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ABSTRACT

In an effort to improve a summer professional development program for inservice secondary mathematics and science teachers in Taiwan, a three-year action research project has recently been completed. The program attempted to provide participating teachers with a better theoretical and practical understanding of teaching and learning based on the constructivist perspective, thereby allowing them to instruct students using related strategies. In addition, the notion of "teachers as researchers" was also emphasized. Several courses were designed to help teachers implement action research projects in their own classes. Meanwhile, a small number of teachers were receiving advice, support and encouragement from the research team. According to the results of this study, such an effort significantly changed participating teachers' beliefs toward learning and teaching. However, due to some external constraints, only a few of them put their belief into practice with success. On the other hand, the teachers supported by the research team not only enhanced their pedagogical performance, but also the students' achievements in and attitudes towards learning science and mathematics. Potential implications of this project and a follow-up study are also discussed. Contains 17 references. (Author)

Development of a Professional Development Program for Science and Mathematics Teachers -- an Action Research

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ABSTRACT

In an effort to improve a summer professional development program for in-service secondary mathematics and science teachers in Taiwan a three-year action research project has recently been completed. The program attempted to provide participating teachers with a better theoretical and practical understanding of teaching and learning based on the constructivist perspective, thereby allowing them to instruct students using related strategies. In addition, the notion of "teachers as researchers" was also emphasized. Several courses were designed to help teachers implement action research projects in their own classes. Meanwhile, a small number of teachers were receiving advice, support and encouragement from the research team. According to the results of this study, such an effort significantly changed participating teachers' beliefs toward learning and teaching. However, due to some external constraints, only a few of them put their belief into practice with success. On the other hand, the teachers supported by the research team not only enhanced their pedagogical performance, but also the students' achievements in and attitudes towards learning science and mathematics. Potential implications of this project and a follow-up study are also discussed.

Introduction

An on campus professional development program has been offering graduate level courses during the summer session for in-service secondary mathematics and science teachers in Taiwan for many years. The program comprises of twenty courses to be completed over four consecutive summers. Because completing this professional development program will lead to salary raises, teachers who are interested in enrolling in this program usually have to go through a very competitive selection process favoring experienced teachers with noticeable performance and achievements in his/her career. Most of the teachers who were admitted to this program were found to hold strong objectivist points of view on the learning and teaching of science and mathematics. Although this program used to provide participants with topics such as contemporary views on science teaching and learning, constructivism, theoretical foundation of science education, instructional strategies, research methods and so on, participants had seldom changed their pedagogical approaches after completing this program. Many of them showed strong interests in constructivist ideas and teaching approaches, but often felt unable to put them into practice.

On the other hand, since secondary school graduates in Taiwan need to take a very competitive exam in order to attend better senior high schools, achieving good scores on pencil-and-paper tests becomes the primary concern for the teachers, students, as well as parents. Given the great deal of textbook contents to be covered, science and mathematics teachers often believe that the most effective approaches for achieving high scores are to rely extensively on teacher-directed instruction and to have students practice as many related problems as possible before taking the tests.

As a result, a lot of students spend a great deal of time memorizing factual knowledge and practicing worked-out examples without meaningful understanding. Important educational objectives such as scientific literacy, science process skills and so on are often neglected. In view of the worldwide and national calls for educational reform, we felt that we had the obligation and knowledge to help these attending science and mathematics teachers to adopt a more constructivist perspective towards teaching and learning and, more importantly, to put the constructivist ideas into practice. In the summer of 1994, we started to redesign and implement this in-service professional development program in accordance with a consistent set of goals, rationales and implementation strategies based on the findings of our previous study (Guo et. al., 1995), our understanding of constructivism and its educational practices (e.g., Hand & Prain, 1995; Tobin, 1993), classroom action researches (e.g., Eisenhart & Borko, 1993; McKernan, 1996; Schon, 1987), and other in-service teacher development projects (e.g., Stofflett, 1994; Gallagher, 1993). In addition, a three-year action research agenda was also set up to continuously revise and evaluate this professional development program.

Main Features of the Program

In this section, we will briefly describe the main features of this revised program with regard to its rationales and implementation strategies as follows:

(1) In contrast with the original program which focused largely on enhancing the content knowledge of the participants and relied on lectures and individual learning as the primary teaching strategies, the revised program placed emphasis on changing teachers' views of learning and teaching and enhancing the

pedagogical knowledge and the pedagogical content knowledge of the participants. Recent research findings and theoretical developments in the areas of science education were introduced with many practical illustrations. Courses on the nature of science, constructivism, alternative assessment techniques, integrated science, instructional media, conducting action research in classrooms, writing research reports, and so on were also provided during the four summer sessions.

(2) Consideration was made of the notion that teachers must be taught in accordance with the constructivist idea of learning and teaching if they were to teach in the same manner (Shymansky, 1992). The faculty members applied a variety of pedagogical strategies deemed conducive to the constructivist perspectives toward designing curriculum and instruction. Alternative means of assessing the teacher's performance were also implemented. A group of faculty members collaboratively taught several courses, and cooperative learning among the in-service teachers was encouraged. Upon completion of each summer session, teachers' reactions to and reflections on the courses were solicited to further improve the program.

(3) The revised program actively encouraged and required the teachers to undertake action research projects in their own classes. Such an initiative corresponds to the notion that teachers should be reflective practitioners, active learners and classroom researchers (e.g., Eisenhart & Borko, 1993; McKernan, 1996; Schon, 1987). To achieve this goal, collaborative research teams among the in-service teachers were formed, with necessary instructions and assistance provided in each of the four summer sessions. Topics such as identifying research problems on teaching and students' learning, data collection and analysis techniques, and

research report writing were covered in a series of summer courses.

(4) Since this project was initiated in the first year, a total of eight participants have been selected as "seed teachers". We have closely examined their classroom instruction in order to assess the program's effectiveness, promising areas, and limiting factors. In addition, the seed teachers also remained in close contact with the research group, participating in various meetings, activities and workshops prepared by either the researchers or themselves during the academic year. The seed teachers constantly received advice, support and encouragement from the research team. It was hoped that, in the near future, these teachers would become mentors for first-time instructors and assume leadership roles in Taiwan's educational reform of science and mathematics instruction.

Research Questions and Data Collections

As our action research aims to improve the summer professional program for in-service secondary science and mathematics teachers, various sources of data were collected, analyzed and cross-checked to address the following concerns:

(1) To what extent has the revised program achieved its goals?

(2) What factors hinder teachers from using strategies in accordance with the constructivist perspectives?

(3) What actions should be taken, as well as revisions made, to further enhance the program?

The various sources of data gathered throughout the study can be categorized as the following: (1) surveys and questionnaires designed to probe participants' conceptions of the revised program and suggestions for improvement; (2) inventories

and questionnaires used to assess teachers' views of the nature of science, their teaching styles, and their beliefs in and attitudes towards science learning and teaching; (3) field notes and videotapes of seed teachers' classroom teaching; (4) interview and meeting notes which provided insights into teachers' concerns about and reflection on their teaching and the difficulties in implementing constructivist teaching strategies ; (5)documents and written reports regarding teachers' personal growth, students' performance, reflections on the change process and so on; and (6) written and oral reports of teachers' action researches.

Results and Discussions

Based on analyses and interpretation of the data collected, this section presents the findings and results of the study. It is worthwhile pointing out that most of the teachers considered themselves experienced, good and responsible teachers when entering the program, with only a few indicating a need for professional and personal development. In view of such self-assurance and self-concepts of the teachers in our program, the readers are advised to take this into account when comparing its effectiveness with similar programs involving teachers with the initiative to seek professional growth and improvement.

Effectiveness of the Revised Program

As pointed out previously, the main aim of this study was to introduce constructivist perspectives on teaching and learning to the attending teachers in hope that they will be able to use constructivist instructional strategies to improve their science and mathematics teaching. The effectiveness of the revised professional development program is to be determined primarily by an overall

assessment of changes in teachers' beliefs and teaching practices. Results obtained from the analysis of collected data indicated that the constructivist perspectives in teaching and learning were received well by most of the teachers, and they were able to adopt constructivist teaching approaches with varying degrees of success.

1. **Change in teachers' beliefs about teaching and learning science and mathematics**

Analysis of data from the questionnaires and interviews indicated that almost every teacher commented that the program had a great impact on their ideas about the nature of teaching and learning in science and mathematics, what counts as good teaching, and what it means to be a good science or mathematics teacher. For instance, some teachers admitted that before they entered this program they paid a great deal of attention to the representation and transmission of subject contents, and less to how students were thinking and learning. They felt that it was the teacher's responsibility to prepare and deliver his/her lessons clearly and thoroughly, while it was the students' responsibilities to study hard, do many exercises and obtain good grades. Most of the time they relied on teacher-directed instruction with students listening and taking notes. For example, some teachers commented:

"...I used to think that students were all the same except for the efforts they put into studying." (SQ, n1, G4, 12)

"I used to punish students for not studying hard enough to achieve their desired test score and I also thought that students would not be able to answer the questions correctly if I had never taught them before." (SQ, n1, G4,35)

Several teachers commented that before entering our program they were

confident of their teaching competency, and used to think the results of their teaching practices, in terms of students' test achievements, were very satisfactory. With such views about teaching and learning, many teachers indicated that they felt uncomfortable and shocked the first time they were introduced to the principles of constructivism and teaching strategies such as cooperative leaning and problem-centered learning activities. For example, one teacher revealed his reaction in the first year of study:

> "*...I was very confident that everyone in my district would consider myself as a good teacher...How could you (the faculty members) said that I was too self-centered and I still needed to improve my teaching!...You are always talking about unrealistic theories... Why don't you teach one of my classes using your theories and show me how effective your theories are?*"(SRG,G4, 11)

But gradually, towards the end of their studies, most of the teachers realized that what they believed to be good teaching could often have a harmful effect on students' cognitive and affective development. They said that they became more willing to listen to what students had to say about what they were thinking and were more patient in coping with students' alternative conceptions. They also recognized that, in addition to having students achieve good scores on pencil-and-paper tests, it is important to attend to other goals of science and mathematics education such as helping students develop scientific literacy, problem solving skills, and so on. For example, some teachers expressed:

> "*... but now I realize that each of them has their own learning style. I start to pay attention to their individual differences and provide various guidance to suit their individual needs.*" (SQ, n1, G4, 16)

"...I will reflect on the way I taught the lessons and pondering how I should improve my teaching to help them construct the concepts." (SQ, n1, G4, 35)

" ...I will encourage my students to think and share their points of views... I will also encourage them to solve problems using their own ways and explain their reasons before providing the correct answers." (SQ, n1, G4, 36)

"Instead of teaching students science knowledge, I would rather teach them how the knowledge is generated and inspire them to think creatively and critically." (SQ, n1, G4, 13)

Although the teachers' understandings of constructivism and its educational and epistemological implications were changing, and varied from one another, an overall impression from the various sources of data collected was that they have learned a great deal about the nature of teaching and learning from constructivist points of view, and that there were noticeable changes in their beliefs about science and mathematics teaching.

2. Commitment to carrying out action researches to improve teaching practices

Although most of the attending teachers tended to think of constructivist ideas about teaching and learning as worthwhile, only a few succeeded in putting these ideas into practice. This was indicated by the research reports that the teachers submitted toward the end of the program, and from interviews with the teachers. About half of the teachers did not feel that they ought to change their teaching practices drastically, and they preferred doing experimental or quasi-experimental studies involving typically a research design aiming at comparing between two different classes the effects of two different teaching strategies, usually with one

oriented more toward the constructivist approaches and the other toward the traditional. The reports submitted by the other half of the teachers were action research studies, with the teachers involved in carrying out systematic inquiries into solving problems of learning and teaching in classroom contexts using constructivist approaches. About 70 percent of the action research papers were authored by the "seed teachers", who had been receiving support and feedback from the research team over the last three years. Analysis of the action research reports indicated that a large portion of the teachers had developed their own teaching strategies for coping with their own classes with varying degrees of success, while a few of them were still under the process of trying out better approaches to suit their special needs. For the teachers who tried to put constructivist ideas into practice, almost everyone of them pointed out that they had gone through a painful process of change during the first two years. They commented that changing their regular teaching styles and methods in the first year often resulted in unpleasant outcomes in terms of students' reactions and their academic performance. Consequently, they suffered criticism and pressure from school administrators and students' parents. As a result, they often faced the dilemma of whether to use constructivist teaching strategies on a regular basis or use them just as a supplement to the ones they were accustomed to using. With advice and support from the research team, the "seed teachers" managed to overcome such difficulties in the long run and demonstrated wonderful professional growth in their own ways. A few other teachers also did beautifully on their own, while there were some who were either still struggling to find a good solution or gradually gave up.

Factors hindering teachers from using strategies

in consistent with constructivist perspectives

Findings presented in the above section suggest that it is very difficult for the participating teachers to initiate and sustain action research studies aiming at systematic improvement of their own teaching without constant support and feedback from the research team. In order to understand what the difficulties and obstacles were, we conducted a series of surveys and interviews with the attending teachers. The information gathered suggested that the obstacles perceived by the in-service teachers could be summarized as follows: (1) lack of time available for the preparation and implementation of new teaching strategies; (2) pressure from the administration and students' parents to stick with their original teaching strategies; (3) pressure to have students perform well on pencil-and-paper tests in order to help them enter better senior high schools; (4)fear of losing control in the classroom; (5) difficulties in designing and planning teaching strategies consistent with the constructivist viewpoints; (6) fear that students won't cooperate with the teacher; (7) failing to grasp the basic understanding of constructivism and other related theories of learning and teaching; and (8) insufficient content knowledge to cope with questions students come up with. Based on the above constraints expressed by the individual teachers, we then asked the teachers to form 11 groups to discuss these constraints and select three of the most critical ones they perceived. The result is presented in Table 1.

Table 1. Percentage of responses for the three most critical constraints perceived by the 11 groups of teachers

Constraint to implement constructivist teaching activities	Number of responses by groups(N=11)	Percentage of responses by groups(N=11)
lack of time available for the preparation and implementation of new teaching strategies	8	72.7%
pressure from the administration and students' parents	3	27.2%
pressure to have students perform well on pencil-and-paper tests	4	36.4%
fear of losing control in the classroom	2	18.2%
difficulties in designing and planning constructivist teaching strategies	9	81.8%
fear that students won't cooperate with the teacher	1	9.1%
failing to grasp the basic understanding of constructivism	4	36.4%
insufficient content knowledge to cope with questions students come up with	2	18.2%

It is shown that, among these, lack of time available for the preparation and implementation of new teaching strategies and difficulties in designing and planning teaching strategies consistent with the constructivist viewpoints were rated by the teachers as the most critical factors hindering their efforts in trying to make instructional improvement using constructivist approaches.

On the other hand, we also noticed several factors which encouraged the teachers to overcome the difficulties they encountered during the change process. For instance, one of the "seed teachers" said that after several trials of applying

cooperative learning activities to students generally considered as lower academic achievers, he found that not only did they become more motivated and involved in the class but also their performances had gradually improved. Some students even demonstrated various abilities and talents which were normally overlooked in typical classrooms. Another teacher reported her experience involving the use of problem-centered cooperative learning activities in one of her mathematics classes. Once she asked her students to discuss one complicated problem in small groups. To her surprise, she found out that nearly half of her students were able to solve this problem correctly in a test taken a few days later, without any reinforcement. The problem was so difficult that she used to have a hard time getting her students make sense of it using her original teaching approach. She added that this unexpected incident significantly encouraged her to seriously reflect on her points of view in the teaching and learning of mathematics. She also became more willing to put constructivism into her teaching practices. Later surveys and interviews with her students also indicated that they preferred learning mathematics when the teacher adopted such an alternative teaching strategy.

These stories seem to suggest that in order to sustain the attending teachers' process of change, not only do they have to perceive the merits of constructivism and the benefit of using constructivist teaching strategies, but they also have to experience personally these merits and benefits in their classrooms. Otherwise, teachers might still have the idea that constructivism is just another unrealistic theory of learning and teaching which is only suitable for people within other social, educational and cultural environments. In fact, we found that only a small number of teachers had the opportunity to encounter such encouraging incidents which resulted in an increase in

their confidence in using constructivist teaching strategies. A larger portion of the attending teachers commented that failing to generate satisfactory student achievements at the beginning stage of their change process consequently prevented them from taking further action towards using new teaching strategies in their classrooms.

Suggestions from the participants concerning program improvement

In addition to studying the effectiveness and constraints of the program, the third goal of this study was to gain insight into possible directions for future improvement of this program. Here we would like to present some of the attending teachers' comments and concerns. In general, the teachers suggested that, rather than spending most of their time on reading and discussing related instructional theories and strategies in the classes, they expected to be more involved in activities such as visiting each other's classroom, observing teachers who have been putting constructivist teaching strategies into practices with success, and discussing and reflecting on their teaching plans with other teachers. However, it came as a surprise to us that receiving constant support and feedback from the research team and faculty members did not seem to be the primary concerns of these teachers. We suspect that this might have something to do with the fact that the number of teachers participating in our program is large and that their schools are spread all over the island. They might have figured that frequent on-site visits by university faculty members are clearly impossible and communication through mails and phone calls are not very practical either. On the other hand, although the "seed teachers" had the opportunity to attend scheduled meetings, usually once every two weeks, and receive feedback and support from the research team, they still said that they needed more time to work

with the research team to fully address their problems and concerns. Moreover, if possible, they also looked forward to collaborating with teachers in their own schools.

Conclusions

Using the action research approach, we have explored the effectiveness and limitations of this in-service professional development program for secondary science and mathematics teachers in Taiwan. As a positive sign, our results point toward a gradual shift among attending teachers regarding their views on teaching and learning: from an objectivist perspective to a more constructivist one. A few teachers have put such beliefs into action with a certain degree of success. However, most of the teachers indicated that factors such as lack of time given to instruction and preparation, inadequate support from others, and their own lack of experience in designing constructivist learning activities prevented them from substantially changing and improving their teaching practices. Adapting the conceptual change model proposed by Ponser, Strike, Hewson and Gertzog (1982) to the development of these in-service teachers, it is certain the revised program has been gradually causing teachers to reconsider their roles and responsibilities, reflect on their teaching practices, and become dissatisfied with their original beliefs and approaches to teaching. The program has also provided sufficient time and resources for the attending teachers to grasp the fundamentals of constructivism and related teaching strategies. Most importantly, the program seems to provide an opportunity for teachers to visualize how alternatives might work in the classroom and to view change as a challenge rather than as a problem or requirement. However, given the limitations of the program, as well as the socially and culturally conceived views of how a good teacher

of science or mathematics should teach, it still remains as a challenge for the in-service teacher development program to assist the teachers in perceiving that changing their beliefs and practices is plausible and beneficial. It might also be necessary to convince the teachers that not meeting with instant success is acceptable, to be expected, and that others are also experiencing frustration in the beginning stage of change, so that they would be more willing to carry out action research studies aiming at instructional improvements in their classroom.

From a social constructivist point of view, Bell and Gilbert (1996) suggested that teacher development involves three types of development -- social, personal and professional development. With regard to social development, social interaction with other teachers is necessary and facilitates the renegotiation and reconstruction of what it means to be a teacher of science. Personal development involves each individual teacher constructing, evaluating and accepting and rejecting for himself or herself the new, socially constructed knowledge of what it means to be a teacher (of science, for example), and managing the feelings associated with changing their activities and beliefs about science teaching. Professional development involves the use of different teaching strategies, the development of beliefs underlying the activities, and learning about the subject contents. These authors stressed that unless all three aspects are addressed, teacher development has difficulty succeeding. This clearly explains why our program, which mainly emphasizes the professional development aspect of teacher development, has failed to provide more significant results. A recent shift of resources and attention to in-service education from higher education based courses to school based in-service programs (Bridges, 1993) might promise an alternative solution.

Finally, we would like to report on a follow-up study which might enable us to disseminate our success with the "seed teachers" to a wider audience and promote a model of school based, in-service teacher development. During our study, we had the opportunity to speak with secondary school principals about our beliefs in teaching and learning, the goals of our research, as well as our plans to achieve those goals. After viewing the success of the "seed teachers" in establishing a more meaningful and active learning environment in their science and mathematics classroom, a few principals told us that they were willing to encourage other teachers in their schools to work in the same direction. With such encouraging responses, we have decided to initiate another action research project designed to bring more widespread educational changes to these schools. In short, the goal of the newly established action research is to assist and empower the seed teachers to work with their colleagues in designing and implementing teaching activities in accordance with the constructivist points of view. Hopefully, this new research project will be able to facilitate ongoing collaboration between institutions of higher education and local public schools (Ellis, 1990), educational researchers and practicing teachers (Clift et. al., 1991), as well as collaboration among teachers themselves (Etchborger & Shaw, 1992). In the long run, it might positively impact science and mathematics education in Taiwan to a significant extent.

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