ELEMENTARY TEACHER EDUCATION AND TEACHER EFFICACY TOWARD MATHEMATICS AND SCIENCE

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Elementary teacher education in Taiwan has been facing the dilemma of cultivating prospective teachers to be generalists or specialists for certain subject areas since 1997. Referring to the significant factors affecting teacher education, “teacher efficacy” deserves to be in the heart of this dilemmatic evolution. This study aimed to compare prospective teachers’ efficacy toward mathematics and science of ten preparation programs. Findings indicated that the more subject-matter preparations the superior efficacy was established. It further provided a deliberation on how to prepare elementary teachers.

INTRODUCTION

A large and growing body of research data indicate that the preparation and ongoing professional development of teachers in mathematics and science for grades K-12 needs rethinking and improvement on a large scale (e.g., Holmes Group, 1995; Hwang, 2003; National Research Council [NRC], 2001; National Science Foundation, 1996; Rodriguez, 1998; Sanders & Rivers, 1996; Wright et al., 1997; Wu, 2004). While re-examining the effectiveness of the design of teacher preparation programs, it indicates that the traditional design of teacher preparation programs are oriented in cultivating elementary generalists (NRC, 2001). Furthermore, for instance, “too often, teacher preparation programs are characterized by a lack of coherence and articulation across the general education, science education, and professional education curriculum strands” (NRC, 1997, p. 9). Even though most programs currently require prospective elementary school teachers to have a major in a discipline other than education, few of them choose majors in mathematics or science. Within this trend of program designing, prospective teachers received inadequate preparation in certain subject areas, for instance, mathematics and science (education). It led to the insufficiency of in-depth content knowledge and conceptual understanding of and efficacy toward mathematics and science needed for teaching these subjects effectively at all grades.

With regard to Taiwan, the design of all teacher preparation programs encountered significant changes beginning in 1997. Perspective teachers who entered the teachers college were categorized into different departments (programs), such as Departments of Mathematics Education for students’ major in mathematics education. Usually, there were eleven departments in one teachers college1, including Departments of Mathematics Education (DME), Science Education (DSE), Elementary Education (DEE), Language Education (DLE), Art Education (DAE), Social Science Education (DSS), Music Education (DMU), Early Childhood Education (DEC), Special

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Wu & Chang

Education (DSP), Physical Education (DPE), and Department of Children’s English Education (DCE). The purpose of separating the whole teacher preparation system by subject matter was to train all prospective teachers to be not only generalists but also specialists in certain subject areas. Following this movement, the teacher preparation programs were modified by having more detailed separation of functions enabling all new teachers to master the subject matter they would teach in the classroom. In addition, there were several new departments established, e.g. DSP and DCE, as well as many graduate schools of education in various subject areas or for diverse purposes. All of these efforts in restructuring the teacher preparation programs were to ensure that there would be well-qualified teachers who had different specialties in every elementary school. This idea just confirmed the previous recommendation (Romberg, 1994) from participants at a 1993 conference sponsored by the U.S. Department of Education, the NCTM, and the Wisconsin Center for Education Research.

However, there are ongoing innovative projects of the teacher education system in Taiwan, e.g. named as “New Regulations of Teacher Education” (Ministry of Education [MOE], Taiwan, 1999), “The Incorporation of Public Universities and Colleges” (MOE, Taiwan, 2002), and “2004 Education in Republic of China” (MOE, Taiwan, 2004). In this movement, teachers colleges are promoted alone or incorporated with other public colleges to become universities of education or comprehensive universities. The teacher preparation program design within these universities is changed again in order to align to the worldwide trend of reconstructing the higher education system, such as reforms in Australia, Netherlands, England, Germany, Japan, the United States, and so forth (MOE, Taiwan, 2002). Programs are oriented to train generalists because of two major strategies of “merging” and “reorienting”. In “merging”, Department of Education (DE) and DEC are the main programs for training elementary prospective teachers. As mentioned above, this kind of program design will result in inadequate preparations for some major subject areas, e.g. mathematics and science, in the elementary level. In “reorienting”, DME is renamed as Department of Applied Mathematics, which emphasizes more in applied mathematics but rather mathematics education. Nevertheless, there will be more mathematicians prepared by this program but rather qualified elementary mathematics teachers, which is still the key issue in this maelstrom of the education debate.

Teacher efficacy and teacher quality

The concept of teacher’s sense of efficacy has gained much attention in recent years (Pajares, 1992). “Beginning with research in the 1970s (e.g., Armor et al., 1976; Berman et al., 1977), teacher efficacy was first conceptualized as teachers’ general capacity to influence student performance” (Allinder, 1995, p.247). Since then, the concept of teacher’s sense of efficacy has developed continuously and currently is discussed relevant to Albert Bandura’s (1977) theory of self-efficacy, which indicates the significance of teachers’ beliefs in their own capabilities in relation to the effects of student learning and achievement. The self-efficacy construct described by
Bandura was composed of two cognitive dimensions, personal self-efficacy and outcome expectancy. Bandura (1977) defined personal self-efficacy (i.e. efficacy expectation) as “the conviction that one can successfully execute the behavior required to produce the outcomes” and outcome expectancy as “a person’s estimate that a given behavior will lead to certain outcomes” (p. 193).

Several studies further reported, “Teacher efficacy has been identified as a variable accounting for individual differences in teaching effectiveness” (Gibson & Dembo, 1984, p. 569) and had a strong relationship with student learning and achievement (Allinder, 1995; Gibson & Dembo, 1984; Madison, 1997). Berman et al. (1977) reported that teacher efficacy had the strongest relationships with the student gain in learning, with a standardized regression coefficient of .21 for sense of efficacy with improvement in student achievement as the dependent variable (Denham & Michael, 1981). Later, Allinder (1995) concluded, “Teachers with high personal efficacy and high teaching efficacy increased end-of-year goals more often for their students … Teachers with high personal efficacy effected significantly greater growth” (p. 247).

**Teacher education and teacher efficacy**

Accordingly, which kind of design is better for preparing elementary prospective teachers, especially for certain subject areas, one program for the generalists or several separated programs for teachers with variety of majors? It will be definitely a dilemma within this teacher education reform in both Taiwan and countries worldwide. How to discover the appropriate practice for designing programs of training elementary teachers will be also the core in this educational action plan.

With regard to factors affecting the teacher preparation, a statement in Ashton’s (1984) study addressed the significance of “teacher’s sense of efficacy” to teacher education:

> A powerful paradigm for teacher education can be developed on the basis of the construct of teacher efficacy. Ashton asserts that no other teacher characteristic has demonstrated such a consistent relationship to student achievement. A teacher education program that has as its aim the development of teacher efficacy, and which includes the essential components of a motivation change program, should develop teachers who possess the motivation essential for effective classroom performance (p. 28).

Benz et al. (1992) further recommended, “Helping pre-service teachers to construct beliefs that most positively effect their decision-making in the classroom is an important effort in teacher education reform” (p. 284). Accordingly, a comparative examination of the teacher efficacy as the factor of the effectiveness of teacher preparation programs may help to clarify elements for improving teacher quality as well as remodelling teacher preparation programs.

**PURPOSE AND METHOD**

The main purpose of this study was to investigate the effectiveness of elementary teacher preparation program designs by examining perspective teachers’ efficacy toward mathematics and science among targeted students. Further, the relationship
in the sense of efficacy toward mathematics and science among all participants was also explored. Altogether, there were ten different programs within the participating college, a national teachers college located at the central part of Taiwan, and 340 participants totally. A quasi-experimental research design with pre- and post-tests was applied in this study. Two standardized instruments, i.e. Mathematics Teaching Efficacy Beliefs Instruments for pre-service teachers (MTEBI, Enochs, Smith, & Huinker, 2000) and Science Teaching Efficacy Beliefs Instruments for pre-service teachers (STEBI, Enochs & Riggs, 1990), and a Participant Main Survey were applied to ascertain the outcomes of pre-service teachers’ sense of efficacy toward mathematics and science and compare the differences among these ten different programs. These three instruments were first administered to these 340 freshmen (the first year of entering the programs) as a pre-test. Then, these instruments were administered again to the same students (as seniors at the forth year) as a post-test. Data were collected, entered, and reorganized right after receiving. Descriptive and inferential statistical analyses (i.e. ANCOVA) were applied in this study associated with a detailed documentation analysis of the curriculum structure and course works.

**FINDING AND DISCUSSION**

Both of pre-service teachers’ sense of efficacy toward mathematics and science found in this study were significantly different among these ten programs. According to the findings of the study, students in DME had a superior rating in the cognitive dimension of Personal Mathematics Teaching Efficacy (PMTE), while students in DSE scored higher in Personal Science Teaching Efficacy (PSTE). After receiving four-year training, both groups of students (i.e. DME and DSE) had more confidence in their own teaching abilities than other students who did not specialize in either mathematics or science (i.e. remained eight programs²), shown as table 1. However, considering the highest mean scores of PMTE and PSTE, DME and DSE students only had approximately 74 percent of confidence in their own teaching abilities. This information provides another warning for all teacher preparation programs: If these pre-service teachers believed they were not ready to assume the teaching responsibility, i.e. they have low confidence in their future teaching ability, teaching quality is potentially jeopardized. Therefore, how to increase the confidence level of these prospective teachers for future teaching is an additional issue and task for teacher preparation programs.

<table>
<thead>
<tr>
<th>Program</th>
<th>DME</th>
<th>DSE</th>
<th>DEE</th>
<th>DLE</th>
<th>DAE</th>
<th>DSS</th>
<th>DMU</th>
<th>DEC</th>
<th>DSP</th>
<th>DPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>PMTE</td>
<td>48.79</td>
<td>46.97</td>
<td>43.88</td>
<td>41.74</td>
<td>43.50</td>
<td>42.97</td>
<td>40.47</td>
<td>42.56</td>
<td>42.68</td>
<td>42.38</td>
</tr>
<tr>
<td>SD</td>
<td>3.179</td>
<td>5.363</td>
<td>5.830</td>
<td>7.085</td>
<td>5.733</td>
<td>3.520</td>
<td>5.915</td>
<td>4.737</td>
<td>5.050</td>
<td>4.278</td>
</tr>
<tr>
<td>PSTE</td>
<td>46.09</td>
<td>57.32</td>
<td>46.68</td>
<td>44.21</td>
<td>46.62</td>
<td>41.68</td>
<td>43.24</td>
<td>43.38</td>
<td>45.24</td>
<td>45.41</td>
</tr>
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</table>

Table 1: Mean Scores (and SD) of PMTE and PSTE in the Post-test
Another finding showed that students in DME had a significantly superior rating in the cognitive dimension of Mathematics Teaching Outcome Expectancy (MTOE), while students in DSE scored higher in Science Teaching Outcome Expectancy (STOE) but no significance, shown as table 2. Data indicated that all students (prospective teachers) had a range from 60 to 80 percent belief that students’ learning can be influenced by effective teaching. However, as indicated above, they did not have adequate confidence in providing efficient teaching in the classroom. Thus, even though they believed effective teaching was essential for students’ learning and achievement, the quality of teaching and learning could still not be guaranteed. As Gibson and Dembo (1984) stated, teachers with high efficacy should “persist longer, provide a greater academic focus in the classroom, and exhibit different types of feedback than teachers’ who have lower expectations concerning their ability to influence student learning” (p.570). Teacher preparation programs need to discover ways to improve the ratings of both personal teaching efficacy and teaching outcome expectancy of their pre-service teachers in order to improve the quality of teaching and learning in all elementary classrooms.

<table>
<thead>
<tr>
<th>Program</th>
<th>DME</th>
<th>DSE</th>
<th>DEE</th>
<th>DLE</th>
<th>DAE</th>
<th>DSS</th>
<th>DMU</th>
<th>DEC</th>
<th>DSP</th>
<th>DPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTOE</td>
<td>32.09</td>
<td>27.76</td>
<td>28.09</td>
<td>26.24</td>
<td>27.79</td>
<td>27.29</td>
<td>28.00</td>
<td>28.12</td>
<td>27.44</td>
<td>27.74</td>
</tr>
<tr>
<td>STOE</td>
<td>39.41</td>
<td>39.65</td>
<td>40.32</td>
<td>38.03</td>
<td>37.59</td>
<td>38.44</td>
<td>38.74</td>
<td>38.06</td>
<td>38.56</td>
<td>37.09</td>
</tr>
</tbody>
</table>

Table 2: Mean Scores (and SD) of MTOE and STOE in the Post-test

Correlations coefficients were computed among the three scores of each category, i.e. Mathematics Total Score, Science Total Score, PMTE, MTOE, PSTE, and STOE in the post-test. Significant correlation was found between teachers’ sense of efficacy toward mathematics and science (i.e. total score). Data also indicated that there were statistically significant relationship between PMTE and PSTE, MTOE and STOE, PMTE and MTOE, and PSTE and STOE. This valuable information provides teacher preparation programs with sufficient reason to devote attention to establishing their prospective teachers’ confidence by increasing the connections between the preparations of mathematics and science. Additionally, they may also endeavor to make more efforts on assisting these pre-service teachers to build up both their personal teaching efficacy and teaching outcome expectancy simultaneously.

A detailed document review was conducted to compare the differences of the curriculum structure and course works among these ten programs before and during the formal study. Since the main purpose of this study was to examine perspective teachers’ efficacy toward mathematics and science, DME and DSE programs were reported separately for showing the desired model of program design. Also because of the similarity of remained eight programs, their curriculum structures were reported together, while only the DEE program was explained as an example of not specializing in either mathematics or science. With regard to the number of general
content knowledge courses and methods courses taken in mathematics and science, students in DME and DSE received more preparations in content knowledge and teaching methodology, a total of 77 or more required credits for both programs, shown as table 3. Students in other 8 programs (departments) took only 22 or more and 25 required credits respectively in the disciplines of mathematics and science.

<table>
<thead>
<tr>
<th>Program</th>
<th>CC (M &amp; $S$)</th>
<th>GKC (M &amp; $S$)</th>
<th>ESFC (Me)</th>
<th>MC</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>DME</td>
<td>10 (2-3)</td>
<td>57 (15)</td>
<td>30 (9)</td>
<td>51</td>
<td>148</td>
</tr>
<tr>
<td>DSE</td>
<td>10 (2-3)</td>
<td>57 (15)</td>
<td>30 (9)</td>
<td>51</td>
<td>148</td>
</tr>
<tr>
<td>Other 8 programs</td>
<td>14 (3-4)</td>
<td>48 (10)</td>
<td>20 (9)</td>
<td>66</td>
<td>148</td>
</tr>
</tbody>
</table>

a. “M & S” indicates common courses or general knowledge courses related to mathematics and sciences.

b. “Me” refers to elementary mathematics and science methods courses.

c. “EE” indicates common courses or general knowledge courses related to elementary education in DEE program, as an example.

Table 3: Curriculum Structure Comparisons (Credit Hours)

The traditional design of teacher preparation programs, which are oriented in cultivating elementary generalists (NRC, 2001), will be inadequate for accomplishing the requirement of having qualified teachers in every classroom and for every subject area. As students have diverse needs and distinct characteristics, it is truly essential that specialized teachers exist for every subject area in every school. In order to reach the goal of enhancing prospective teachers’ sense of efficacy toward mathematics and science, including both personal teaching efficacy and teaching outcome expectancy, teacher preparation programs and their faculty members should rethink the program design, the curriculum structure, the content provided, and the pedagogy used in preparing them to teach mathematics and science. Further, even though more preparations in these two subject areas are no guarantee of higher quality of pre-service teachers and their better understandings of their subjects, insufficient preparation will definitely result in inadequacy of content and pedagogical knowledge and teaching skills in mathematics and science. This inadequacy will surely have a great influence on the quality of future teachers and the performance of their students (Chang, Wu, & Gentry, 2005).

CONCLUSION

According to the findings of this study, the teacher preparation program design did play a significant role in preparing future teachers in mathematics and science for the elementary school. Referring to how to make progress in improving the quality of elementary mathematics and science teachers, the program designs of DME and DSE of the participating teachers college in Taiwan demonstrated both more extensive curriculum frameworks in preparing prospective teachers’ subject matter knowledge and more self-confidence in delivering effective teaching in the classroom. While Taiwan’s teacher education system is trying to pursue a more organized restructuring
system for elementary teacher preparation in the current evolution, is it the right time to rethink and react for the purpose of advancing a new elementary teacher education component, especially for mathematics and science education?

Endnotes

1 Number of programs (departments) varied in every teacher college. There were 9 teachers colleges totally in Taiwan in the year of 1997.

2 Remaining 8 programs from DEE, DLE, DAE, DSS, DMU, DEC, DSP, and DPE in the participating teachers college.

Acknowledgement One part of this research was found by the National Science Council (NSC) of Taiwan, numbered as “NSC 93-2511-S-451-001”. An ongoing research project will provide in-depth information qualitatively of how to improve teacher efficacy in PME 31.

References


