韓國數學敎育學會誌 시리즈 A <數學敎育>
1995. 6. 제 34권, 제 1호, 1-6.

Journal of the Korea Society of Mathematical Education
Series A: Jun. 1995, Vol. 34, No. 1, 1-6.

The Reconceptualization of Teacher Education Program in Mathematics

Joong Kwoen Lee (Univ. of Georgia)
Woo-Hyung Whang (Korea University)

I. Prelude

The vast majority of what passes for teacher preparation makes little effort directly or indirectly to provide preservice or inservice teachers with precise professional intellectual, affective, or psychomotor skills called for in surveys, by scholars or as a result of research on teaching (Cruickshank & Metcalf, 1990, p.475). Teacher candidates and experienced teachers alike tend to see courses as "theoretical" by which they generally mean "vague and impractical" (Darch, Carnine, & Gersten, 1988, p.35). The reality and the teachers' belief in teacher education have not produced positive results. Even Cruickshank & Metcalf(1990, p.475) note that teachers simply are not trained. What is the "ideal" teacher education program and how can one implement it? Brown & Borko(1992) suggested a clue for the solution:

> Neither current academic nor current professional educational coursework are particularly good at helping prospective teachers develop high literacy in their content areas. …… improvements in both should be the focus of teacher education reform (Brown & Borko, 1992, p.221).

Many efforts have been made to improve academic and professional educational coursework. One of the most culminate efforts is that posed by the National Council of Teachers of Mathematics. The Council has developed standards for the content and pedagogy of teachers through the Curriculum and Evaluation Standards for School Mathematics(1989) and Professional Standards for Teaching Mathematics (1991). According to Brown & Borko (1992, p.235), both sets of standards provide the direction but not the mechanisms for reform in school mathematics; however, neither NCTM document is well grounded in systematic research, although both are widely accepted as guidelines representing the mathe matics education community's "best thinking" on these topics. Thus we need an ideal teacher education program that satisfy both direction and mechanism for reform in mathematics teacher education programs.

The following section describes a set of philosophical ideas that would drive the "ideal" teacher education program, providing one response to the call for reform in the teacher education program.

II. An "Ideal" Teacher Education Program

Teacher education program should include an operational plan for instruction that details what mathematics teachers need to know, how preand in-service teachers are to achieve the identified curricular goals, what university instructors are to do to help teachers develop their mathematical knowledge, and their behavioral knowledge in which mathematics learning and teaching occur. Thus, to conceptualize an ideal teacher education program we need to discuss what kind of knowledge should be taught and how teachers should be taught in the teacher education program.

1) What kind of knowledge should be taught

In general, teachers teach their students as they were taught. Thus, the kind of content included in the teacher education program is very important for students learning mathematics. This philosophical foundation naturally leads us to inductive approaches to the topic "What kind of knowledge should be taught?"

All teacher education programs should involve systematic learning which is helpful for improving teachers' mathematical content knowledge. Content knowledge consists of an understanding of the key facts, concepts, principles, and explanatory framework of a discipline as well as the rules of evidence and proof within that discipline (Shulman & Grossman, 1988). The most important knowledge for math teachers is content knowledge of mathematics. According to Ball (1990), subject knowledge should be a central focus of teacher education programs. According to Kilpatrick (1987), Polya used a mix of subject matter and teaching methods in the ratio of 9:1. According to Borko et. al. (1992), in a case study of preservice middle school mathematics teachers, the preservice teacher demonstrated a lack of conceptual knowledge in mathematics. These are evidences for the importance of subject knowledge in teacher education program. Brown & Borko (1992) reviewed contemporary studies which suggest that an increase in subject matter knowledge for preparing mathematics teachers is most essential. The results of the contemporary studies imply that strong subject matter knowledge is enable novice teachers to plan more productively. On the other hand, lack of subject matter knowledge impedes the classroom transition to pedagogical thinking. According to Borko, et al. (1992), although mathematics education majors take courses in both mathematics and mathematics education, conceptual understanding of the content is typically not stressed; even when a course focuses on concepts, students regularly do not make conceptual understanding explicit enough to challenge previous algorithmic constructions of mathematics. According to Ball (1988), to teach mathematics effectively, individuals must have knowledge of mathematics characterized by an explicit conceptual understanding of the principles and meaning underlying mathematical topics, rules, and definitions. Therefore, teacher education program should provide a systematic learning to improve mathematical content knowledge.

Teacher education program should also provide methods courses that can enhance teachers' pedagogical content knowledge. Pedagogical content knowledge, or subject-specific pedagogical knowledge, consists of an understanding of how to represent specific topics and issues in ways that are appropriate to the diverse abilities and interests of learners (Borko, et al. 1992, p.196). According to Kilpatrick (1987, p.87), Polya described pedagogical content knowledge as "know-how." Mathematical know-how is primarily the ability to formulate, solve, explain, and critically reflect on problems. Cruickshank & Metcalf(1990) suggest that pedagogical content knowledge can be analyzed to determine specific behaviors that teachers must attain. Several research reviews (Cruickshank & Metcalf, 1990; Brown & Borko, 1992) indicate that a teacher education proram which emphasizes pedagogical content knowledge with application can produce positive results. However, the reality of current mathematics teacher education program is still far from the research results. According to Brown and Borko's(1992) review of contemporary studies, pedagogical content knowledge is relatively undeveloped in novice teachers. According to Bush (1986), preservice teachers say that methods courses are the primary influence on their pedagogical content knowledge. Brown & Borko (1992) also add that methods courses should make pedagogical content knowledge a central priority. Therefore, teacher education programs should provide methods courses that can enhance teachers' pedagogical content knowledge.

Teacher education program should provide programs and guidelines that can develop teachers' pedagogical reasoning. As Brown & Borko (1992) have commented,

> Pedagogical reasoning is that the process of transforming content knowledge into forms that are pedagogically powerful and adaptive to particular groups of students…… making the transition from a personal orientation to a discipline to think about how to organize and represent the content of the discipline to facilitate student understanding (p.221).

Feimen-Nemser & Buchmann(1986) identify the transition to pedagogical reasoning as a major component of learning to teach; however, preservice teachers show difficulties to make that transition. Lanier & Little (1986) recommend that teacher education should focus on the actual challenges that teachers will face in the classroom in order to devlop pedagogical reasoning. Teacher educators should take an active role in guiding preservice teachers' pedagogical reasoning by demonstrating what decisions and methods are necessary in the classroom (Feimen-Nemser & Buchmann, 1986). Thus, teacher education programs should provide programs and guidelines that can develop teachers' pedagogical reasoning.

Even though we know what kinds of knowledge should be taught in teacher education programs, if we do not know how to teach them, then the programs are still inadequate. For the ideal teacher education program, we need to make a combination of what to teach with how to teach it. The following section describes how teachers should be taught.

2) How teachers should be taught

Cruickshank & Metcalf (1990, p.475) have said that teachers simply are not trained. Learning does not occur by passive absorption alone (Resnick, 1987). These two statements imply that the subject of how to teach teachers needs a lot of research. "Knowing" of teaching mathematics is "doing" of teaching mathematics. Math teacher education programs should persistently emphasize "doing" rather than "knowing." On this philosophical foundation, the following recommendations were drived for helping to teach teachers.

Teacher education classrooms should become a mathematis education community. The classrooms should not be a collection of individuals. They should be a mathematics education society. In other words, teacher educators should help students work together to communicate with each other and to make sense of mathematical content knowledge, pedagogical content knowledge, and pedagogical reasoning. To make classrooms into mathematics education communities, educators need to increase the number of questions they ask to stimulate their students, and need to have small groups working together on some tasks as well as conducting large group discussion.

Teacher educators should help to develp teachers' logical thinking and mathematical verification. They should not just show correct answers. They should make their own logical arguments to verify conjectures. They also need to help students rely more on themselves to determine whether something is correct or not. Problem-solving techniques with open-ended questions are good instructional methods to develop teachers' logical thinking and mathematical verification. "Why is that true?" and "How did you get that result?" are effective questions to strengthen this kind of thinking.

We need to develop teachers' mathematical and pedagogical reasoning. Merely memorizing mathematical and pedagogical procedures is not helpful for teachers' mathematical and pedagogical reasoning. Teacher educators should not push students to memorize mathematical and pedagogical procedures. Teacher educatiors should give students the opportunities to practice mathematical and pedagogical procedures not only in the classroom but also in field internships. They also should help teachers to connect mathematics and teaching mathematics. Mathematics and teaching mathematics is not a body of isolated concepts and procedures or process. According to Borko, et. al. (1992), university course work must help develop the concepts and language to draw connection between representations, applications, algorithms, and procedures as well as encourage the practice and reflection necessary for the development of those components. Thus, to help teachers to connect mathematics and teaching mathematics, teacher educators need to pose tasks and questions involved in real classroom situations.

Teacher education programs should provide systematic training programs. Joyce (1988) claims that training can enable teachers to learn and control pedagogical skills that most novice teachins fail to learn. According to Joyce(1988), the system of training consists of four components: 1) the study of the theory and research of a teaching skill, 2) demonstrations of the teaching skill, 3) simulated practice of the skill, and 4) self-feedback on skill acquisition. Cruickshank & Metcalf (1990, p.474) state fifteen principles of training from research findings:

1. Establish clear performance goals and communicate them to learners.

2. Insure that learners are aware of the requisite level of skill mastery.

3. Determine learners' present level.

4. Introduce only a few basis "rules" during the early learning stages.

5. Building upon learners' present skill level during the early learning stages.

6. Ensure during the initial acquisition stage, a basic, essential conceptual understanding of the skill to be learned and when and why it is used.

7. Demonstrate during the initial acquisition stage what final skill performance should look like, drawing attention to salient features of the skill or subskills, as in the case of clarity. Provide sufficient opportunity to learn and apply the feature labels to the demonstration.

8. Provide opportunity for learners to discuss the demonstration.

9. Provide sufficient, spaced, skill practice after understanding of the skill has been developed, in both subskills and cumulative whole-skill acquisition.

10. See that practice of the skill is followed by knowledge of results.

11. Provide frequent knowledge of results early in the learning process which is more effective if give with less emphasis on response quantity than on quality.

12. Provide knowledge of results after incorrect performance of a skill, which is most important.

13. Delay knowledge of results when the learner is beyond the initial stage of learning, which can be effective as immediate knowledge of results when performance is correct or good.

14. provide for transfer of training that is enhanced by maximizing similarity between the training and the natural environment, over learning salient features of the skill, providing extensive and varied practice, using delayed feedback, and inducing reflection and occasional testing.

15. Provide full support and reinforcement for use of the skills in natural settings.

These principles are closely related to Kilpatrick's (1987) arguments. He said that "because such arts [problem solving and teaching] can be learned by imitation and practice, teachers need to provide appropriate examples to be imitated followed by opportunities for practice" (p.94). Thus teacher education programs should develop principles of training.

Ⅲ. Denouement

We have addressed what should be taught and how teachers should be taught in a teacher education program. Teacher education programs should be opened to new mathematics educational issues and documents, such as Curriculum and Evaluation Standards for School Mathematics (1989), and Professional Standards for Teaching Mathematics(1991). And teacher education programs should be vehicles to disseminate and implement new ideas and suggestions. The combination of what and how described here can be one response to the call for reform in teacher education. The use of the word "ideal" sometimes gives us an image which is not realistic. But the "ideal" teacher education program suggested here can be and even must be implemented in order to develop our mathematics education program.

References

Ball, D. (1990). Prospective elementary and secondary teachers' understanding of division. Journal for research in mathematics education, 21, 132~144.

Borko, H. et. al. (1992). Learning to teach hard mathematics: Do novice teachers and their instructors give up too easily? Journal for research in mathematics education, 23(3), 194~222.

Brown, C. & Borko, H. (1992). Becoming a mathematics teacher. In D. Grouws (Ed.), Handbook of research on mathematics teaching and learning (pp.209~239). New York: Macmillan.

Bush, W. (1986). Preservice teachers' sources of decisions in teaching secondary mathematics. Journal for research in mathematics education, 17(1), 21~30.

Cruickshank, D. & Metcalf, K. (1990). Training within teacher preparation. In W. R. Houston (Ed.), Handbook of research on teacher education (pp.469~497). New York: Macmillan.

Darch, C., Carnine, D., and Gersten, R. (1984). Explicit instruction in mathematics problem solving. Journal of educational research, 77(6) 351~359.

Feimen-Nemser, S. & Buchmann, M. (1986). The first year of teacher preparation: Transition to pedagogical thinking? Journal of curicular studies, 18, 239~256.

Joyce, B. (1988). Training research and preservice teacher education: A reconsideration. Journal of teacher education, 39(5), 32~36.

Kilpatrick, J. (1987). Is teaching teachable? George Polya's views on the training of mathematics teachers. In F. Curcio (Ed.), Teaching and learning: A problem-solving focus (pp.85~97). Reston, VA: NCTM.

Lanier, J. & Little, J. (1986). Research on teacher education. In M. C. Wittrock (Ed.), Handbook of research on teaching (3rd ed., pp.527~569). New York: Macmillan.

National Council of Teachers of Mathematics. (1989). Curriculum and evaluation standards for school mathematics. Reston, VA: NCTM.

National Council of Teachers of Mathematics. (1991). Professional standards for teaching mathematics. Reston, VA: NCTM.

Resnick, L. B. (1987). Education and learning to think. Wahington, DC.: National Academy Press.

Shulman, L. & Grossman, P.(1988). Knowledge growth in teaching: A final report to the Spencer foundation. Stanford, CA: Stanford University.