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ABSTRACT

This study investigated the impact of different teaching styles on students' perceived effective learning strategies, and students' perceived learning goals for a university physics course. Participants included 55 students taught by an education researcher (the author) based on a constructivist view of learning, and 51 students taught by a physicist. Students' responses showed that the main features of the constructivist teaching, in comparison with the physicist's, included a reduction in teaching time spent on mathematical derivation, the introduction of challenging questions to stimulate thinking, and providing time for discussion. Results indicated that the constructivist group seemed to place higher value on facilitating learning engagement, whereas the physicist's students seemed to place more value on information presentation regarding effective teaching strategies. The students' perceived effective learning strategies appeared to be consistent in both groups, while their perceptions distorted significantly regarding obtaining good grades and understanding concepts. With respect to the goals of the course, the constructivist students ranked more highly both developing thinking to focus more on knowledge accumulation. Suggestions regarding the implications of these findings for instruction are then discussed. (Author)

The Impact of Constructivist Teaching on Students' Perceptions of Teaching and Learning

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The impact of constructivist teaching on students' perceptions of teaching and learning

Abstract

This study investigated the impact of different teaching styles on students' perceived effective learning strategies, and students' perceived learning goals for a university physics course. Participants included 55 students taught by an education researcher (the author) based on a constructivist view of learning, and 51 students taught by a physicist. Students' responses showed that the main features of the constructivist teaching, in comparison with the physicist's, included a reduction in teaching time spent on mathematical derivation, the introduction of challenging questions to stimulate thinking, and providing time for discussion. Results indicated that the constructivist group seemed to place higher value on facilitating learning engagement, whereas the physicist's students seemed to place more value on information presentation regarding effective teaching strategies. The students' perceived effective learning strategies appeared to be consistent in both groups, while their perceptions distorted significantly regarding obtaining good grades and understanding concepts. With respect to the goals of the course, the constructivist students ranked more highly both developing thinking ability and promoting interest in learning, while their counterparts seemed to focus more on knowledge accumulation.

Suggestions regarding the implications of these findings for instruction are then discussed.

Introduction

In recent years, the development of the constructivist view of learning has resulted in modifications of teaching design in many science classes (eg, Hewson, 1981; Osborne and Wittrock, 1985; Posner, Strike, Hewson and Gertzog 1982). The modifications involve not only a change of teaching methods, but, are more likely to bring about a revolution in the culture of classrooms, including the behaviors of teachers and students, as well as the goals of the course (Wubbels & Brekelmans, 1997). In other words, a constructivist innovative teaching program normally implies modification of teaching tasks/strategies, learning tasks/strategies, and criteria of learning achievements. Based on the constructivist view of learning, it is suggested that the teachers' role shifts from knowledge provider to learning facilitator, and that the student's role shifts from information collector to active participator (Hewson and Thorley, 1989; Roth, McRobbie, Lucas and Boutonne, 1997). Meanwhile, the focus of learning achievement may be broadened from merely knowledge accumulation to personal development, including attitudes of learning and adoption of learning

strategies (Cross and Angelo, 1992; Donald, 1993; Gibbs,1995).
However, while a teacher may have implemented an innovative teaching program, which appears to be more meaningful and effective to him/her, will the students feel the same way? Will the students' previous learning experiences in traditional teaching impede the implementation of teaching innovation. The literature has addressed the importance of students' perceptions on the outcomes of teaching design (eg, Hammer, 1995). Halloun (1997) found that the more consistent the students' and lecturers' perceptions were regarding learning physics, the better these students performed in university physics. The success of an innovative teaching program is based on favorable perceptions of the students towards the teaching design (Fraser & Wubbels, 1995).
Meanwhile, the development of students' perceptions of learning and teaching is regarded as one of the goals of education, as their perceptions can determine the students' learning strategies and commitments for ongoing learning (De La Harpe & Radloff, 2000; Trigwell and Prosser 1991).
The objective of this study was to examine whether a constructivist innovative teaching approach would result in shifts in the students' perceptions of teaching and learning, in comparison with their peers under a conventional teaching approach. The context of this study is a university physics course in Taiwan.

Research Questions

The research questions of this study can be grouped into three areas.
The first area is about teaching performance and strategies. How did the students perceive their professors' teaching performance, and which teaching strategies were perceived as important? Did the students' perceptions reflect what the professors emphasized in their teaching?
The second area is about learning strategies and learning engagement. How did the students evaluate their own learning engagement? How did they perceive the effective learning strategies either for obtaining good grades or for understanding physics concepts? Did the constructivist teaching encourage the students to adopt more meaningful learning and/or develop their perspectives towards learning tasks/strategies?
The third area is about the learning outcomes and teaching goals of the course. How did the two groups of students evaluate their learning outcomes from the course, and what did they perceive as the most important goals of the course?

Rationale

There are three main reasons for this study based on the literature:

Firstly, learning physics is both a social practice as well as an individual cognitive process (eg, Salomon & Perkins, 1998; Duit & Treagust, 1998). Learning physics is much more complex than simply transferring knowledge from the instructors' brain to the students', and "piling it up" in their memory (Osborne & Wittrock, 1985). Meanwhile, learning physics is not simply an individual cognitive activity, but rather, it involves social participation and practice in order to be acquainted with the culture and the "way of seeing" of the science community (O'Loughlin, 1992; Scott, Asoko & Driver, 1991). A combination of personal constructivist and social constructivist views of learning is more fruitful than the transmission view, in order to describe students' learning in physics. The learners' cognitive engagement, emotional influence, and social interactions may all influence their learning outcomes (Pintrich, Marx & Boyle, 1993; Strike & Posner, 1992).

Secondly, the literature in science education has highlighted the importance of students' beliefs of learning and science knowledge in the outcomes of science learning (eg, Prosser, Walker and Millar, 1996). Students' epistemological beliefs are critical to determining their foci and strategies for learning physics (Hammer, 1995). Recent literature suggested that students' epistemological beliefs can be influenced by their learning experiences with respect to different teaching designs (Bell, 1999), while, many studies found that the conventional teaching in university physics seemed to encourage a tendency towards an objective view of knowledge and dependent learning strategies (Redish, Saul & Steinberg, 1998).

Thirdly, the literature has suggested that the goals for university physics combine with the goals of higher education in general. The teaching goals of the course can be summarised as: (1) knowledge goals, focusing on better comprehension rather than an increase in physics concepts; (2) intellectual capability goals, cultivating the ability for description, selection, representation, inference, synthesis and verification; (3) learning attitudes goals, enhancing students with positive attitudes towards physics and learning in general; (4) belief goals, encouraging a transition from behaviorist -objective commitments to constructivist-sociocultural perspectives (Donald, 1993; McIntosh, 2001).

The above discussion of the rationale highlights the significance of this study. The mismatch between the conventional teaching design and the goals of university physics may fail to demonstrate the goals, and encourage an adoption of superficial learning strategies (Biggs, 1987; Kember, Ng, Tse & Pomfret, 1996). The didactic teaching approach may fail to engage students in learning participation, and enhance their objective commitment of science knowledge and transmitted view of learning (Roth & Roychoudhury, 1994). Meanwhile, Strike & Posner (1992) suggested that university study may be a critical time for students to develop their epistemological beliefs. Therefore, it is worthwhile to examine the students' perceptions towards learning university physics under a constructivist teaching model and a comparatively conventional design.

Methodology

This is a self-reported study. The researcher is a physics associate professor at Feng-chia University, a large private university in Taiwan.

The data of this study includes a student questionnaire survey and student interviews. The questionnaire survey was conducted near the end of the semester, and was completed by one constructivist class taught by the researcher, and five traditional classes taught by different instructors. The questions comprised three dimensions, namely, the students' perceptions of teaching performance /strategies, learning strategies/engagement, and teaching goals/learning outcomes of the course. The survey was anonymous and given out by the researcher's assistants. The results of the closed questions showed that one of the five traditional classes (class TD) gave significantly more positive responses to the dimension of teaching performance/ strategies than the others, appearing to be more comparable with those of the constructivist teaching. The researcher thus decided to only compare class TD with the constructivist class (class CT).

The constructivist teaching design included three features: providing context-rich conceptual questions, engaging students in small group and whole-class discussion on the conceptual questions, and greatly reducing the teaching time spent on mathematical derivations. The in-class discussion took about 1/4-1/5 of the teaching time, and the focus of the teaching was shifted from solving exercises/end-of- chapter problems to concept clarification. Students' perceptions of the features of the teaching design were also investigated in order to examine the consistency between how the researcher intended to implement the design and how the students perceived it.

The student interviews were processed by the end of the academic year. The author interviewed the physicist's students and a research assistant interviewed the author's students. Eight students from each group were interviewed based on random selection of various academic performances. In order to encourage willingness of participation and honesty in the responses, all the participants were informed that the results would not be disclosed to their instructors before the grading process was completed in order to eliminate the students' hesitations.

Results

The findings of this study can be discussed in three parts: teaching performance/strategies, learning strategies/commitments, and learning achievement/goals.

Teaching performance and strategies

Firstly, the study examined the students' evaluation of teaching performance/ strategies to reflect on their perceptions of the features of the teaching design. The results of the closed questions are listed in Table 1, which show that the constructivist teaching placed more emphasis on providing challenging questions to stimulate thinking, encouraging students to participate in discussion in class, and being aware of learning outcomes while teaching, than the traditional teaching, while the latter spent more time on derivation of formulas and problems. Both teachings were found to be consistent in introducing life examples as well as showing demonstrations.

Table 1. Students' evaluation of teaching performance/strategies

Questions	Agreement %		One-tail t-test
	CT	TD	
1. Providing lucid and systematic lecture	82	86	n.s.
2. Emphasis on derivation of formulas or problems	27	76	TD, $P<0.001$
3. Being aware of learning outcomes while teaching	98	65	CT, $P<0.001$
4. Providing challenge questions to stimulate thinking	91	55	CT, $P<0.001$
5. Introducing examples in everyday life	98	90	n.s.
6. Showing demonstrations, which are related to physics	80	88	n.s.
7. Encouraging students to participate in discussion in class	98	35	CT, $P<0.001$

n.s.: not significant for both groups at $p=0.01$

Consistently reflecting the researcher's attempts, the efforts of engaging students in thinking and discussion seemed to receive more agreement from the constructivist students in comparison with those of the other class. This implies that the instruction of the traditional class is still dominated by didactic teaching, focusing on presenting information. Meanwhile, the physicist's teaching appeared to introduce as many everyday life examples and demonstrations as the researcher's. This used to be regarded as an agenda of innovation in physics instruction, but is not a significant feature of the constructivist teaching. However, based on the high agreement percentages of the constructivist class in providing challenging questions compared with the students of the physicist's class, the two instructors may have very different reasons for introducing the everyday life examples. The researcher's strategy of designing these examples/demonstrations to be embedded into discussion questions might not have been adopted by her colleague.

In addition to the evaluations of teaching performance on different strategies, the survey also asked the participants to choose the 2-3 most important strategies for exemplar teaching, to investigate the students' priorities regarding effective teaching strategies. The results are tabulated in Table 2, and appear to be discrepant in several dimensions.

Table 2. Students' perceived effective teaching strategies

Questions	Selected % CT	Selected % TD	X2 value	Probability of significance
1. Providing lucid and systematic lectures	70	69	0.33	n.s.
2. Emphasis on derivation of formulas or problems	11	22	5.82	TD>CT, P<0.01
3. Being aware of learning outcomes while teaching	36	35	0.3	n.s.
4. Providing challenging questions to stimulate thinking	40	29	1.83	n.s.
5. Introducing examples from everyday life	79	80	0.72	n.s.
6. Showing demonstrations, which are related to physics	23	37	6.89	TD>CT, P<0.01
7. Encouraging students to participate in discussion in class	40	23	4.59	CT>TD, P<0.05

The physicist's students seemed to have greater appreciations of demonstrations and mathematical derivation than the constructivist students, while the latter group placed more value on encouraging students' participation in discussion. Meanwhile, the strategies of the constructivist teaching in reducing mathematical derivations and encouraging discussions were both found to be appreciated by the students in the constructivist class.

In addition to the statistical analysis of closed questions, the responses of the open-ended questions and interviews may provide deeper insights into the students' perceptions. The two groups have both consistent responses and divergent points of views.

A major consistent response for both groups was praise for the introduction of life examples and/or showing demonstrations, since they promote interest or are "mind-refreshing", as well as reinforcing memorization of physics concepts. For example:

> (The instructor) utilizes examples in everyday life to explain physics principles, which is appealing (TD).
>
> (Please) introduce more examples in everyday life, because it is quite fun (CT).

I feel much enthusiasm about learning physics, every time when we are discussing the life examples (CT).

However, disparate opinions between the two groups were also found. The physicist's students placed most value on showing demonstrations and teaching thorough mathematical derivation, referring to them as "verifying" or "showing" physics theories. Meanwhile, while related to the features of the class, the students' descriptions were found to focus on teaching performance, eg, introducing, explaining, deriving, showing...., rather than learning participation. Although a few traditional students seemed to praise the adoption of brief pauses in lecturing to elicit students' responses during class, they seemed to regard the strategy as subsidiary to lecturing. The students' responses imply their epistemological commitments to the positivist view of physics knowledge and the transmission view of learning. For example:

The teacher introduced a lot of life examples and experiments to verify the principles found in the textbooks (TD).

The mathematical derivations can help me understand the meaning and the reasons of physics principles (TD).

The instructor emphasizes derivation of formulas, which I think is important...it makes the formulas more acceptable. They (formulas) are the same as mathematical theorems; you must give some evidence in order to convince people to believe them (TD).

The teacher will ask us whether we understand or not (while teaching), thus he can give further explanations when necessary (TD).

The teacher will give questions to let us think, but the students just respond indifferently (TD).

I don't agree with adopting more of the (questioning and discussing) method. It is too hard to design questions which fit well to our background (TD).

(Although) I feel the (questioning and discussing) method is quite good, the teaching time is very limited. The teacher has already omitted many chapters (due to time constraint). I would regret missing more fantastic lectures more of this (teaching method) was adopted (TD).

The above quotes indicate that the major strengths of the course perceived by the traditional students are in the aspect of teaching performance. However, the students' appreciation of teaching performance hardly seemed to link to learning engagements. The students' positivist view of physics knowledge and transmitted view of learning may contribute to, or be enhanced by, the lack of interaction between teaching and learning.

On the other hand, the constructivist students seemed to express some important messages that were absent from their counterparts. The two major features of teaching performance that the constructivist students praised were the introduction of life examples and adoption of questioning/discussion in class, which appeared to be interwoven with each other. The teaching design seemed to benefit the learning outcomes of promoting interaction, inspiring thinking, and facilitating conceptual construction. The positive appraisal of their own learning engagement, found amongst the comments of the constructivist group, was hardly found in their counterparts' comments. In addition, despite the drastic deduction of time spent teaching mathematical derivation of formulas, quite a few of the constructivist students still argued against the need for derivation, which may imply their skeptical attitudes towards the positivist view of physics knowledge. For example,

> Discussing everyday life conceptual reasoning questions is excellent; (I) prefer to (have the chance) to think a lot (CT).
>
> (I love) the flexible teaching style, which is completely different from the baby-feeding teaching in high school (physics), enabling students to understand the principles, rather than (dealing with) complicated calculation (CT).
>
> The teaching of everyday life examples released me from the rote-learning adopted in high school. It was so painful (learning) in high school, (but) now the (learning in) university physics is interesting and fun (CT).
>
> (I love) small group discussion, because the answers which come from peer discussion are more meaningful than those given by the instructor (CT).
>
> Through (small group) discussion, I can discover my own weaknesses, as well as correct others' (conceptual) defects - very enjoyable (CT)!
>
> (I love) small group discussion, because (through it, I) can learn various ideas towards the same phenomenon perceived by different people (CT).
>
> Small group discussion helps the people like me a lot, who are too shy to ask the teacher questions in public (CT).
>
> (I don't like) mathematical derivation, because throughout the tedious derivations, we still simply obtain the final results, which don't have much meaning in terms of the physics concepts (CT).

The above quotes indicate that the strategies of introducing everyday life examples through questioning in constructivist teaching were beneficial to learning engagement and achievements. The constructivist students' appreciation of cognitive engagement, and the process of actively constructing/modifying their understanding of physics concepts are in accordance with the key notions of the personal constructivist view of learning (Duit & Treagust, 1998). With respect to obtaining physics knowledge, the authority of the instructor seemed to be weakened, while peers and the learner her/himself gradually took place of the instructor. Meanwhile, the constructivist students' respect of alternative interpretations and the limited value they placed on logic verification, implied their epistemological beliefs had shifted from the objective-positivist to the constructivist view of physics knowledge (Hammer, 1995).

Besides, the study found that the teaching design may not only have influence on the students' perceptions of effective teaching strategies, but also have an impact on shifting the students' epistemological beliefs of knowledge development as well as their views of the learning process.

In addition to the impact of the perceptions of effective teaching strategies and epistemological beliefs, the teaching design may have influence on the students' learning strategies, which will be examined as follows.

Learning strategies and commitments

Firstly, the students were asked to self-evaluate their learning engagement, and the results are listed in Table 3.

Table 3. Students' self-evaluation of learning engagement

Questions	Agreement %		One-tail t-test
	CT	TD	
1. Concentrating on listening to lectures	64	61	n.s.
2. Engaging in thinking in class	76	39	P<0.01
3. Participating in discussion in class	73	31	P<0.001
4. Attending the class only for roll-call	7	14	n.s.
5. Often discussing physics questions with peers or instructors	40	22	P<0.01
6. Often practicing solving-problems after class	13	14	n.s.
7. Often trying to clarify physics concepts	67	45	n.s.
8. Memorizing formulas without understanding	51	55	n.s.

Table 3 shows that the constructivist group has engaged more in thinking and discussing than the traditional group. In class, thinking and discussing seemed to be major learning engagements for the constructivist students, while their counterparts seemed to limit their learning to listening to the lectures. There were no significant differences between the two groups engaging in lower-level learning strategies, ie, listening to the lectures, willingness of attendance, and rote learning.

The high learning engagement in thinking and discussing of the constructivist class as found in the answers to the closed questions was consistent with the responses in the open-ended questions quoted previously.

The study also investigated effective learning strategies as perceived by the students. The meaning of so-called "effective strategies" may range divergently in terms of obtaining good grades and conceptual comprehension. Despite the differences in learning engagement between the two groups, the responses appeared to be consistent regarding their perceived effective learning strategies. Both groups of students distorted their perceived effective learning strategies in a similar way considering grades and comprehension.

Both groups of students responded that thinking and discussing seemed to be crucial to conceptual comprehension, while reciting formulas and practicing solving problems were regarded as beneficial to grades. The distortion of perceived effective learning strategies between aiming for better grades and comprehension found from this research is consistent with Elby's (1999) study. Although the constructivist teaching seemed to promote the students' commitments in deep learning strategies in class, ie, thinking and discussing, the students still did not abandon the adoption of superficial strategies because of their consideration of grades. Therefore the assessment design of the constructivist teaching might need further modifications, emphasizing reasoning rather than fact-recalling (Redish, Saul & Steinberg, 1998).

Table 4. Students' perceived effective learning strategies

Questions	One-tail X^2 test between CT & TD teaching		McNemar test between grades & comprehension	
	grades	comprehension	CT	TD
1. Concentrate on listening to lectures	n.s.	n.s.	n.s.	n.s.
2. Engage in thinking in class	n.s.	n.s.	comprehension P<0.01	comprehension P<0.01
3. Participate in discussion in class	n.s.	n.s.	comprehension P<0.01	Comprehension P<0.01
4. Attend the class only for roll-call	*	*	*	*
5. Often discuss physics questions with peers or instructors	n.s.	n.s.	comprehension P<0.05	n.s.
6. Often practice solving-problems after class	n.s.	n.s.	grades, P<0.001	grades P<0.001
7. Often try to clarify physics concepts	n.s.	n.s.	n.s.	n.s.
8. Memorize formulas without understanding	n.s.	*	grades, P<0.001	Gades P<0.001

*: invalid for X^2 tests due to zero frequencies

The results of the student interviews indicated that although most of the constructivist students regarded the everyday life conceptual questions as challenging when first introduced in class, similar questions may greatly lose their cognitive demand when appearing again in examinations. Regardless of the researcher's efforts to modify questions when designing examinations, many of the students felt that the everyday life conceptual questions simply required memorization.

Learning Outcomes/ Goals

Thirdly, the study investigated the achieved learning outcomes through students' self-assessment, and the priority of learning goals perceived by the students. The self-assessed learning outcomes comparing the two groups are tabulated in Table 5.

Table 5. Achieved learning outcomes self-assessed by students

Questions	Agreement %		One-tail t-test
	CT	TD	
1. Promoting understanding of physics concepts	80	55	CT>TD, P<0.01
2. Cultivating thinking and reasoning ability	80	45	CT>TD, P<0.001
3. Enhancing mathematical ability	18	43	TD>CT, P<0.01
4. Adoption of flexible learning methods	64	33	CT>TD, P<0.01
5. Establishing a knowledge basis for advanced study	33	47	n.s.
6. Promoting interest in learning physics	69	41	CT>TD, P<0.01
7. Reinforcing my confidence in learning physics	42	25	n.s.
8. Informing knowledge on life application	93	88	n.s.
9. Learn nothing from the course	2	12	n.s.

Table 5 shows that the students in the constructivist group were more satisfied with their learning achievements in many aspects, including comprehension of physics concepts, thinking and learning ability, and interest. The outcomes of the constructivist teaching are particularly significant in cultivating students' thinking ability. However, the traditional students seemed to achieve more on mathematical skills than the constructivist group. The modifications of the constructivist teaching design, a reduction of mathematical derivation, and the adoption of the questioning and discussing approach might have influenced the learning outcomes.

The next step is to investigate the priority of learning goals for university physics as perceived by the students, in order to examine whether the two groups of students valued what they achieved and de-valued what was neglected. The students were asked to select 2-3 items from the learning outcomes as the most important goals, and the comparison between the two groups is listed in Table 6.

Table 6 shows that the two groups seemed to have different foci regarding learning goal priorities. The constructivist group focused on cultivating thinking ability and promoting learning interests, while the traditional group placed more value on knowledge basis of advanced study and life application. In other words, the constructivist group valued the development of learning ability and attitudes, while their counterparts viewed learning as mainly to accumulate knowledge. Meanwhile, both groups seemed to agree that mathematical skills are a trivial goal for the university physics course, which underpins the strategy of reduction of mathematics in constructivist teaching. In summary, the strategies of constructivist teaching seemed to help students achieve what they valued through the reduction of what they praised the least.

Table 6. Priorities of learning goals perceived by the constructivist and the traditional students

Questions	Selected % CT	Selected % TD	One-tail X^2 test
1. Promoting understanding of physics concepts	80	73	n.s.
2. Cultivating thinking and reasoning ability	82	69	CT, $p<0.01$
3. Enhancing mathematical ability	4	10	n.s.
4. Adoption of flexible learning methods	17	8	n.s.
5. Establishing a knowledge basis for advanced study	13	33	TD, $p<0.001$
6. Promoting interest in learning physics	43	20	CT, $p<0.001$
7. Reinforcing confidence in learning physics	7	4	n.s.
8. Informing knowledge on life application	50	80	TD, $p<0.001$

In addition to the results of the closed questions, the responses of the open-ended questions were also found to be in accordance with the above assertion. For example,

> The teacher often brings scientific toys and life examples to show us the application of physics, which can accumulate our knowledge in everyday life (TD).
>
> The teacher should list all the key points of the whole year course (content), so that we can learn it effectively (TD).
>
> I don't like the traditional examinations, because the physics course should emphasise the interpretation of natural phenomena, not get stuck on testing formulas and solving problems. The physics course should emphasize the learning process, otherwise we still only know how to take examinations (CT).
>
> (I appreciate the fact that) the teacher would give us novel questions and let us learn from searching for information. Also the everyday life questions can inspire our reasoning ability (CT).

The responses found from some constructivist students stressing the development of learning ability through the learning process, were scarcely found amongst the traditional group, whose concerns seemed to focus on knowledge accumulation and learning effectiveness. The neglect of the learning process by the traditional group implies their behaviorist commitments, while some of the constructivist students have shown a shift from behaviourist to constructivist commitments regarding learning goals of physics (Duit & Treagust, 1998).

Conclusion and Discussion

In conclusion, the results of this study indicated that the teaching design seemed to have a certain degree of influence on the students' perceptions of the learning process. After three months of teaching, both the physicist and the researcher seemed to successfully convince their students respectively that their different teaching foci were valid or even valuable to help learn physics, which may contribute to the students' perceptions of their roles as learners in class as well as their epistemological beliefs of physics knowledge.

The constructivist teaching, which provided time and questions to induce students' thinking and discussing in class, was likely to benefit the students' learning engagement. In contrast to the physicists' students, the constructivist students seemed to take an active role in participating in the physics class, and regarded the teaching design of engaging learning as crucial. Meanwhile, through the discussion process, some of the constructivist students expressed the negotiation of the meaning of their understanding of physics conceptions and appreciating alternative interpretations from peers, which indicated a change in their epistemological beliefs from objective-positivist perspectives to social-constructivist perspectives (Roth & Roychoudhury, 1994). Compared with their counterparts, the constructivist students seemed to place more value on the development of learning ability and attitudes rather than knowledge considerations, which might be contributed to the shift in their epistemological beliefs. In short, the constructivist teaching seemed to guide the students towards coherent perceptions of constructivism, including perceptions of learning and teaching, epistemological beliefs, and perceived priorities of learning goals.

On the other hand, the traditional students' responses seemed to remain limited to teaching performance when describing their perceptions of the class. Providing opportunities and stimulation to engage learning participation by instructors seemed not to be an issue of concern, regardless of whether the students' responses were favorable or unfavorable towards the current teaching design. The physicist's students seemed to regard teaching to engage learning as impractical, ineffective, or even unfeasible. In addition, the appreciation of teaching performance and commitments appeared to be irrelevant to promoting learning engagement. Although many students may not feel satisfied with their learning outcomes, most of them seemed to see nothing wrong with the didactic teaching approach. The responses implied that the physicist's students' hold perceptions of the transmitted view of learning, which may be enhanced by the learning experiences of didactic teaching (Roth & Roychoudhury, 1994). Meanwhile, the physicist's teaching, which stressed mathematical derivation of formulas as well as showing demonstrations, highlighted the crucial role of "verifying physics theories" to the students, and thus enhanced the students' positivist beliefs of physics knowledge (Redish, Saul & Steinberg, 1998; Roth & Roychoudhury, 1994).

However, despite the differences summarized above, the two groups appeared to possess the same perceptions towards effective learning strategies. Although the constructivist group seemed to devote more time to deep-level learning strategies in class, and perceived them as meaningful methods, they did not abandon superficial learning strategies, which seemed to be beneficial to their grades. The adoption of deep learning strategies may not necessarily lead to the abandonment of superficial learning strategies, as noted in Biggs' (1987) study. The results provided the researcher with an opportunity to reflect her assessment design, which may need to be modified further in order to encourage meaningful learning as well as discourage superficial learning. While many researchers criticized the problems provided in physics textbooks as simply requiring "plug-in" formulas, and suggested more meaningful conceptual questions to enhance cognitive challenge for the students (Zajchowski & Martin, 1993; Di Stefano, 1996), this study found that the goal of reasoning-orientation in assessment design may require tremendous efforts to fulfill. Thus, it would be worthwhile to put efforts into investigating the impact of innovative assessment design on students' learning strategies, and the search for ways to facilitate deep-level learning.

The results of this study have several implications for physics teaching in practice. Simple modification of teaching content, or introducing teaching aids cannot help to facilitate learning engagement. Providing time and challenging questions to discuss appeared to promote the students' learning participation in class, as well as to lead to better learning outcomes, including conceptual comprehension and affective learning outcomes (Gautreau & Novemsky, 1997; Hake, 1998). The learning experience of engaging in thinking and discussion may help to demonstrate the significance of cognitive participation in class.

In a macroscopic aspect, this study has indicated the significant favorable attitudes of the constructivist students towards the innovative teaching design. However, there is a small group of students, identified in their responses to both the closed and open-ended questions, who still possessed traditional perceptions/beliefs, ie, a positivist view of physics knowledge and transmitted view of learning. This minority of students was likely to argue against the time spent discussing as a waste of time, and to criticize the teaching as ineffective. How to eliminate these students' hesitation becomes an important task for teaching innovators. The skeptical students' opinions may provide critical clues to help the innovators, and thus are worthwhile to investigate in further research. The task is crucial to teaching innovators, not only to promote the students' willingness of learning participation, but also to eliminate the instructors' tension while teaching caused by the negative attitudes from these students.

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