important indicator as to how effectively they will teach in the future. In this sense, we aimed to determine the views and evaluations of secondary school mathematics student teachers regarding the undergraduate courses expected to develop SMK, and to reveal their suggestions as to improve those courses.

2. Method

This study is a qualitative research in which case study design is used to determine the views and evaluations of secondary school mathematics student teachers regarding the courses they have taken which meant to develop SMK, and to reveal their suggestions as to improve those courses.

2.1. Participants

36 secondary school mathematics student teachers in their last year of teacher education program participated in this study in 2006-2007 spring term. In Turkey, since 1998 secondary school teacher education is an integrated program which lasts five years. The first 3.5 years mostly focuses on mathematics, and the last 1.5 years focuses on teacher education. In this context, all participants were in the above-mentioned program, and were about to complete their program one month later. The participants were from four different state universities from three different regions of Turkey (Aegean Region, Central Anatolia Region, and Marmara Region). In the data collection, we found out that there are eight universities throughout Turkey which had fifth grade secondary school mathematics student teachers at that time. Instruments were sent to those eight universities, and four of them agreed to administer the instruments based on voluntariness. Instead of drawing conclusion based on findings from one university, we took advantage of findings from four different universities; so that the comprehensiveness of the study was increased. In this way, the maximum variation sampling technique which is a purposeful sampling technique was used in this research. We received 8 to 15 instruments from each of four participant universities. However, we excluded some of them if a student teacher did not respond some questions or if responded mostly as ‘yes-no’. After this elimination, our final sample consists of 5 participants from A and B universities (out of 40 student teachers) and 13 participants from C and D universities (out of 65 student teachers). Each university was randomly assigned a letter (A, B C and D) when presenting the research findings.

2.2. Instruments

Student mathematics teachers were asked to write their responses to four open-ended questions regarding their experiences in the courses they had taken which were intended for developing SMK such as Calculus, Analytic Geometry, Linear Algebra, Abstract Mathematics, Topology, Differential Equations, etc. Those questions comprise the evaluations of student teachers about how those courses contributed to their SMK development, the student teachers’ views regarding the necessity and quality of such courses, and their suggestions for improving those courses. In short, we aimed at identifying how those courses improved student teachers’ SMK development.

2.3. Procedures

In order to carry out the research we communicated with a willing instructor from each of three participant universities (except the university we work), and explained the structure and the aim of the research. Then each instructor posed the open-ended questions to the participants at their universities. The aim of the study was explained to the student teachers as we wanted them to evaluate their training with respect to the undergraduate courses they have taken. In one of the participant universities in the Central Anatolian Region and in the university where the authors work, candidate mathematics teachers were asked to write their responses on the papers that were provided them by the instructor. In the other cases, teacher candidates from other participant universities sent their responses directly to the authors via e-mail. Responses received via e-mail were printed without any change. This study constitutes the third part of a comprehensive study which consists four parts. In each part of the overall study, it is aimed respectively to examine the views of student teachers regarding 1-SMK, 2-Pedagogical Knowledge, 3-
Pedagogical Content Knowledge, and 4- Professional Practicum Experience. The findings and conclusions regarding the fourth part of the study is presented in another article which is accepted to be published in December-2009 issue of the Journal of Inonu University Education Faculty (Özgür, Bukova-Güzel, Kula, & Uğurel, 2009). This study focuses only on the first part of that broader study, in which it is aimed at identifying student teachers’ evaluations toward their training in terms of the courses and applications with respect to SMK development. Therefore, in this study only pertinent findings are presented and discussed.

2.4. Data Analysis

Student teachers’ responses to the open-ended questions were analyzed by means of content analysis. Then, common or very similar categories in each author’s analysis report were identified by constantly comparing student teachers’ responses with each other in the frame of the themes emerged. Then subcategories were defined with their context, and then codes in each category were determined. The following categories were used in the study:

Category-I: Views regarding the Contributions of SMK Courses
Category-II: Self-Assessment in terms of SMK
Category–III: Suggestions regarding Undergraduate Courses Aimed at SMK Development

Findings regarding each category are presented below in the tables constructed based on the frequency of student teachers’ responses at each participant university. The column named Total in the tables refers to the percentage of student teachers who mentioned that particular code in their response regardless their university.

3. Results (Findings)

The participants’ agreement on each code is presented in percentages derived from the frequency of their statements. Excluding the codes stated under 5%, other codes are presented in the tables below. Additionally, some excerpts from participants’ responses which underpin the context of the related codes follow the tables.

3.1. Views Regarding the Contributions of SMK Courses

Based on the participant student teachers’ responses, subcategories of Category-I “Views regarding Contributions of Subject Matter Courses” is determined as “Positive Views” and “Negative Views”. Findings of each subcategory are given in the Table-1. When the subcategories and related codes are examined in Table-1, it is seen that 83% of student teachers hold a view that the content of the undergraduate courses aimed at developing SMK is not connected to secondary school mathematics curriculum. 25% of student teachers expressed that only first year undergraduate courses like Calculus, Abstract Mathematics and Analytic Geometry are related to and coherent with secondary school mathematics curriculum. Some of the student teachers (17%) supported that undergraduate courses contributed them in improving their mathematical thinking, and 19% of them considered those courses as a foundation for secondary school mathematics, while some of them (22%) stated that such courses did not contribute them adequately since they mostly covered advanced level mathematics. Apart from these, almost half of the student teachers explained that they could not fully take advantage of those courses since they were very theoretical and based on rote-learning.

| Table 1. Category–I: Views regarding Contributions of Subject Matter Courses |
|---------------------------------|-----------------|---|---|---|---|
| Views regarding Contributions of Subject Matter Courses | A | B | C | D | Total |
| I- Positive Views | | | | | |
| I-a First year undergraduate courses (Calculus, Analytic Geometry, Abstract Mathematics, etc.) correspond with secondary school mathematics curriculum. | %20 | %40 | %15 | %31 | %25 |
| I-b Those courses provide a foundation for secondary school mathematics. | %20 | %20 | %31 | %8 | 19 |
| I-c Those courses improve mathematical thinking. | %20 | - | %15 | %23 | 17 |
| II-Negative Views | | | | | |
| II-a Those courses are not well connected to secondary school mathematics curriculum. | %100 | %100 | %77 | %77 | 83 |
| II-b Those courses are instructed very theoretically; based on rote -learning. | %60 | %100 | %31 | %38 | 47 |
| II-c Those courses involve advanced level mathematics. | %20 | %60 | %8 | %23 | 22 |
Some excerpts from the student teachers’ statements regarding the contributions of SMK courses are given below:

“Undergraduate SMK courses serve as a basis for secondary school mathematics. I think the education I received is sufficient to a great extent.” (25th student teacher- University C)

“At the university, we learn the foundations of secondary school mathematics. It would be better, I think, to address secondary school mathematics curriculum in detail besides the courses such as Calculus, Abstract Mathematics.” (21st student teacher- University C)

“Here I quote a statement of one of my friends as exactly it is; “I have never studied limit at secondary school, thus I cannot prepare a question about limit because I don’t know the topic.” This conversation was made this fall semester. That is to say courses are too theoretic; there is nothing about applications; knowledge is memorized.” (4th student teacher- University D)

“Since the courses are based on memorizing theorems and passing exams, it is really hard for us to apply even useful knowledge. At least on my own behalf, I was better at secondary school mathematics topics when I graduated from secondary school.” (28th student teacher- University A)

“Rote-learning based instruction causes topics not to be stored in the memory for a long time.” (20th student teacher- University C)

3.2 Self-Evaluation in terms of SMK

As it is shown in Table-2, the student teachers evaluated their SMK in terms of mathematics, geometry, and history of mathematics knowledge. The student teachers described their knowledge as sufficient mostly in mathematics knowledge (28%) and least in geometry knowledge (22%). We found out that the student teachers at University B consider themselves more sufficient in mathematics knowledge, and that the student teachers at University D consider themselves more sufficient in history of mathematics when compared to other student teachers at different universities. Interestingly, none of the student teachers at University A consider themselves sufficient in history of mathematics.

| Category–II: Self-Assessment in terms of SMK | Percentages of Statements by Universities
<table>
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<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>I– Considering Sufficient</td>
<td></td>
</tr>
<tr>
<td>I-a Mathematics</td>
<td>%20</td>
</tr>
<tr>
<td>I-b Geometry</td>
<td>%20</td>
</tr>
<tr>
<td>I-c History of Mathematics</td>
<td>-</td>
</tr>
<tr>
<td>II– Considering Insufficient</td>
<td></td>
</tr>
<tr>
<td>II-a Mathematics</td>
<td>%60</td>
</tr>
<tr>
<td>II-b Geometry</td>
<td>%40</td>
</tr>
<tr>
<td>II-c History of Mathematics</td>
<td>%80</td>
</tr>
</tbody>
</table>

When the subcategory of Category-II, which is named as “Considering Insufficient”, is examined, it is seen that more than half of the student teachers consider themselves insufficient in all of the above-mentioned areas. When compared to other universities, we found out that student teachers at University D (62%) most frequently described themselves insufficient in mathematics knowledge, while student teachers at University C described themselves insufficient in geometry and history of mathematics most frequently (62% and 85%, respectively). A great number of teachers (72%) expressed that the history of mathematics is where they consider themselves the most insufficient. Some of the student teachers’ views about the Category-II are given below.

“I just know the names of the mathematicians whose theorems I memorized.” (32nd student teacher- University A)

“I consider myself insufficient in topics known as Mat-2 such as derivative, integral because at the university those topics were taught; constantly taught, but at a much higher level than the secondary school level. Since we don’t learn the basic knowledge well, I don’t think that I know those topics well.” (19th student teacher- University C)

“I feel insufficient myself particularly at most geometry topics because there is no such a course at the university.” (2nd student teacher- University D)

3.3 Suggestions Regarding Undergraduate Courses Aimed at Developing SMK

The student teachers’ suggestions regarding the enhancement of undergraduate courses aimed at developing SMK are presented in Table-3.
Table 3. Category-III: Suggestions regarding Undergraduate Courses Aimed at SMK Development

<table>
<thead>
<tr>
<th>Suggestions regarding Undergraduate Courses Aimed at SMK Development</th>
<th>Percentages of Statements by Universities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>I-Instruction should not be based on rote-learning; instead theory and applications should be merged.</td>
<td>%40</td>
</tr>
<tr>
<td>II-New undergraduate courses devoted to secondary school geometry should be designed.</td>
<td>%60</td>
</tr>
<tr>
<td>III-New undergraduate courses devoted to secondary school mathematics should be designed.</td>
<td>%40</td>
</tr>
<tr>
<td>IV-The syllabi of courses should be rearranged to be pertinent to the secondary school mathematics curriculum.</td>
<td>%20</td>
</tr>
</tbody>
</table>

It is clear from the Table-3 that 56% of student teachers suggested giving more emphasis on the applications besides theoretical knowledge in order to evade rote-learning and ensure meaningful learning. In parallel with student teachers’ dissatisfactions with undergraduate subject matter courses since those courses are not relevant to secondary school mathematics curriculum, as stated in Category-I, student teachers suggested designing new undergraduate courses. To be more specific, 53% of the student teachers recommended designing new courses directed towards secondary school geometry, and 42% of them recommended designing new courses directed towards secondary school mathematics. Likewise, 22% of the student teachers suggested rearranging the syllabi of courses to form coherence between the undergraduate courses and the secondary school mathematics curriculum.

“It is necessary to develop more application based, and thought-provoking programs.” (28th student teacher- University A)

“It would be really great if new courses related to (secondary school level) mathematics and geometry would have been added.” (11th student teacher- University C)

“A new course whose content are geometric topics should be added (to the teacher education program).” (2nd student teacher- University D)

“An in-depth analysis of the topics to be taught at secondary school should be practiced; and those topics’ instruction should be extensively based on applications.” (33rd student teacher- University A)

4. Discussion

The overall picture revealed in all three categories used in the study shows that the student teachers largely hold a negative opinion with respect to undergraduate courses aimed at developing SMK. For each of the four universities, incidences of negative opinions appear to be very close to each other in general. However, some significant distinctions as well are found in some subcategories. For instance, in the subcategory II-b (Negative Views) of Category-I (Views regarding Contributions of Subject Matter Courses) significant differences exist between University A, B and University C, D. In addition to that, in the subcategory II-c (Considering Insufficient) of Category-II (Self-Assessment in terms of SMK), the percentage of student teachers at University D who consider their knowledge in the history of mathematics sufficient significantly differs from the other student teachers in the positive direction. In the subcategories II, III, and IV of the Category-III (Suggestions regarding Undergraduate Courses Aimed at SMK Development), the views of the student teachers at University C significantly diverge from the others. Differences in some subcategories besides general similarities in negative views can be explained by differences in courses in each university and/or by instructors’ knowledge, attitude and approach. To illustrate, at the time when this study was conducted there were two courses (3 credits/each) related to the history of mathematics at University D, there was one course (3 credits) at University C, while there was no such a course neither at University A nor at University B. What’s more, according to the student teachers’ responses, History of Mathematics course at University C was not instructed in accordance with the course goals, but rather the content of the course was changed, and other topics were taught. In this context, it makes sense that the student teachers at University C believe that their knowledge in history of mathematics is insufficient. Following statements exemplify the belief held by some student teachers that their insufficiency is due to instructors.

“There was a course named ‘History of Mathematics’, but only its name was ‘History of Mathematics’, that’s it. Other topics were taught.” (18th student teacher- University C)

“We had a course named ‘History of Mathematics’, however; the historical structure of mathematics was never taught in this so-called course.” (20th student teacher- University C)
It is understood that future teachers generally focus on both the theoretical courses and the practical use of those courses in the secondary school mathematics curriculum. As it is evident in their recommendations, future teachers insistently point out to the necessity of replacing theoretical instruction and rote-learning with more applications. In addition to that, they suggest the undergraduate SMK courses to be handled so as to help them -directly or indirectly- to teach mathematics at secondary school level.

5. Conclusion and Recommendation

The student teachers’ views, in the frame of the general structure of the content analysis of the data, indicate that undergraduate courses aimed at developing SMK contributed them much less than they expected. In parallel with this, the student teachers rated their sufficiency in mathematics, geometry, and history of mathematics knowledge as low. The student teachers’ primary association in their views regarding the structure, content, and application of SMK courses is the contribution and support to secondary school mathematics teaching dimension (e.g. Category-I, II-a). This tendency of future teachers is also an indicator as to how they perceive undergraduate courses. Put another way, student teachers opt to perceive undergraduate courses under the limitations of the content and context of mathematics they will be teaching during their career, instead of holding a broader perspective about mathematics as a science and study area, especially the nature and structure of theoretical mathematics, which has potential to help their development. Yet, as it is stated in the Glenn Commission (U. S. Department of Education, 2000), it is a prevailing opinion that strong SMK is a requirement for teachers for quality teaching (Kahan, Cooper, Bethea, 2003). In this sense, revision of the quality of the undergraduate courses aimed at developing SMK seems both useful and, more importantly, necessary. Consequently, our main recommendation is to further investigate how theoretical mathematics can be handled more functionally and from a different perspective by emphasizing the mathematical applications more and connecting it to the secondary school mathematics, on the other side; to investigate how it can be achieved to move to a better designed undergraduate program which will enable future teachers to better make sense of the nature and structure of theoretical mathematics, and the essence of the mathematical knowledge.

References