Challenges encountered in implementing constructivist teaching in physics: A qualitative approach

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Abstract

The development of constructivism has resulted in teaching modifications in the science classroom. While the majority of the literature has focused on the promising outcomes of the teaching reform, the present study reports various minor but persistent criticisms. This paper qualitatively analyzes skeptical students' criticisms regarding the author's teaching from 2000 to 2004, in her first year university physics classes in Taiwan. An open-ended questionnaire survey was administered seven times during the five-year study. In 2000 and 2001, investigations were conducted twice, during and post each academic year. Different groups of students filled in the survey in different years, giving a total of 618 students who participated in the study. The major concerns of these skeptical students include the increase of cognitive difficulty and learning responsibility, the effectiveness of the teaching performance, and the standards of the course. Many of the criticisms form an opposing opinion to the positive appraisal from their peers. Based on the findings, teaching practitioners might face challenge in grasping the optimal points between enhancing the majority of the students' expectations and alleviating the skepticism of a minority of students.

Key words: Constructivist teaching, innovation, physics, challenge, qualitative analysis

Introduction

In recent years, the development of constructivism has resulted in dramatic modifications in teaching design in many science classrooms, including the area of university physics (eg., Crouch & Mazur, 2001; Meltzer & Manivannan,, 2002). While the majority of the literature has focused on the promising results in terms of students' academic performance as well as affective learning outcomes from innovative teaching programs (eg., Gautreau & Novemsky, 1997; Meltzer & Manivannan, 2002), the present study reports various minor but persistent criticisms which contrast with the positive appraisal of the students. Student skepticism still exists even in a considerably successful teaching program, based on a macroscopic quantitative analysis (Chang, 2005a). These opposing voices might provide a critical message for further implementation of constructivist teaching.

Since 1999, the researcher has been designing and implementing an innovative teaching program based on the constructivist view of learning, and has evaluated the outcomes both during and after each course. This study summarizes the students' comments, both positive and negative, with respect to the constructivist teaching of university physics during the implementation period, from 2000 to 2004.

The context of the current study is a year-one university physics course for engineering students at Feng-Chia University, a large private university in Taiwan. The university physics course is a two-semester course, consisting of 16 weeks each semester. The course consists of three hours per week of lectures and three hours per week of laboratory sessions. The course is a prerequisite for all engineering and science students, and if a student fails to obtain the passing score of 60%, he/she has to take the course until passing grade is achieved. This requirement must be met before graduation.

The size of the lecture class is about 55-70 students. Most of the students come straight from high school. They are homogeneous in their ages (18-20) and the physics background of the Feng-Chia entrants is around the median (60% - 40%) of all high school graduates in Taiwan.

Traditionally in Taiwanese college physics courses, the physics professors' major teaching task (including the researcher's prior teaching) in the lectures involves explaining physics principles/concepts, followed by solving manipulating-type problems, and occasionally giving demonstrations. The students are expected to listen to the lecture and copy notes in class and practice end-of chapter problems after class. Discussion in class is rare. In Taiwan, this type of transmission-style of teaching is also prevalent in high school physics classrooms; thus, the incoming students are likely to perceive this didactic teaching approach as normal (Chang, 2005b).

Literature

The innovative teaching design was based on the incorporation of personal and social constructivist views of learning, and is referred to as constructivist teaching. The personal constructivist view emphasizes the influence of preconceptions on the construction of new ideas (e.g., Clement, 1982). Learning tasks are viewed as mainly to achieve conceptual change, thus teaching tasks should provide anomalies and engage students in cognitive processing (Posner, Strike, Hewson & Gertzog, 1982). Therefore, the adoption of interactive teaching is regarded as superior to a didactic way of teaching in facilitating conceptual change (Hake, 1998). On the other hand, the social constructivist view of learning has highlighted the socially constructed nature of science knowledge, which has been influenced by social, historical, and cultural factors (Hennessy, 1993). Learning science requires not only individual cognitive processing (to make sense of nature by rational derivations), but also involves a process of enculturation in order to become acquainted with the artificial tools and to grasp the scientific way of viewing the world (Salomon & Perkins, 1998). Thus, the incorporation of individual cognitive reasoning and social practice is essential for achieving effective learning. In addition to providing abundant questions and time to stimulate students to think and discuss, teachers are also expected to provide essential mediations (background knowledge) for the students, to ensure the effectiveness of the interactive teaching (Driver, Asoko, Leach & Scott, 1995; Roth, McRobbie, Lucas & Boutonne, 1997).

The development of constructivism has triggered many teaching reform programs in university physics. The features can be summarized as (eg., Redish, 1996) (1) emphasizing verbal elaborations on context-rich questions rather than mathematical derivations on traditional problems (eg, Gautreau & Novemsky, 1997; Heller & Hollabaugh, 1992), (2) providing teaching time and concept questions for the students to observe, think about, and discuss the underlying principles (eg., Heller & Hollabaugh, 1992; McKittrick, Mulhall & Gunstone, 1999), (3) monitoring of the learning processes and providing instant feedback to students (eg. Beichner et al., 2000), and (4) emphasizing the responsibility of learning usually incorporated with intelligent technology, such as the adoption of on-line preview assignments (e.g. Mazur, 1996). Many studies have reported the outcomes of constructivist teaching reform programs both in academic and affective terms. Most studies note that although their teaching reforms reduced derivations in traditional problems (in the textbooks), their students' performance in solving problems was not worse than, or was in fact superior to, that of their peers in traditional classes (eg., Crouch & Mazur, 2001; Gautreau & Novemsky, 1997). By means of adopting standardized multiple-choice tests with a large number of participants, the students' performance in conceptual tests was found to be significantly better than that of the traditional groups (Hake, 1998).

In addition to the encouraging outcomes, several studies have reported potential challenges that instructors might need to confront regarding the constructivist teaching reforms. First, the conducting of an in-class discussion may need long-term practice to achieve an appropriate style and pace. Both the context and content of the responses and reactions to questions need to be taken into account when conducting inquiry-type questioning (Roth, 1996). Meanwhile, the ability to achieve an appropriate extent and timing of intervention during discussion is very challenging (Bell & Gilbert, 1996). Physics teaching innovation is more complex than traditional lecturing in terms of materials and activities management, i.e. thorough comprehension of the content knowledge is required by the instructor, and the classroom may be criticized as being out of control (Maclsaac & Falconer, 2002). Second, the demands for designing conceptual questions are great. The conceptual questions need to tackle the prevalent learning difficulties, but must avoid plug-in "hot formulas" without conceptual comprehension (Heller & Hollabaugh, 1992; Van Heuvelen, 1991). Third, the success of an innovative teaching program depends on the favorable attitude of the students towards the teaching design (Fraser & Wubbels, 1995). For example, when students possess transmission views of learning, they may regard the conducting of in-class discussion as ineffective in terms of knowledge accumulation ((Banerjee, Vidyapati & Vidyapati, 1997; Cottle & Hart, 1996). On the other hand, the literature suggests that different teaching designs may alter the students' beliefs about teaching and learning (Trigwell & Prosser, 1991).

Based on quantitative analysis of closed questionnaire surveys, prior studies have suggested that constructivist teaching in university physics seems to benefit students' affective learning outcomes as well as their beliefs about the learning process (Chang, 2005b; Elby, 2001; Gautreau & Novemsky, 1997). However, the qualitative findings of Buncick et. al. (2001) note that the students were more critical when taught in a more interactive way.

Design of the constructivist teaching

In this study, the constructivist teaching allocated about one quarter of the teaching time for the students to discuss conceptual questions, by means of reducing the time spent on derivations of traditional problems. The reduction of arithmetical problems in class was compensated for by assigning end-of-chapter problems for the students to solve after class. Quick tests on the assignments were given to monitor the students' learning. The questions for group discussion were mostly embedded in everyday life contexts, and some were presented along with demonstrations. About 6 to 10 questions were assembled as a worksheet for group discussion, which took 20 to 30 minutes to discuss. During the group discussion, the researcher assigned several groups to write their answers on the blackboard. Then all the students were encouraged to voluntarily correct the answers on the board. Answers from the assigned groups were mostly not graded, while the volunteer students who made right corrections received credits. The researcher then took about 15 minutes to review the answers and instruct the related theories when necessary. In addition, the researcher introduced an independent study project in which students were asked to write up a reading report. Meanwhile, so-called 'challenge questions' were occasionally introduced to the students, allowing about 10 days for them to be answered. The students were also encouraged to join an on-line learning website for this course to discuss their questions, which were mainly context-rich. The independent reading reports, challenge questions, and on-line discussions were not compulsory, but students could earn extra credits (< 15% in total) if participating with acceptable performance.

Based on the macroscopic quantitative evaluations of the program, the learning outcomes since the second year (2000) of teaching innovation appeared to be encouraging; the gain in percentages of the constructivist students' achievement in conceptual tests ranged from 12% to 24% compared with 5% to 9% in traditional classes (Chang, 2005a). Meanwhile, the students in the constructivist classes gave significantly positive responses about the teaching performance as well as about their learning achievements (Chang, 2005a).

Methodology

The data of this study were from seven open-ended questionnaire surveys throughout the five years of implementation. Details of the surveys are listed in Table 1.

Table 1. *Time, purpose, and number of participants of the seven surveys from 2000 to 2004*

Survey code	2000A	2000B	2001A	2001B	2002	2003	2004
Time of the survey	11/2000	10/2001	4/2002	10/2002	4/2003	4/2004	11/2004
Number of participants	106	106	112	137	108	156	111
Purpose	Midterm exam reflections	Post semester reflections	Midterm exam reflections	Post semester reflections	Midterm exam reflections	Midterm exam reflections	Midterm exam reflection

Each year, different groups of students responded to the questionnaire survey, while the repeated investigations within the same year comprised of the same cohort of participants. For example, 2000A and 2000B were based on the opinions of the same group of students.

The questions for the midterm examination reflection included the students' reflection on their learning commitments and strategies as well as suggestions for improving the teaching design, namely, assessment orientation, teaching content, and teaching approaches. The post-semester surveys asked the students to comment on the strengths and weaknesses of the overall course.

To analyze the results of the seven open-ended surveys, the students' opinions are grouped with respect to three aspects: (1) the interactive teaching approach, (2) the adoption of real-life teaching content, and (3) the open-form assessment policy. The categories were selected based on three reasons, (1) the key features of the researcher's teaching program, (2) the foci of the students' comments, and (3) the trends of physics teaching innovations found in the literature (e.g., Redish, 1996). Some responses reflect the students' perceptions and attitudes towards the course overall rather than being focused on one aspect. These comments are categorized into their main concerns according to the author's interpretations of the individual's overall comments.

Finally, quantitative analysis of the positive /negative opinions ratio was applied to reveal the trends of students' satisfaction with the teaching design and performance within the five years of investigation and modification.

Results

The results showed both positive and negative opinions throughout the program. Many of the criticisms form opposing ends to the positive appraisal, which was found to dominate. The results are described as follows.

1. Interactive teaching: Stimulating thinking vs. Insufficient Knowledge background;

First, with respect to the teaching approach, while many students expressed their appreciation that the constructivist teaching successfully stimulated their thinking, a few students were concerned about the unsatisfying teaching performance. For example, Stimulating thinking

- I appreciate that the group discussion has made learning physics alive, which is very different from the rote-learning skill that I used to adopt. (2004)
- The worksheets for (group) discussion help us a lot to promote thinking. (2004)
- The instructor is good at inducing us to think step by step. (2002)
- (The physics class) provides us with time for group discussion, allows me to listen to what others think as well as to stimulate myself to think more. (2003)

Insufficient Knowledge background

- I want to know more about the background of the principles and formulas but the content is trivial and is presented as unrelated pieces. (2001A)
- The pace of the lecturing seems too fast; the explanations need to be clarified further. And I hope that more exercises could be introduced in class. (2002)
- Some assignments are too hard to solve. Even after reading the solutions, I still have difficulty understanding. Hope that the instructor can explain them briefly in class. (2003)

The responses of students at both ends of the continuum indicate that while constructivist teaching highlights the role of cognitive engagement and overcomes unfavorable preconceptions (based on the personal constructivist view), instructors need to be aware of mediating the students with thorough background knowledge, which is an essential foundation for facilitating effective reasoning (based on the social constructivist view). Therefore, instructors need to grasp the optimum point between inspiring thinking and providing sufficient background knowledge.

2. Interactive teaching: Facilitating conceptual comprehension vs. ineffectiveness;

Second, some students regarded the interactive teaching as beneficial to their conceptual comprehension in contrast to concerns about the ineffectiveness of the teaching in terms of learning achievement. For example,

Facilitating conceptual comprehension

- (I like) the open-form teaching, which is completely different from the "baby-feeding" way of teaching in high school. It can make people understand more about the principles, not just the complicated mathematical derivations… I have learnt a lot from it (2000B).
- I like group discussion, because we can examine whether we really understand the reasons or not through discussion (2001A).
- he group discussion and the demonstration facilitate our understanding of meanings of the formulas, no need to keep reciting. Group discussion makes us notice how much we know. (2003)

Ineffectiveness

- don't like group discussion because we may become even more confused through this kind of discussion. (2001A)

- Some group members lack background knowledge or are hard to communicate with. I wish to join a group with active members (2002)
- I like the teaching focusing on conceptual clarification, but suggest reduction of group discussion. It wastes too much time and the teacher gives incomplete instruction afterwards (while reviewing the answers). (2004)

While the two groups of students expressed conflicting opinions, their comments also imply different views of learning. The favorable group seemed to comprehend more with a complex learning process. On the other hand, the responses of the opposing group indicate that there are barriers to conducting effective discussion, which include insufficient knowledge to conduct effective dialogue and characteristics of group members. These barriers are surmountable by means of better understanding the students' background, and by making modifications to the grouping policy. In line with Heller & Hollabaugh's (1992) notion, grouping a variety of abilities and allowing the students partial freedom in selecting group members were adopted by the author from 2001 (Chang, 2005a). (2001A)

3. Interactive teaching: Encourages independence vs. lack of well-organized information;

Third, some students praised the way in which independence is encouraged by the constructivist teaching approach, whereas the other group indicated their desire to receive well-organized information.

Encourages independence

- I like the time for group discussion, because it is more meaningful to obtain the results from peer discussion than obtaining answers from the teacher. (2001A)
- Physics can hardly be learnt by simply listening. Only by means of discussion, questioning and exploration, can we excel in physics. (2003)
- (I like that) there are questions for us to discuss, to think independently and to learn interactively from the classmates. (2003)

Lack of well-organized information

- The time for instruction allowed me to receive answers. I really like it more than discussion… I am more used to receiving knowledge. (2001A)
- Don't assume that all the students are geniuses; don't keep skipping parts in the handout. Besides, don't ask the students to find the answers of the questions that you don't even know yourself. (2002)
- Maybe I am used to the didactic way of teaching in high school, I feel it is hard to adjust myself to the current way of teaching, but I don't think of it (the interactive teaching) as a shortcoming. (2004)

The students who comprehended the importance of independent learning were more likely to appreciate the efforts of the teacher on questioning, while students who possessed a transmission view of learning focused on the teacher's information presentation. However, the students' skepticism may be alleviated when the quality of the teaching design is improved to allow the students to comprehend the outcomes of the program soon after commencement.

4. Interactive teaching: Cultivating a supportive atmosphere vs. classroom disorder;

Fourth, the atmosphere of the classroom is also an issue of concern to some students. Both positive and negative comments were found. For example,

Cultivating a supportive atmosphere

- A good feature of the class is that it is vivid and lively. It lets us have space for thinking, not like the monotony of high school physics. (2001A)
- I appreciate the committed attitude of the teacher and the relaxed classroom atmosphere because I think a good classroom atmosphere is very important to learning. (2001B)
- I like teaching that lets the classmates discuss and explore the questions in-depth, which also makes the classroom full of laughter and joy. And everyone likes the physics lesson even more. (2003) (2001A)

Classroom disorder

- The group discussion is quite helpful. We learn a lot from thinking and sharing different ideas. But sometimes the order of the classroom is quite poor. I hope that the students can maintain order. (2000B)
- The teacher is conscientious about teaching, but sometimes the attitude of dealing with knowledge seems to be frivolous. (2000B)

In order to induce the students' motivation to participate in discussion, cultivating a supportive atmosphere may be important for teachers. The attempt to manage a friendly atmosphere may affect the classroom organization negatively, or may even change the students' image of the teacher. Such opposing opinions have not been found since 2001, indicating an improvement in the teaching performance.

5. Real-life examples: cultivating reasoning vs. confusing answers;

With respect to the modification of the teaching content, plenty of real-life examples were introduced by reducing the mathematical derivations of problems and formulas. Many students regarded the modifications as more meaningful than their previous learning, whereas the open-form questions may have increased the difficulty for the instructor to clarify the conceptions. For example,

Cultivating reasoning

- (I like) the everyday life questions; they are unusual and novel, (which) can stimulate our reasoning ability. (2000B)
- The teacher can reduce the calculation stuff even more and reduce the time spent deriving formulas because they limit the scope of learning, simply working on numbers. I think physics is to cultivate thinking and understanding of our everyday life. (2001B)
- The interesting and real life mini labs introduced in class are very inspiring. (2003) The discussion questions are very good. They are relevant to daily life and good for promoting thinking. (2004)

Confusing answers

- The teacher is sometimes too subjective to accept students' answers when those do not match her thoughts. (2001B)
- I don't like the instruction after discussion, because I can't understand. Sometimes the answers are irrelevant to the questions, hardly explaining the questions. (2001A)
- While explaining the real-life examples, I found it lacked structure, preventing me from absorbing the material. (2002)
- What impresses me is the process of demonstrations, but in the end the concepts of the underlying principles remain confusing. (2004)

From the students' responses, the real-life questions seemed to be effective in cultivating reasoning. However, real-life phenomena could involve alternative interpretations or entail multiple variables, which may be beyond the teacher's anticipation. This may increase the complexity of the teaching while reviewing the students' answers. Meanwhile, verbal interpretations of real world phenomena could be more profound than mathematical derivations, and thus be difficult for the students to understand. Therefore, teachers need to be aware that adoption of everyday life examples greatly increases the teaching demands of both content knowledge and instruction skills (Maclsaac & Falconer 2002), such as how to avoid directly rejecting students' responses when their answers are unfavorable.

6. Real-life examples: promoting motivation vs. lowering course standards;

Many students noted that the real-life examples have promoted their interest in learning physics, but a few students were concerned that the reduction of practicing problems may be harmful to the standards of the course. For example,

Promoting motivation

- Adopting everyday life examples to explain physics theories makes me feel fresh and benefits learning. (2002)
- The discussion questions are very good. Because they are everyday life examples, they allow us to realize that physics principles are embedded in many interesting phenomena. (2003)
- The instructor introduces a lot of everyday life examples, thus demonstrating the value of learning physics. (2004) (2000B)

Lowering course standards

- The strength is that the class is vivid and appealing! But I would hope that the examination questions could provide more calculation problems in order to merge the physics concepts into calculations, not just dealing with new physics concepts plus high school problems. Otherwise, everyone is just playing around with what we already knew. (2001B)
- Most of the teaching content is relevant to life, and thus reduces the calculation part in return. I feel it is different from my previous learning, which had many practice calculations. Perhaps this is the style for university learning, but it makes me feel that the learning is a bit in vain. (2001B)

- I feel that the level we are dealing with in the class is far below what appears in the (textbook) problems. I feel discouraged while encountering the difficulties of solving problems. (2003)

According to the quotes, the opposing group did not deny the affective value of introducing real-life examples. However, the reduction of traditional problems and mathematics seemed to raise their concerns about the standard of the course. Complex-forms of mathematics may be more convincing to many people as an indication of the high standard of the course than verbal interpretations of physics concepts. In reflecting on these criticisms, incorporating real-life examples with formulas may help to demonstrate the standard of the course as well as effectively facilitate knowledge construction (Buncick et. al., 2001). The students' criticisms have triggered gradual modifications to the author's ongoing teaching innovations (Chang, 2007). (2001B)

7. Assessment: prefer vs. dislike the open-form assessment;

During the constructivist teaching, the researcher also introduced some open-form assessment in addition to the traditional examinations. These optional alternative assessments included answering challenging questions, independent reading reports, and discussing issues on the teaching web. The students expressed their attitudes about the different types of assessment. For example,

Prefer open-form assessment

- Reading reports should have the same weight as the examinations. A university education should cultivate students' independent learning abilities, otherwise, we will only know how to sit examinations. (2000A)
- I hope that the teacher can provide us with more 'challenge questions', as they stimulate my thinking. (2001B)
- (I like) the supplemented teaching materials and challenge questions, because they can cultivate our thinking ability. (2003) (2002)

Dislike open-form assessment

- (I don't like) 'challenge questions', because I don't understand and have no idea at all. Although it is optional I still feel uncomfortable if I don't respond. (2001A)
- I don't like the optional assignments, because the teacher is too objective, forcing us to spend too much time on those questions which make me feel very stressed. (2001A)
- The questions for on-line discussion should provide more hints, otherwise we don't know where to start. (2002)

The students who appreciated the open-form assessments were more concerned with the considerations of developing their learning abilities rather than knowledge accumulation. On the other hand, the opposing students may have felt incapable of facing the cognitive challenges or may possess passive learning attitudes. In reflecting on the notions of social constructivism (Driver, et al., 1995; Roth, et al., 1997) and the students' criticisms, the researcher has gradually modified the questions mainly by supplementing more hints to guide effective reasoning (Chang, 2005a).

8. Assessment: increasing the difficulty/workload vs. frustrating/overwhelming with the difficulty/workload;

It was found that the students gave disparate responses about the assigned workload. One side expected to increase the difficulty and/or quantity of the workload, while the other felt the course was frustrating and/or overwhelming. For example,

Increasing difficulty/workload

- The weakness of the course is giving too few assignments. Some students, who genuinely want to learn more, may find it difficult to select some more problems to practice. (2000B)
- The examination is too easy, it hardly distinguishes between levels. Students learning attitudes are passive. It would be helpful if the teacher could increase the difficulty and quantity of assignments. (2000B)
- If the examination questions appear to be the same (as what we have discussed in class), it reduces the discrimination. I suggest that the examination can involve a few questions which incorporate many conceptions but are not too complicated. (2004)

Frustrating/overwhelming

- There is too much homework. In addition to the assignment (of problem-solving) given every week, the teacher also gives quizzes and reading reports, and asks us to discuss questions on the course website. Although some of these are very appealing, the workload is far too much. (2001A)
- I had reviewed similar questions, but still don't know how to start to answer the examination questions. I have reviewed the handouts over 6000 times, but can still hardly grasp the key points. (2001B)
- Too difficult! I agree that the examination can include some conceptual questions. But not everyone can comprehend the principles of everyday life phenomena. (2002)

The opposing opinions highlight the challenge for teachers to find an appropriate balance to the assigned workload to satisfy most of the students. The backgrounds and attitudes towards learning varied widely amongst students in the same class. Meanwhile, teachers need to have an in-depth grasp of the students' learning pace in order to find the fine line between providing stimulating challenges and undermining the students' confidence.

9. Conflicting views;

Lastly, conflicting views were not only found from different students, but also some individuals had conflicting opinions about the course. Some responses were found to include both positive and negative perceptions with respect to the overall innovative teaching design.

- I appreciate that the lessons provide time for group discussions, but the explanations of the formulas and exercises are insufficient. (2000A)
- (I don't like) discussion. I don't really dislike it, but since I don't have creative thinking, I am afraid that while others have already thought of a lot, I still have no idea at all. I am scared that I may behave like a good-for-nothing person sitting in class. (2001A)

- Every lesson has surprises and makes me feel impressed because the instructor uses a lot of equipment. However, to explain these phenomena often requires many extra formulas which make me confused. (2003)
- The instructor has used a lot of equipment to facilitate our understanding and to reinforce our concepts. But sometimes after the lesson, I still feel confused about the key points. (2003)
- (With respect to the real-life questions), if you give the questions (repeatedly) in the examinations, everyone will simply recite the answers. That is meaningless. However, if you introduce the challenge (novel) questions in the examinations, students may find them overwhelming. (2004)

While the students appreciated the features of the innovative teaching, including the adoption of interactive teaching and context-rich questions, they were also concerned about the coverage of the information provided and the degree of learning comprehension. These opinions highlight the complexity and sophistication of conducting an innovative teaching program, as well as providing specific suggestions for continuing improvement.

10. Quantitative analysis of positive/negative ratio

Since the author has taken the students' comments as important guidance to continuously modify her teaching, as illustrated above, it would be meaningful to examine whether the action of continuous teaching modification has alleviated the proportion of negative comments towards the constructivist teaching. Occurrences of positive and negative comments about the teaching, and the percentages of the positive/negative comments to the sum of both were calculated and are presented in Table 2. The transition of the proportion of the opposing opinions is illustrated in Figure 1.

Table 2. *Occurrence and percentages of positive and negative comments towards teaching design/performance during the five years of survey*

Survey codes	Occurrence of positive comments (%)*	Occurrence of negative comments (%)
2000	97 (73%)	35 (27%)
2001A	76 (66%)	39 (34%)
2002A	90 (68%)	43 (33%)
2003	151 (76%)	49 (25%)
2004	104 (79%)	28 (21%)
*%: indicates the ratio of positive comments to the sum of positive and negative comments		

Figure 1: The comparison of the proportions of positive and negative comments in the five years of investigation

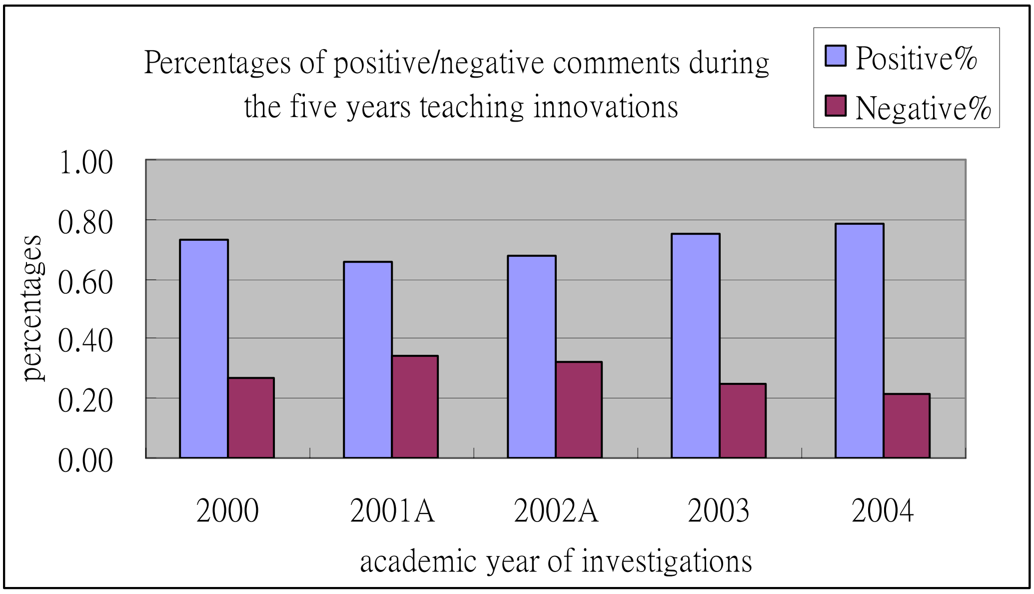

Table 2 and Figure 1 show a trend of slight improvement during 2001 to 2004, i.e., the percentages of negative comments has gradually reduced while the positive comments have increased. However, responses in 2000 appear to be (slightly) less skeptical than in the years 2001 and 2002. Most of the students who made negative comments also provided positive comments. Therefore, they might have disagreed with some of the teaching design but they did not reject the course overall.

As discussed above, the students' criticism may provide valuable messages for the instructor to modify his/her teaching to better suit most students' preferences. However, opposing opinions may be inevitable due to the discrepancy amongst individual student's ability, learning disposition, and expectations of the course. Therefore, the existence of a small proportion of negative comments should be acceptable.

Conclusion and Implications

Summarizing the results, the students' skepticism about constructivist teaching can be grouped into two types: the improvable and the controversial.

The improvable issue was the dissatisfaction with the teaching performance while using constructivist teaching methods. This included the discreteness of the teaching content, the frustrations experienced when confronting real-life questions, and the lack of details and structure in the instructions. All sorts of student complaints highlighted the complexity of adopting constructivist teaching (Roth, 1996). Throughout the implementation of the program, the researcher was aware of the challenges in the constructivist teaching program and put more effort into all aspects required for teaching preparation. In addition to reviewing the teaching content, teaching preparation involves the development/modification of real-life conceptual questions, re-organization of teaching sequences, investigation of students' backgrounds and learning attitudes, and even one-to-one interviews with skeptical or passive students. Some of these efforts may be unnecessary for traditional lecturing, but could be greatly beneficial to the outcomes of constructivist teaching.

The second type of criticisms are controversial, including raising issues about developing cognitive abilities or content coverage, conceptual clarifications or problem-solving practice, challenging vs. frustrating, enjoyable vs. frivolous, encouraging independence vs. insufficient support, etc. Possible reasons for the conflicting stances include (1) students' attitudes towards university study: genuinely expecting to learn vs. just for earning the required credits, (2) students' beliefs about the learning process: active construction vs. passive reception, (3) students' perceived priorities of their learning goals: development of learning ability vs. accumulation of knowledge, and (4) background knowledge in previous learning: insufficient vs. overwhelming difficulties/workload. The conflict may become significant if the students are more diversified, which is beyond the control of the teacher. However, teachers may still gradually grasp the optimal points to alleviate the conflicts. By means of accumulating experience in constructivist teaching, teachers may obtain better insights into the students' knowledge background, preferences for topics, and favorable strategies, which provide crucial information for on-going modifications of the innovative teaching program.

The results of this study have some implications for teaching practice dealing with the constructivist teaching reforms.

Firstly, this study reveals the complexity of the implementation of the teaching reform. The difficulty of implementing constructivist teaching is much greater than that of didactic teaching (Maclsaac & Falconer, 2002). The success of constructivist teaching depends on frequent responses from students, which are not easy to obtain in Taiwan. This finding is in accordance with Bell and Cowie's assertion (2001, p. 65) that uncertainty and risk-taking are two of the characteristics of formative assessment.

Secondly, this study found that novel challenges might emerge when the teacher tries to eliminate weaknesses. While real-life examples seemed to be appreciated by most of the students, a few were concerned about the standard of the course, the completeness of interpreting the phenomena, and the coverage of the topics. While many students criticize the didactic way of teaching in high school, some of them may not be prepared to learn independently.

Thirdly, the students taught using constructivist methods were also found to have a deeper comprehension of the learning process and outcomes, and as a result, became more critical than those in traditional classes. Several studies indicate that constructivist teaching is beneficial to developing students' perceptions of learning, in terms of independence in learning, coherence of concepts, and cognitive engagement (Chang 2005b; Elby, 2001). However, the outcomes of promoting the students' cognitive commitment in one aspect may result in the students being more critical in another. The students' criticisms/suggestions, such as requesting the integration of several concepts in designing examination questions, may be rarely found amongst students used to traditional teaching. The finding of the current study is coherent with Buncick et al.'s (2001) study. The students' criticisms may provide the teacher with important messages for improvement on the one hand, whereas the minor skepticism may also result in creating tension for the instructor, or even in undermining the willingness of the instructor to continue to implement the innovative teaching.

This study also highlights the significance of the open-form qualitative research methods. Through the open-form investigation, multiple perspectives of the students' opinions towards teaching and learning could be comprehended. Minor students' responses may hardly alter the statistical assertions, but they might have a vital impact on the instructor and/or their peers in real classrooms. Hence, in order to obtain in-depth understanding of the students' perceptions, qualitative studies are suggested. This study has highlighted the potential challenges that a constructivist teacher may need to confront. These challenges are more likely to occur in the early stages of the implementation. A variety of barriers may need to be faced and overcome before the teacher can enjoy the sweetness of the expected positive learning outcomes of the constructivist teaching design.

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