Science and Mathematics Education Centre

Learning Physics in a Taiwanese College Classroom:

A Constructivist Perspective

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Declaration

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university. To the best of my knowledge and belief, this thesis contains no material previously published by any person except where due acknowledgement has been made.

Signature:

Date:

Abstract

The purpose of this study is to use a constructivism as a referent to investigate how students learn physics in a Taiwanese career college classroom. Forty-nine first year, engineering major first students participated in this study of teaching and learning in my college level classroom. The theoretical framework for the study was based on the five dimensions of the Constructivist Learning Environment Survey (CLES) (Taylor & Fraser, 1991: Taylor, Fraser & White, 1994; Taylor, Fraser & Fisher, 1997), namely Personal Relevance, Student Negotiation, Shared Control, Critical Voice, and Uncertainty. These dimensions were employed as analytic themes to examine the qualitative data.

A total of six lessons were observed: two lecture classes, two laboratory practice sessions, and two group discussion sessions. My qualitative observations, supplemented by video- and audio-recordings, of these six lessons were used to produce six classroom narratives. These six narratives were analyzed individually and then comparatively using a cross case analysis whereby the five dimensions of the CLES were employed as analytic themes. The CLES questionnaire was administered at the commencement of the semester and again at the end of the semester in order to determine any quantitative changes in students' perceptions of their classroom environment. The various analyses were used to make several propositions about the constructivist nature of my classroom. I conclude the study with a discussion of the implications of the study and my reflections on the thesis experience.

The study found that, in my Taiwanese career college physics classroom, (a) the teacher plays a central role in establishing the overall classroom learning environment, (b) student group dynamics are important in the classroom learning environment, (c) the central role of content often works against the establishment of a constructivist classroom, (d) cultural factors play a large role in determining the constructivist nature of the classroom, (e) language plays an important role in the construction of the learning environment, and (f) the students’ learning attitude affected the classroom environment.

Acknowledgements

Most of my university-level education has been in the pure sciences and I have a master's degree in physics. I have found that learning science education is quite different from learning physics. I have experienced the struggle and adjustment in confronting a new domain of learning. At same time, I also received extensive support and help from people who surround me. Here, I wish to express my sincere appreciation to those who have supported and assisted me in conducting my doctoral research.

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Chapter 1: Introduction

Introduction

This study employs a constructivist framework to examine my own teaching and my students' learning in my Taiwanese college physics classroom. The study utilizes the theoretical frameworks of the Constructivist Learning Environment Survey (CLES) (Taylor & Fraser, 1991: Taylor, Fraser & White, 1994; Taylor, Fraser & Fisher, 1997) as analytic tools to critically examine my classroom learning environment. Two kinds of data are collected, quantitative and qualitative. The CLES questionnaire was administrated twice — at the commencement of a semester of work and at the end — to generate some quantitative measures of student perceptions of their environment. Qualitative data, in the form of observational records, and field notes were use to construct six narrative accounts of key episodes or lessons (two involving lectures, two laboratory activities and two student discussions). Each narrative was analyzed in the first instance to identify pertinent teaching and learning issues. The five theoretical frameworks of the CLES – personal relevance, student negotiation, shared control, critical voice, and uncertainty — were then used to conduct a cross-case analysis of the six narratives and the questionnaire data. In the final chapter, I draw from the analyses to develop several overarching propositions about the constructivist nature of my classroom in a Taiwanese context, concluding with the implications of the study and my reflections on the thesis experience.

Background

Like many others worldwide, children in Taiwan start their education at the age of six. They are educated under a system of 6-3-3-4, that is, six years of primary school, three years of middle and high school, and four years of university education. The primary and middle school education is compulsory and is supported by the government. In the last year of middle school, students who wish to be educated in high school are required to take a Regional Examination. The results from the Regional Examination determine which high school students will enter. A National Examination is required again at the third year of high school for tertiary education.

At the same time, vocational education is offered after middle school for students who are more interested in improving their technical ability to obtain employment. Typically, vocational students are not accepted into a normal high school because they do not obtain adequate results in the Regional Examination. Career colleges of technology are available to those students who graduate from vocational high schools and desire to further their studies (Lee, 2000).

General Physics is required in the first year of college in Taiwan for students who are majoring in Engineering. General Physics, which includes mechanics, heat, optics, and electrics, provides a foundation of professional knowledge for Engineering majors. To succeed in the course, students need a sound understanding of mathematics and high level of logical reasoning. General Physics aims to provide students with the knowledge they need for their specialty and to skill them with reasoning training for later in their career. This study takes place in the context of such an environment — a Taiwanese career college-level General Physics classroom.

Theoretical Framework

Theories about the teaching and learning of science have undergone many changes of the past 50 years (Bodner, 1986; Duit & Treagust, 1998; von Glasersfeld, 1995). Wallace and Louden (1998) assert that there are two streams of theories about the construction of science knowledge in recent waves of curriculum "reform" — philosophy of science and cognitive science. One stream of theories, informed by philosophers of science, such as Lakatos and Popper, proposes that "knowledge is not discovered but rather constructed within communities of like-minded people" (Wallace & Louden, 1998, p. 475). From this view, science is seen as " imperfect and imperfectible" (p. 476). The other stream, informed by the cognitive science, asserts that the science knowledge that students possess is possibly a misconception and therefore needs to be perfected.

Much research has contributed to our understanding of constructivist teaching and learning in recent years (Anderson, Holland, & Palincsar, 1997; Geelan, Wildy, Louden, & Wallace, 2004; Jang, 2007). Among these studies there are three prominent lines of thinking about constructivism. They are radical constructivism (Hardy & Taylor, 1997; von Glasersfeld, 1996), critical constructivism (Taylor, Dawson, & Fraser, 1995), and socio-cultural constructivism (Anderson et al., 1997; Novak, 1998b). Radical constructivists suggest that learners go through a "dissatisfaction" (Posner et al, cited by Taylor, 1996) phase before realizing that scientific concepts can be more "intelligible", "plausible" and "fruitful" (Taylor, 1996, p.156). Another group of researchers, critical constructivists, assert that we learn by exposing ourselves to an atmosphere that has been emancipated from repressive cultural myths, environmental constraints and political agendas (Taylor, Dawson, & Fraser, 1995). Discursive activities can be thought-provoking while communicating with others in a relaxed and free manner. The situation in which learning can take place under an emancipated environment involves social events. The sociocultural constructivists find that science knowledge develops by engaging in social activities, sharing problems or tasks (Driver, Asoko, Leach, Mortimer, & Scott, 1994). Driver et al. (1994) also assert that knowledge can not be constructed solely and individually. Duit and Treagust (1998) suggest that under social-constructivist views, knowledge is ‘distributed’ and ‘shared’ rather than being the property of individuals.

As a response to the constructivist movement, Peter Taylor and his colleagues developed the Constructivist Learning Environment Survey (CLES) (Taylor & Fraser, 1991: Taylor, Fraser & White, 1994; Taylor, Dawson & Fraser, 1995; Taylor, Fraser & Fisher, 1997). The CLES employs the theories of critical constructivism to assess students’ perceptions of their learning environment when constructivism is used as a referent in teaching and learning. The questionnaire contains five scales, Personal Relevance, Uncertainty, Critical Voice, Shared Control, and Student Negotiation. The five scales are described as follows (Aldridge, Fraser & Taylor, 2000, p. 39)

- Personal Relevance (Learning about the World) – the extent to which teachers relate science to students’ out-of school experiences
- Student Negotiation (Learning to Communicate) – the extent to which opportunities exist for students to explain and justify to other students their

newly developing ideas and to listen and reflect on the viability of other students' ideas

- Shared Control (Learning to Learn) – the extent to which students are invited to share with the teacher control of the leaning environment, including the articulation of their own learning goals, design and management of their learning activities and determining and applying assessment criteria
- Critical Voice (Learning to Speak Out) – the extent to which a social climate has been established in which students feel that it is legitimate and beneficial to question the teacher's pedagogical plans and methods and to express concerns about any impediment to their learning
- Uncertainty (Learning about Science) – the extent to which opportunities are provided for students to experience scientific knowledge as arising from theory dependent inquiry, involving human experience and values, evolving and non-foundational, and culturally and socially determined

While the notion of constructivism has been widely applied in other educational settings, its use in primary, middle, high school (Chung, 1998; Tsai, 2000; Tsai, 2005) and in career colleges in Taiwan is relatively recent. In this study I aim to use the theoretical underpinnings from the five CLES scales to conduct a critical analysis of my classroom learning environment from a constructivist perspective. I am interested in several aspects of this topic. For example: What are the reasons for my students' perceptions of their learning environment? To what extent do I provide students with opportunities to compare their personal knowledge with formal scientific knowledge? To what extend do I encourage students to improve their relationships with other students and with me? To what extent do I provide the opportunities for students to co-construct the curriculum? and How are my actions and my students' responses affected by cultural factors? These and other related questions form the basis for this thesis.

Research Objective

To use constructivism as a referent to investigate how students learn physics in my Taiwanese college classroom

Methodology and Methods

This research is a case study of my own classroom — employing a constructivist framework to critically examine my teaching and my students' responses and perceptions of their classroom learning environment. The study is largely qualitative. Erickson (1998) defines the aim of qualitative research "…to document in detail the conduct of everyday events and to identify the meanings that those events have for those who participate in them and for those who witness them" (p. 1155). This study will help me understand more in depth how my teaching strategies affect my students but also how social activities affect their learning through sharing, talking, and cooperating with me and with others.

Data collection

The participants in my study consisted of one class of Engineering major students (n = 49) in the first year of college. I documented the actions and events in my classroom across different activities — including lectures, laboratory sessions and group discussions. In particular, six classroom episodes or lessons (spaced at intervals across the semester) were be carefully observed and recorded. Each episode was video-recorded as well as audio-recorded. Field notes also were written for every lesson and I also kept a reflective journal.

To supplement the qualitative data, a Chinese language version of the CLES (Aldridge et al., 2000) was administered to students at the beginning and again at the end of the semester to obtain a quantitative measure of their perceptions of the classroom learning environment.

Data analysis

Data from the six classroom episodes were reviewed and constructed as six narrative accounts. In this process, called narrative analysis, "researchers collect descriptions of events and happenings and synthesize or configure them by means of a plot into a story or stories" (Polkinghorne, 1995, p. 12). Following Polkinghorne's suggestion, I analyzed the observational data of video-tapes, listened to the audio-tapes, and also referred to the field notes in writing the narratives. My presence in the narratives was as both participant and a researcher; therefore, the narratives were written in the first person.

I then analyzed the six narratives, first individually and then comparatively as a cross-case analysis. Polkinghorne describes this technique as paradigmatic analysis (analysis of narrative) or "description of themes that hold across the stories or in taxonomies of types of stories, characters, or settings" (p. 12). The comparative, cross-case analysis utilized the theoretical frameworks from the five CLES subscales — learning about the world, learning to communicate, learning to learn, learning to speak out and learning about science — as analytic tools to interpret the six narratives and the questionnaire data.

Drawing on these analyses, I offered several overarching propositions about the constructivist nature of my classroom, drew some implications for practice, and reflected on my experience in conducting this research.

Ethical Issues

For this research I sought and obtained written permission from the president of the college and the written consent of the students in my class. All data collected in this study will be stored in a secure place for five years after the study is completed. Any identifying information was removed to protect the confidentiality and anonymity of the participants, and pseudonyms used throughout.

Significance

The study is significant at several levels. Firstly it will inform my practice, as I will become more aware of the factors affecting my teaching and my students' learning, and build my capacity to improve my physics teaching. Secondly, and consequently, it will hopefully assist my students' understanding of physics and its applications. And finally, this thesis will be available to inform the wider community of educators in Taiwan and elsewhere about the application of constructivist principles in teaching and learning.

Limitations

This research is limited by the context within which it was conducted, a Taiwanese college level physics classroom. It is also understood that I came to this work with my own background, preconceptions and theoretical frameworks. With these limitations and biases in mind I will be describing and analyzing the particulars of my own classroom, to enable others in similar circumstances to learn from my experience.

Thesis Structure

The thesis will be organized into six chapters as follows:

Chapter One: Introduction summarizes the background, theoretical framework, methodology and methods, ethical issues, significance and limitations of the study.

Chapter Two: Literature Review provides a background discussion on education in Taiwan, reviews the literature on constructivism and outlines the theoretical framework for the study based on the scales of the Constructivist Learning Environment Survey (CLES).

Chapter Three: Methodology and Methods describes the methodological rationale for the study, and details the techniques used for data collection and analysis.

Chapter Four: Narrative Analysis draws on the qualitative data to present six narrative accounts of teaching and learning and provides an analysis of each narrative.

Chapter Five: Cross-case Analysis draws from the narratives and the questionnaire data to present a comparative cross-case analysis.

Chapter Six: Propositions, Implications and Reflections presents six overarching propositions, implications for practice and my final reflections.

Chapter 2: Literature Review

The aim of this thesis is to examine how constructivism operates in the context of a Taiwanese college level physics classroom. In this chapter I provide a background to education in Taiwan, review the literature on constructivism and outline the theoretical framework for the study based on the Constructivist Learning Environment Survey (CLES).

Constructivist theory proposes that knowledge is constructed in each individual’s mind by drawing on his or her pre-existing knowledge. People make decisions about what to do base on whether new knowledge fits with what they already know. Knowledge construction takes place in various environments, among different people, and in diverse circumstances. It is not limited by age, gender, race, religion, environment, or activity. Constructivism, as a theory about how people learn, can be used as a useful referent for teaching.

Taiwan commenced a major education reform initiative in 1994. The reform aimed to reduce the emphasis on the National Examination for those students who wished to have an advanced education. The reform was also expected to promote a better quality learning environment for children (Wu, 2006). The five goals of the educational reform were to: provide a liberal education with diverse learning experiences, produce more thoughtful students, provide an alternative pathway for higher education, enhance educational quality, and promote lifelong learning (孫仲山 & 吳思達, 2006). Within this context, constructivist mathematics instruction

(CMI) was seen as a way of moving teachers away from the prevailing pedagogy of didactic instruction and repetitive exercises. Students who entered elementary school after 1996 were exposed to aspects of CMI in mathematics education, and the practice has been subject to many research studies (Wu, 2006; 翁秉仁, 2005).

Several factors appear to contribute to the effectiveness of CMI. It appears that student learning will be facilitated if a teacher is sympathetic towards a constructivist epistemology (Marra, 2005; Taylor, 1996; Tsai, 1999). However, it was found that parents were not always happy with the CMI approach. Chung (1998), who played a role of a specialist in education, and is the mother of an elementary child, David, who was educated in the CMI system, described the suffering that she and David had gone through. David struggled with the pace of constructivist mathematics teaching, and was more comfortable with traditional teaching approaches. David and Chung felt that CMI was being imposed on them. Chung concluded that constructivist approaches should be implemented with great care. She argues that no single instructional method, including CMI, is applicable to all students and all classrooms.

Notwithstanding the experiences outlined above, Wu and Tsai (2005) contrasted the effects of constructivist-oriented and traditional instructional practices on students' cognitive development. They found that the constructivist-oriented instruction group obtained better learning outcomes, had a higher capability of monitoring their own process of thinking, and developed more integrated cognitive structures. Wu and Tsai suggested that constructivist-oriented science instruction "facilitate[d] the connections between new conceptions and pre-existing knowledge within learners' cognitive structures and promote[d] the usage of higher order information processing modes" (p. 833) for fifth grade learners. Further, Tsai (2000) studied the perceptions of constructivist learning environment that Taiwan high school students embraced. He proposed that, while students respected the authority of the teacher in facilitating their learning, they enjoyed the learning issues that related to their prior knowledge or everyday applications. Students preferred “more opportunities to interact with others, integrate their prior knowledge, think independently and resolve personally problematic experiences” (p. 201).

Constructivist instruction has also been studied in Taiwanese college physics classrooms. Reporting on the results of a three-year research project, Chang (2005) describes how her constructivist teaching strategies were initially unsuccessful. In the first year of constructivist instruction, she found that students were dissatisfied with her teaching performance and found it difficult to learn physics. During this initial period, some of her students skipped classes, had low commitment to learning, and a lack of learning motivation. In the final two years of her project, Chang adjusted her teaching strategies to enhance her lecturing style, encourage discussions, provide more everyday-life examples, and inspire thinking. With these adjustments students’ academic achievements and learning attitudes improved considerably. Chang found that innovative teaching in the final year of her project provided students with a more meaningful, challenging, and authentic learning environment. The constructivist learning environment enhanced her students’ awareness and learning purpose, and promoted their learning motivation.

In the USA, Bentley (1998) studied a constructivist-based educational reform during the years 1990–1996. Participants included parents, teachers, principals, teacher educators, community members, and educators from informal educational institutions. Institutions involved local elementary schools and regional schools. Bentley purposed four propositions regarding constructivist-based educational reform. First, “time is required for practitioners to reconceptualize their teaching roles and the outcomes of practice, and to engage in activities and processes in which they are both learners and teachers.” (Darling-Hammond and McLaughlin, cited in Bentley, p.246) Second, “curricula and instruction need to be tied to the cultural experience and values of the student – that is, to the child’s world.”(Gardner, cited in Bentley, p.246) Third, “classroom environments conducive to learning are more likely to develop when teachers are engaged in activities such as integrating the subjects, connecting content to applications outside the classroom, using technologies in meaningful ways for significant amounts of time, applying ideas to different situations, thinking critically and creatively about practice, reflecting on experiences, sharing ideas and experiences with others, and working collaboratively in groups.”(Fort; Peck and Dorricott; Villasenor and Kepner, cited in Bentley, p.247) Fourth, “parents, community members, and community resources all must be incorporated into the learning framework.” (Department of Education; Henderson and Berla, cited in Bentley, p. 247)

The aforementioned studies suggest that constructivist-based instruction in Taiwan has some considerable cultural barriers to overcome. In other jurisdictions however there is good evidence from a number of studies (Beichner et al., 1999; Hake, 1998; Meltzer & Manivannan, 2002; Roth, 1998; Roth & Bowen, 1995; Roth, McRobbie, Lucas, & Boutonne, 1997; Tsai, 1999) that, from elementary school to college physics classrooms, students have benefited from a constructivist learning environment. It is important to note, however, that students’ achievement levels is proportional to goal direction, classroom organization and harmony (Fraser, 1994; Roth, 1998).

My own students in freshman college physics classroom displayed characteristics similar to those described by Chang (Chang, 2005; Chang & Bell, 2002), that is, they had a vocational high school background with little formal training in fundamental scientific principles. What is clear, in these kinds of classrooms, is the centrality of the role of the teacher in shaping the classroom environment. As Fraser (2001) said “There is no doubt that the teacher is a central figure in the classroom environment. How the teacher behaves in the classroom determines whether students feel comfortable, happy, threatened or motivated” (p. 4). In this study, I intend to examine my own teaching and the students’ learning in a college physics environment using a constructivist framework as the basis for my analysis. The outcomes of the research will be used to improve teaching and learning in my own classroom, and hopefully, make a further contribution to research about constructivist learning environments.

Constructivism

Over the past century, science education has undergone three stages of reform in keeping with the demands of human civilization. Mintzes and Wandersee (1998a, 1998b) integrated the historical progress into three stages of development, Practicalist, Academic, and Human Constructivism. The Practicalist stage started in the late nineteenth century and continued for several decades thereafter. This was the era of industrialization and urbanization, when society was in transition from agriculture to industry. The essence of the reform was inquiry into the nature of science and essence of knowledge, and the pragmatic application of science. The beginnings of the Academic stage coincided with the Sputnik era of the 1950s. At this time, there was a major effort to nurture outstanding scientists and engineers to regain American’s scientific and technological leadership in the world. Curriculum reform was focused on the development of understanding the nature of science structure and science inquiry. A considerable number of research studies were conducted to investigate the link between learner’s knowledge acquisition and curriculum implementation (Duit & Treagust, 1998). Many of studies showed that these reforms were largely unsuccessful in terms of student outcomes. The scientific concepts held by students were found to be substantially different from the scientific concepts that scientists held (Julyan & Duckworth, 2005; Roth et al., 1997). The third stage of reform, beginning in the late 1970s, is referred to Human Constructivism period. The emphasis during this stage was on the way in which scientific knowledge is constructed.

Four blind people fumble the elephant, one

who touches the trunk says that elephant is like a pipe,

who touches the tail says that elephant is like a rope,

who touches the leg says that elephant is like a tree,

who touches the ears says that elephant is like a fan.

Above is an eastern proverb that illustrates the issue that the image of elephant is such an enormous system to the people who cannot see. For a blind person, experiences of the elephant can be thought of as a series of subjective conjectures.

The blind person has no way of checking the authenticity of the conjectures, and therefore cannot represent the true (as known by a seeing person) image of the elephant. Knowledge, like the elephant to the blind person, is an enormous system, containing a variety of disciplines, feelings, reasoning, interactions etc, for a person to peek at and conjecture, without any way of confirming the authenticity of those conjectures.

Cognitive Constructivism

How do we obtain knowledge? Von Glasersfeld stated that knowledge "could be treated not as a more or less accurate representation of external things, situations, and events, but rather as a mapping of actions and conceptual operations that had proven viable in the knowing subject's experience" (1996, p. 4). "Viable" is an applicable idea, is accomplished effectively, is an action, or is an achievable goal. To attain knowledge, " every result, every type of knowledge was originally a problem which, to exist as such, necessitated a theory and a language, not to mention actors, who could structure and organize it so it was amenable to analysis or, depending on the circumstances, presentable in terms of convincing colleagues of the utmost promise held for setting out the issues" (Meyer, cited in Larochelle & Bednarz, 1998, p. 7).

Piaget, after observed the evolution of snails and children's intellectual development, proposed his famous theory of developmental cognitive structure, assimilation, accommodation and equilibration. Assimilation means to modify the cognitive structure to incorporate the incoming message when external stimuli (including objects, events, perceptions, propositions, and ideas) occur. The pre-existed cognitive concept is restructured to accommodate the external stimuli when incoming stimuli are inconsistent with the concept that already exists in the mind. Internal cognitive structure and external stimuli are interplayed through the processes of assimilation and accommodation in attempt to reach a state of equilibrium, called equilibration. Cognitive concepts develop in the process of successive re-equilibration of assimilation and accommodation. Assimilation and accommodation occur actively and are complementary. A new balanced cognitive structure is achieved through a sequence of spiraling equilibration of experiences and ideas (Duit & Treagust, 1998; Fosnot, 1996; Novak, 1978). Fosnot (1996) suggests that Piaget’s ideas about cognitive sense making are constructivist in nature. Humans develop not “only in a physical, biological sense, but also in a cognitive sense, therefore there is no structure apart from construction” (p. 13). Knowledge is constructed, reconstructed and in this way cognitive structures evolve and are reproduced.

Piaget’s theory of developmental cognitive structure has had a significant influence on science education. However, Piaget’s cognitive developmental theory excludes the existence of pre-existing conceptions and individual contextual variables, “Piaget placed great emphasis on general cognitive functions rather than the structure of domain-specific knowledge” and “failed to account for differences among individuals due to contextual variables or prior knowledge” (Mintzes & Wandersee, 1998a, p. 36). Duit and Treagust (1998) found that a student’s pre-existing understandings often persist in the face of external stimuli and new learning situations. Logical thinking depends on the context of the individual’s scientific knowledge and their prior knowledge. What a student learns therefore is unpredictable.

Von Glasersfeld (1998) proposed radical constructivism to break through the traditional epistemology. According to this view, knowledge represents “true” reality and can be mediated as a commodity from teacher to students, into pragmatic, more relevant to reality, more attainable by children, and, in his words, “can approach a more or less “true” representation of an independently existing, or ontological, reality” (p. 23). Constructivism “aims not at developing a theory of the world but, rather, at elaborating a theory of the organism who creates for him or herself a theory of the world” (Von Glasersfeld, cited in Larochelle & Bednarz, 1998, p. 5).

Four characters of radical constructivism were summarized by von Glasersfeld (1998). First, it is heuristic, is a tangible reality of our experience, not only of the conceptual structures, the actions and the mental operations but also the patterns of thoughts and actions that either have succeeded or failed. Second, cognition operates within the realm of experience, including the segments of experience, orders and results that related to sensorial and pre-existed conceptions. Third, the constructed model is expected to be proven and viable to future events because it is constructed or abstracted rationally from the experience of previous events. Fourth, scientific knowledge is not a unique solution to the problem, it is preferred simply is because it coherent with other understandings.

Von Glasersfeld (1993) states that absolute reality exists but we have no way of knowing it for the reason that we are in the frame of the reality, where the reality “exists by itself prior to our noticing, perceiving, and thinking about it” (p. 25). The image of elephant in the aforementioned proverb, is subjective, is adjusted whenever the environment varies (such as temperature, humidity, jungle or dessert), is varied with different participants, and different goals of actions. As Fosnot (1996) suggested “we as human beings have no access to an objective reality since we are constructing our version of it, while at the same time transforming it and ourselves” (p. 23). While the image of elephant could be agreed through experience sharing, and ideas evoked through discourse, we still cannot confirm whether the reached image represent the "true" image of elephant.

There has been a considerable amount of research into how to enhance students' learning. Hellden and Solomon (2004) examined the longitudinal development of children's conceptual understandings. They interviewed the same children at aged 9, 11, 13, and 15, asking the same question on each occasion. For instance, "What do you think will happen to the leaves on the ground?" What they found was that each individual child provided essentially the same meanings in each interview, albeit expressed in different terms. Core understandings seemed to persist in spite of the children's classroom experiences of learning science. Hellden and Solomon concluded that, answering Gunstone and White's question "Why do (original) beliefs persist in the face of contrary teaching", the earlier episode in memory survives better than new ideas introduced later. Hellden and Solomon asserted that ideas in the mind may decay as time passes but "priming" brings forth nonconscious clues that prompt the memory to recall certain things. That is ideas could be awaken at right time with the right clue to prompt. The study indicates that human conceptions are not easily changed.

There appear to be two pathways of learning with respect to the development of cognitive structures, the continuous pathway – whereby new concepts are introduced with reference to pre-existing concepts, and the discontinuous pathway – where attention is focused on the inconsistency between external stimuli and resident concepts (Duit & Treagust, 1998). Ausubel's famous dictum "the most important single factor influencing learning is what the learner already knows" (cited by Novak, 1978, p. 4) suggests that a new idea is easier to understand and more meaningful when it can be interpreted by pre-existed conceptions. Novak (1998a) found that knowledge learned meaningfully is related to what we know, makes sense out of experience, provides ownership and control of learning, and can be used in a variety of contexts. Knowledge learned meaningfully is retained longer, strengthens learning abilities, facilitates related learning, is applicable in a wide range of contexts (high transferability), and allows for creative thinking. Traditional instruction, which is didactic and rote learning oriented, fails “to support higher order thinking and problem solving while cultivating compliant and superficial understanding” (p. 1).

Conceptual change is a discontinuous pathway, Posner et al. (interpreted by Duit & Treagust, 1998) suggest that pre-existed conceptions will remain unchanged unless new stimuli are proven, intelligible, plausible and fruitful from one’s perspective. Duit and Treagust (1998) stated that conceptual change, “involves major restructuring of students’ already-existing preinstructional conceptions” (p. 11). Conceptual change involves the task of reconstructing resident cognitions to accommodate external stimuli. Learning based on cognitive reconstructing is achieved actively rather than passively, with or without the intention of learning (Jonassen & Duffy, 2000).

Pintrich, Marx and Boyle (1993) state that student’s conceptual change is not driven solely by logic and scientific findings (what they refer to as a cold model of change) but is also affected by the personal interests, motivations, and social/historical processes (a hot model of change). In other words, learners’ motivational beliefs and classroom contextual factors are involved in the process of conceptual change. He proposed four critical issues for conceptual change models to consider. First, that prior knowledge is used to interpret and accommodate new ideas. However, prior knowledge resists to change when their is a discrepancy between existing and incoming ideas. According to Pintrich et al. (1993), students' goal orientation, values, efficacy beliefs, and control beliefs "are likely candidate[s] for conjunction with student motivation in conceptual change instruction" (p. 192).

Second, learners' intentions, goals, purposes, and beliefs drive and sustain the thinking in the process of balancing the biological and environmental forces in the cognitive conceptual ecosystem. Pintrich and colleagues stated that "these motivational beliefs can influence the direction of thinking as the students attempt to adapt to the different constraints and demands placed on them by the tasks and activities they confront in classrooms" (p. 192). Third, four conditions, dissatisfaction, intelligibility, plausibility, and fruitfulness are affected by learners' motivational beliefs. Such as, satisfaction is influenced by value beliefs, personal interest, and situational factors. Intelligibility is related to the depth of cognitive process that learners are engaged in. Depth of learning is related to the level of learners' mastery, interest, and efficacy beliefs. Fourth, it is unreasonable to expect students to learn and to think as scientists do in scientific communities because of the discrepancy between the context of the classroom and the community of scientists. Pintirch and colleagues stated that "even if some students approach school learning as intentional learners with a goal of developing integrated and sophisticated understanding of a field of study, they might not believe that the goals of the schooling enterprise are to foster such understanding" (p. 193).

Overall, conceptual change is not only influenced by the rationality of the incoming ideas but also affected by motivational factors, goal orientation beliefs, interest and value beliefs, and self-efficacy beliefs.

Sociocultural Constructivism

Social constructivism theory can be traced back to the prominent psychologist Vygotsky who believed that learning is a developmental process, and that this development takes place in a social setting.

Instead of believing that knowledge is constituted primarily in cognitive structures and is reconstructed based on prior knowledge that resided in cognitive structure (as in radical constructivism), social constructivists believes that knowledge develops and deploys in people's interactions during social activities (Cobb, 1996; Desautels, Garrison, & Fluery, 1998; Lerman, 1996; Tobin, 1990). Knowledge does not rely on the development of systematic concepts, but rather depends on the social experience that is relevant to the domain knowledge. It is by "legitimat[ing] a plurality of possible answers to significant problems through rational debates that the best type of learning occurs, individually and collectively" (Desautels et al., 1998, p. 254). Knowledge construction is not only a matter of an individual's cognitive constitution but also a matter of interaction within social contexts and within the surrounding contextual cultural environment (Bentley, 1998; Brill, Kim, & Galloway, 2007; Lerman, 1996). Akatugba and Wallace (1999) found that one of the reasons students had problem in learning proportional reasoning of mathematics in Nigeria is that people in Nigerian do not habitually use proportional reasoning in their daily life. Desautels (1998) at el. described "knowledge developed by students in the context of their local culture as viable and genuine" (p. 255). Tobin (1990) also stated science knowledge is "not the thought of one person acting independently of others in the community, but is a result of belonging to a culture, coming to understand life in that culture, and using the language and concepts that emerge within the domain of science" (p. 31).

In explaining how knowledge is constructed through individual cognition relates to the knowledge that constructed in social activities, Tobin and Tippins (1993) stated that "knowledge is both social and individual, a dialectical relationship existing between the individual's contribution to knowledge and the social contribution" (p. 6). Cobb (1996) compared and contrasted the differences between sociocultural theory and cognitive theory by suggesting that cognitive theorists are concerned "with the development of ways of knowing at more of a microlevel, and with the participants' interactive constitution of classroom social norms and mathematical practices" (p. 39). On the other hand, sociocultural theorists "use the individual's participation in culturally organized practices and face-to-face interactions as primary explanatory constructs" (p. 39). Thoughts are influenced by social and cultural processes are "located on the borderline between the organism and the outside world" (Bakhurst, cited in Cobb, 1996, p. 36).

The notion of Zone of Proximal Development (ZPD), proposed by Vygotsky (depicted by Brill et al., 2007; Fosnot, 1996), is the level of potential between being capable and not capable of doing tasks independently. Cognitive Apprenticeship (Brill et al., 2007; Roth, 1993) involves learning under the guidance of the one who knows more in the knowledge domain and is skillful in techniques. Under this method, learners, after repeated practices, become increasingly knowledgeable and skillful, and ultimately reach the higher level of capability. Scaffolding is the mechanism to bridge the student from what he/she already knows to a new domain that he/she was originally not capable of knowing or doing (Fosnot, 1996; Roth, 1993). These are the pragmatic theories that apply in sociocultural constructivist learning. Student's knowledge is elaborated spirally by cognitive apprenticeship and/or through scaffolding to a higher level.

In the process of thinking, communication, reflection, language plays crucial role. Teachers use language to interpret the content of knowledge. Students use the language to think, to elaborate ideas, inquiries, to perform discussion. A common language “can be accessed by all participants to engage the activities of the community with a goal to facilitate the learning of others” (Tobin, 1998, p. 205). Concepts are elaborated into hierarchical levels through dialectical processes until mutual agreements are reached. When two persons reach consistent meanings, they understand each other in shorthand words and gestures to convey ideas and with greater confidence (Tobin, 1998). However learning is impeded when students unable of using their familiar language to learn science, Tobin (1998) called this mismatch between formal classroom language and familiar language “symbolic violence”. Unfamiliarity with semantic representations impedes students from fully understanding the content of learning and from discourse with peers.

Teaching provides a vehicle to assist students to reconceptualize or reconstruct their science knowledge. In constructivist-based learning, the teacher is not the sole source of knowledge, but is an active co-constructor of learning activities to enable conflict resolution, negotiation of meaning, and mutual development of understandings. The teacher also is a learner in the constructivist teaching domain.

Taylor (1996) integrates Habermas’s theory of knowledge construction, and sociocultural constructivism, into three stages: communicative action – whereby the knowledge constructed is deeply involved in cultural elements and mediated by social experience; the practical interest – whereby knowledge is constituted through the process of communication for the purpose of reaching mutual understanding; and the emancipatory interest – whereby knowledge is formed from “self-critical” reflection, in a free classroom atmosphere that with absence of cultural and academic restraints can help students attain intellectual autonomy and social responsibility. The third notion, the emancipatory interest, aims at societal reform and the promotion of discourse to reach reciprocal understandings. Reciprocal understanding involves the rational examination of implicit validity claims such as truth and rightness rather than simply understanding and accepting them. Societal discourse reform also aims at critically examining those disempowered cultural myths inherited from contextual of history and to provide the opportunities to inquire into the process of conversation and critical self-reflection. The emancipatory interest according to Taylor is connected to a version of constructivism called critical constructivism.

Critical Constructivism

Taylor (1996) describes critical constructivism as “a social epistemology that addresses the sociocultural context of knowledge construction and serves as a referent for cultural reform”, and is a “a powerful theoretical framework for making visible and deconstructing repressive cultural myths that distort social roles and discursive practices” (p. 159). To illustrate these cultural myths, Taylor highlights the “cold reason” and “hard control” repressive learning environments that exist in mathematics pedagogy. “Cold reason” is found in those learning environments where it is assumed that knowledge represents the nature of reality and is waiting to be discovered rather than to be invented. Taylor states “the pedagogical implications of this myth include a belief in the certainty of mathematical knowledge which leads to the perception that disembodied mathematical facts are knowable by means of an asocial cognitive activity of pure reason that transcends human lifeworlds" (p. 165). As one who has experienced a cold reason environment, I can see that science and mathematics learning often results in the manipulation of abstract signs and symbols disconnected from everyday life.

"Hard control" results from the assumption that teacher is an expert who, with several years of training, has a picture of reality and knows more about subject knowledge than the student. Therefore teacher plays the role of the authority figure, controls classroom and provides the "correct" answers for students. Under these assumptions, the teacher will typically announce the "correct" answer shortly after a brief discussion. The peremptory announcement not only terminates students' discussion without offering the opportunity for further discussion to clarify the alternative opinions, but also suppresses students' interests in subject content and active learning.

Desautels, Garrison, and Fleury (1998) explore other repressive cultural myths in science education. The essence of scientific factual knowledge, for example, such as the measurement of distance from earth to moon, is often so irrational so that students struggle to make sense of it. Science knowledge, often deemed to represent the nature of reality, is seen as accessible only to those students who are intelligent enough to learn it. This idea of science knowledge as being fixed and immutable, disregards the notion of knowledge as constructed and divergent. It also does not allow for science for all students. Therefore, it is the teacher's obligation to draw students' curiosity and interests in learning activities and to foster students' own scientific way of learning in order to adapt new knowledge. A critical perspective would have teachers help emancipate student from their own biographies,

> …school knowledge is considered as but one of the instruments in helping them emancipate themselves from their own biographies, admittedly a time-consuming but potentially powerful process… a critical-constructivist pedagogy does not rank forms of knowledge, but rather promotes a pluralistic epistemological democracy which favors the enrichment of the field of possibilities for the students through their participation in different knowledge games. (Desautels et al., 1998, p. 256)

In summary, critical constructivism is designed to emancipate students from repressive culture myths and teachers from role of authority figure. Students are empowered through equal discussion with teachers and peers in an open-ended classroom environment. The emancipatory learning environment provides an atmosphere for logical thinking and critical voice to question what teachers are doing, why they are doing, what they think, how they feel, what decisions they make, and which strategy they employ.

Overall, under a constructivist epistemology, knowledge is not a representation of truth or reality, rather it is about pursuing goals or purposes. Knowledge is useful when it is viable in everyday life; is unique in that it exists only in the knower’s mind and can not be separated from the knower; is not an object therefore can not be conveyed from one to other; is mediated in social activities; is co-constructed through participants’ negotiation to reach mutual consensus agreements in the context of the classroom; and is elaborated through the process of discourse, reflection, and critique. Knowledge that learners develop is constructed with the guidance of teachers, parents, or more knowledgeable others who model, coach, scaffold, articulate and reflect back to the learner.

Teachers who use constructivism as referent (Tobin & Tippins, 1993) initiate students’ discourse; provide materials that students demand in learning; encourage students to solve problem; and create a free atmosphere in the classroom for students to interpret their ideas and listen to others. Such teachers clarify inconsistence through discussion. They do not respond immediately when the answer is right or wrong, instead they provide space for students to figure out appropriate solutions (Costa & Liebmann, 1995). The teacher creates the learning environment for students to construct or reconstruct their knowledge through the process of social interaction and negotiation, rather than reproduction. Knowledge is constructed in the process of collaboration with others, in consensus building, and in critical thinking or in the reflection on the experiences of actions, thinking and feelings. Learning is reached through active construction rather passive message input; is willful, intentional, active and conscious.

In this study, social constructivism is employed as a theoretical framework to examine my teaching strategies, students’ learning, and the nature of their learning environment in my college-level physics classroom.

Constructivist Learning Environments

The environment is “what surrounds all of us; we think of it as existing as such, whether we happen to be in it or not” (von Glasersfeld, 1996, p. 5). Von Glasersfeld abstracted two meanings of environment from the constructivist model. From oneself, environment is the totality of permanent objects and all their relations that have been abstracted from our experience. From others, it “refers to the surroundings of the item we have isolated, and we tend to forget that both the item and its surroundings are parts of our own experiential field, not an observer-independent objective world" (p. 5). Both the environment and its interaction with personal characters of the individual are potent determinants of human behavior (Fraser, 1998). Knowledge is formed in the process of abstraction and reflection from the interaction within the context of environment and within the context of students' alternative concepts (Jonassen & Duffy, 2000).

A constructivist learning environment provides for students' natural curiosity and their individual learning styles and pace. Further, a critical constructivist perspective also promotes an ideal speech environment where students are given equal opportunity to converse with peers and with the teacher, and where rational discussion is the norm rather than naïve acceptance of ideas (Taylor, 1996). Jonassen (1994) proposes eight general characters of constructivist learning environments. According to (Jonassen, 1994, p. 35) such environments:

- provide multiple representations of reality;
- avoid oversimplification of instruction by representing the natural complexity of the real world;
- focus on knowledge construction, not reproduction;
- present authentic tasks (contextualizing rather than abstracting instruction);
- provide real-world, case-based learning environments, rather than pre-determined instructional sequences;
- foster reflective practice;
- enable context- and content-dependent knowledge construction;

- support collaborative construction of knowledge through social negotiation, not competition among learners for recognition.

Constructivist Learning Environment Survey (CLES)

In this study, the theoretical rationale of the Constructivist Learning Environment Survey (CLES) (Taylor & Fraser, 1991: Taylor, Fraser & White, 1994; Taylor, Fraser & Fisher, 1997) was employed as a framework to observe the classroom learning environment of a college-level freshmen students' physics classroom. The CLES was designed to assess constructivist-based reform of the classroom learning environment, where the student is a co-constructor of knowledge, and where teaching is designed to facilitate students' conceptual development. In its original form (Taylor & Fraser, 1991), the cultural frame of classroom environment was excluded from the questionnaire, thus supporting only a weak version of constructivist reform. The questionnaire was later revised to include the cultural and emancipatory aspects of constructivism (Taylor, Fraser & White, 1994; Taylor, Fraser & Fisher, 1997). Thus the theoretical underpinnings of the version used in this study are more in keeping with the notion of critical constructivism as espoused by Taylor (1996).

The revised version of the CLES questionnaire has been tested in various countries, such as Australia (Dorman, 2001; Peter C Taylor, Fraser, & Fisher, 1997), Canada (Roth, 1998; Roth & Bowen, 1995), Korea (Cho, 2002; Kim, Fisher, & Fraser, 1999), South Africa (Aldridge, Laugksch, Seopa, & Fraser, 2006), Taiwan (Aldridge, Fraser, & Taylor, 2000), USA (Harwell, Gunter, Montgomery, Shelton, & West, 2001), etc, with sound psychometrical results in each case. The questionnaire has also been translated into other languages, including a Chinese version used successfully in Taiwan by Aldridge, Fraser and Taylor (2000). The CLES also has been used in qualitative studies by employing the five scales as analytical criteria (Marra, 2005; Roth, 1998).

In this study, the scales from the CLES, rooted as they are in the above critical constructivist literature, provide the theoretical framework for my observations. The five scales of the questionnaire are: Personal Relevance, Uncertainty, Critical Voice, Shared Control, and Student Negotiation. Personal Relevance, or learning about the world, examines the connectedness of school science to students' everyday life experiences and the supportiveness of experiential context in developing students' scientific knowledge. Uncertainty, or learning about science, examines how students learn scientific knowledge, in a manner that is evolving, non-foundational, and culturally and socially determined. Critical Voice, or learning to speak out, examines the social climates of the classroom, and the degree to which students feel legitimate and able to question the teacher's pedagogical plans and methods, and are free to express their concern about the impediments to their learning. Shared Control, or learning to learn, looks at the degree to which students are invited by the teacher to set their learning goals, share control in the design and management of activities, and the establishment of assessment criteria. Student Negotiation, or learning to communicate, assesses the opportunities offered to students to express their ideas, listen to the ideas of others, and reflect on the ideas presented in the activities.

In my study, I will use these five theoretical notions as observational and analytical lenses to help me examine critically my own classroom learning environment. I am interested in the degree to which I provide students with the opportunity to share, negotiate, and make meaning as they construct new knowledge.

To what extent do I inspire and encourage students to construct new knowledge? What degree of student autonomy is present in my classroom?

In this research, I will use the five theoretical ideas of the CLES to qualitatively explore these kinds of questions. My aim, here, is to examine the degree to which my classroom reflects a constructivist model through a critical examination of my pedagogical approach and my students’ responses to my teaching.

Chapter 3: Methodology and Methods

Methodology

In this study, I employed both qualitative and quantitative techniques to observe and understand the teaching and learning environment of my college-level physics classroom. Qualitative researchers are interested in the meanings that people construct, and try to understand the phenomenon from the participants' perspectives (Stake, 2006). Qualitative research also "helps us understand and explain the meaning of social phenomena with as little disruption of the natural setting as possible" (Merriam, 1998, p. 5). According to Patton (in Merriam, 1998, p. 6),

> Qualitative research is an effort to understand situations in their uniqueness as part of a particular context and the interactions there. This understanding is an end in itself, …but to understand the nature of that setting – what it means for participants to be in that setting, what their lives are like, what's going on for them, what their meanings are, what the world looks like in that particular setting – and in the analysis to be able to communicate that faithfully to others who are interested in that setting…. The analysis strives for depth of understanding.

In proceeding with my study of my physics classroom, I was trying to gain an in-depth understanding of the situation and meaning for those involved (Merriam, 1998). A case study attempts to reach comprehensive, holistic, and rich descriptive findings, while reflecting the complexity, situatedness, and problematic nature of relationships (Stake, 2006). Stake described case study as, “an arena or host or fulcrum to bring many functions and relationships together for study” (2006, p. 2). Case study is appropriate when the variables that affect the classroom learning environment are difficult to separate (Merriam, 1998). Stake interpreted case study as follows:

> In certain ways, the case is dynamic. It operates in real time. It acts purposively, encounters obstacles, and often has a strong sense of self. It interacts with other cases, playing different roles, vying and complying. It has stages of life – only one of which may be observed, but the sense of history and future are part of the picture. (p. 3)

In contrast, Grbich (2007) suggests that quantitative studies are “generally viewed as deductive, where the conclusion drawn follows logically from certain premises – usually rule based – which are themselves often viewed as proven, valid or ‘true’” (p. 196). By combining qualitative and quantitative data, as I have done in this case study, I hope to improve “the validity of the findings, providing more in-depth data, increasing the capacity of cross-check[ing] one data set against another, and providing other ‘takes’ on [my] data” (Grbich, 2007, p. 197).

In this study, I conducted the case study in order to identify and understand the variables at play in determining the nature of the learning environment in my college-level physics classroom. My research objective is to examine my own teaching and my students' learning using a constructivist framework as the basis for my analysis. I have employed qualitative data in conjunction with the CLES questionnaire data in order to provide "the detail of individual experience behind the statistics…, to help in the development of particular measures", and "to track changes over time" (Grbich, 2007, p. 197).

Theoretical Framework: Constructivist Learning Environment

A constructivist learning environment provides students with a willful, active, authentic, meaningful and emancipated learning environment to assist students to construct and reconstruct their own knowledge. In this case study of my own classroom, I plan to use a constructivist framework as the basis for analysis. To this end I have selected the subscales categories from the Constructivist Learning Environment Survey (CLES) (Taylor et al., 1997) as referents to guide my observations, data collection and analyses. The original version of CLES (Taylor & Fraser, 1991) was based on the psychosocial view that the student should be a co-constructor of knowledge and that the teacher should be concerned with the development of teaching approaches to facilitate students' conceptual development. The more recent version of the CLES (Taylor et al., 1997) was modified to incorporate the cultural dimensions of the learning environment. This cultural frame included factors such as emancipation from cultural myths, awareness of the political repression, the idea that knowledge is constructed rather than received, the liberation of teacher’s authority in the classroom, and the perspective of critical theory. Hence the questionnaire now contains five scales, Personal Relevance, Uncertainty, Critical Voice, Shared Control, and Student Negotiation.

- Personal Relevance (Learning about World) – the extend to which the teacher relates science to students’ out-of-school experience
- Student Negotiation (Learning to Communicate) – the extent to which opportunities exist for students to explain and justify to other students their newly developing ideas and to listen and reflect on the viability of other students’ ideas
- Shared Control (Learning to Learn) – the extent to which students are invited to share with the teacher control of the learning environment, including the articulation of their own learning goals, design and management of their learning activities and determining and applying assessment criteria
- Critical Voice (Learning to Speak Out) – the extent to which a social climate has been established in which students feel that it is legitimate and beneficial to question the teacher’s pedagogical plans and methods and to express concerns about any impediment to their learning
- Uncertainty (Learning about Science) – the extent to which opportunities are provided for students to experience scientific knowledge as arising from theory-dependent inquiry, involving human experience and values, evolving and non-foundational, and culturally and socially determined

The new version of the CLES questionnaire has been tested in various countries, such as Australia (Dorman, 2001; Peter C Taylor, Fraser, & Fisher, 1997), Canada (Roth, 1998; Roth & Bowen, 1995), Korea (Cho, 2002; Kim, Fisher, & Fraser, 1999), South Africa (Aldridge, Laugksch, Seopa, & Fraser, 2006), Taiwan (Aldridge, Fraser, & Taylor, 2000), USA (Harwell, Gunter, Montgomery, Shelton, & West, 2001), etc, with sound psychometrical results in each case. The questionnaire has also been translated into other language, including a Chinese version used successfully in Taiwan by Aldridge, Fraser and Taylor (2000). The CLES also has been used in qualitative studies by employing the five scales as analytical criteria (Marra, 2005; Roth, 1998).

In the remainder of the chapter, I focus the study on how I collected my data, conducted my analyses and integrated my findings to propose several propositions.

Methods

Data collection

The subject of my case study was my college-level physics class located in a large regional city in Taiwan. The class consisted of myself as teacher and 49 students (43 males and 6 females) who were majoring in Electronic Engineering. These students had recently graduated from a vocational high school and this course in physics was held in the first semester of their college studies. At high school, the majority of students had studied electronic engineering, while a few studied printing or art design.

While some students had studied a semester of physics in high school, most had no physics background. Typically high school physics employs rote learning strategies, where students memorize the contents of whatever teacher wrote on the blackboard. Overall, therefore, the physics background of the students in my class was poor. In all likelihood, most students did not see this as a problem, because they did not see physics as being directly related to their future job demands.

Prior to the commencement of the study, I sought and obtained permission from the president of the college. I also informed the students as to the purpose and procedures of the study and obtained their written consent to proceed. All names used in the study are pseudonyms.

My role in this study was that of instructor or teacher. I was therefore a central participant in the case study. At same time I observed the phenomena in the classroom and thus played the role of observer. Merriam described the advantage of being participant-observer by citing Patton’s words:

> Experiencing the program as an insider is what necessitates the participant part of participant observation. At the same time, however, there is clearly an observer side to this process. The challenge is to combine participation and observation so as to become capable of understanding the program as an insider while describing the program for outsiders. (Patton, cited in Merriam, 1998, p. 102)

The physics course is a one-year course, consisting of a weekly three-hour lecture and a three-hour laboratory study. The laboratory study is designed to complement the theoretical ideas introduced during the lecture. The experiments therefore were designed to follow the theories introduced in the lecture classroom. For the purpose of this study, I focused my observations on six classroom episodes, comprising two lectures, two laboratory works, and two group discussions. The physics topics covered during this period included vectors, friction force, conservation of momentum, conservation of energy, and torque. The six observational episodes were evenly spread out through one semester, so as to achieve fullness, profusion and divergent representations of the classroom learning environment. As Stake (2006) points out, the complexity of any case requires observations from a diverse range of situations and times, and as such is more likely to validate the study.

Each of the six episodes, therefore, consisted of a three-hour lecture, laboratory or discussion. All six episodes were video and audio recorded (Wilkinson, 2004) by two of my former students, FonChin and ChiSun (all names in this study are pseudonyms). Prior to formal recording, FonChin and ChiSun practiced recording techniques by setting the video camera at a certain positions, sometimes at the front corner and sometimes at back of the classroom. Merriam (1998) warns that “the act of observation itself may bring about changes in the activity, rendering it somewhat atypical” (p. 103). In this study, I found that after a period of time the students soon became familiar with presence of the equipment and operators and behaved in their “normal” patterns. Since the purpose of study to explore the students’ experience, the observations were focused on one or two persons or laboratory groups in each episode. I chose the focus students and student groups randomly.

Apart from the audio and visual records of the six episodes, I constructed my own field notes of my observations and impressions of each episode. The field notes were written immediately after each of the activities, following Merriam's suggestion "not to talk to anyone about the observation before notes have been recorded" (1998, p. 105). The notes were as detailed as possible and included the time of the activity, the weather of the day, student attendance records, my impression of the learning atmosphere, examples of my interactions with the students and interactions among students, selected comments made by students, after class interactions, a summary of each activity, and my reflections on the experience.

In order to obtain a quantitative measure of students' perceptions of the classroom learning environment, I administered the Chinese version of the CLES (Aldridge, Fraser & Taylor, 2000). Such quantitative data — which examine the variables from "the majority point of view" (Merriam, 1998, p. 6) — were used as a means of triangulating with the qualitative accounts. The questionnaire was administered to students on two occasions, at the beginning of the semester and at the end of the semester (English and Chinese versions of the CLES are provided in the Appendix). Mean pre and post-unit scores on all five sub scales as well as Cohen's effect sizes (Coe, 2002) are provided in Chapter 4.

Data analysis

Narrative analysis

Data from the six classroom episodes were consolidated and re-presented as six narrative accounts. The six narratives were constructed iteratively, by watching and listening to the video-recordings, reading my field notes. Narrative was employed as “an organized linguistic interpretation of a sequence of events of which involves attributing agency to the characters in the narrative and inferring causal links between the events” (Murray, 2004, p. 113). It reveals our experiences and priorities (Grbich, 2007, p. 124). According to Polkinghorne (1995) narrative “draws together diverse events, happenings, and actions of human lives into thematically unified goal-directed processes” (p. 6) and “provide[s] an understanding of [the] idiosyncrasy and particular complexity” (p. 15) of an episode.

In my six narratives, I attempted to explore why particular events occurred in order to help the reader understand how the occurrence could have come about (Polkinghorne, 1995). In writing my narratives, I tried to capture the essence of the events — in rich, thick, holistic descriptive and pragmatic terms (Merriam, 1998; Polkinghorne, 1995; Stake, 2006). The narratives are intended to provide reader with an insightful understanding of the learning environment as well as offer me the opportunity to experience, through linguistic interpretation, what students perceived about my physics classroom.

From narrative analysis to analysis of narrative

After the six narratives were written, they were analyzed in the first instance by repeated reading. According to Stake (2006) “a case study is both a process of inquiry about the case and the product of that inquiry” (p. 8). He refers to the importance of identifying “issues” (p. 9) to reflect the complex, situated, problematic relationships of the case studies. Hence in analyzing each of the narratives, — what Polkinghorne (1995) refers to as analysis of narrative — I attempted to tease out the various issues embedded in the case, using my own perspectives, opinions and experiences to examine how and why the events came about, interpret the contextual cultural evidence from narratives, depict the unusual incidences in the narratives, and reason about student’s behavior. These issues were described under a series of headings, including my teaching strategies, students’ learning attitudes, student cooperation, the interaction between teacher and pupils, training outcomes, group performances, and group learning attitudes.

From narrative to cross case analysis

After the analysis of each individual narrative, I attempted to find the common relationships among the six narratives through a cross-case analysis (Merriam, 1998; Stake, 2006). According to Miles and Huberman, when conducting a cross case analysis, “Simply summarizing superficially across some themes or main variables by itself tells us little. We have to look carefully at the complex configuration of processes within each case, understand the local dynamics, before we can begin to see patterning of variables that transcends particular case” (Miles & Huberman, cited in Merriam, 1998, p. 195). At this level “analysis can result in little more than a unified description across cases; it can lead to categories, themes, or it can result in building substantive theory offering an integrated framework covering cross-case” (Merriam, 1998, p. 195).

To facilitate the cross case analysis, I employed the theoretical frameworks embedded within the five scales of CLES questionnaire – personal relevance, uncertainty, critical voice, shared control, and student negotiation. These frameworks were used as analytic criteria to critically examine the issues previously identified in the analysis of the six individual narratives. To assist this process, I compiled a summary of relevant events from each the narratives under each of the five CLES theoretical categories. This summary is provided in Table 1.

As part of the cross case analysis I also examined the quantitative data to compare students' pre- and post-course perceptions of the classroom learning environment. I used these comparisons to further identify issues for discussion.

From cross-case analysis to propositions

In conducting my cross case analysis, from the perspective of Critical Voice and Shared Control, I realized that my classroom is largely teacher-centered, and the curriculum and strategies are dominated by me to a large degree. From the perspective of Personal Relevance and Uncertainty, students found difficulty in relating the physics theories to practical experience, and/or relating practical experience to theories. Building these insights from my cross-case analyses, led to the development of several overarching propositions about how the constructivist referent operated in my college-level physics classroom. These propositions, discussed in the final chapter, serve as tentative assertions, highlighting those issues that may have applicability beyond the boundaries of this study. The thesis concludes with a discussion of the implications of the study, and my reflections on my experience of conducting this research into my own classroom.

Table 1-1: Summary of selected events for each narrative relevant to the CLES categories of Personal Relevance, Shared Control and Uncertainty

	Personal Relevance	Shared Control	Uncertainty
1	• I used daily life experience to explain vectors	• CS solved the vector problem on the blackboard the way I did • He responded me how he understood the content	• Students responded to questions in everyday language rather than scientific language
2	• I demonstrated the experimental procedures, showed them how to enter the data into table • Students placed the weight arbitrary on the inclined plane, caused experimental errors	• The class was intruded to remind the proper position for the weight to place & the function of timer to use • Students played with the equipment and missed my demonstration • Group 1, played with the equipment while I gave the briefing, collected unreasonable data	• DH and LL tried to find the proper place to put the weight • I helped to get appropriate data to support student learned the theory • Instrument was treated by students as fancy toys
3	• Students' careless attitude resulted in incorrect findings		• Students reasoned 200% error by themselves through the discussion with me • SH's unusual calculation procedures were accepted by partners
4	• Students had hard time to relate the gun shooting experience to the theory of conservation of momentum • Students pointed out the impracticality of calculating the speed of the car when turning on the corner	• LS raised problem about the homework assignment • No response to my query of impulse • My teaching schedule was changed to meet the demands of students' problem solving problem • The atmosphere turned to quiet and passive again when relating experience to the theory	• ChiSun still worked on the solution that I left on the blackboard. Accepting the solution in words form required a change of learning habit • Students checked the solution with a friend after they finished the problem solving
5	• Students' ability to manipulate equipment remarkably improved after three months of practice	• I interrupted the class to remind them about the proper position for the ball	• Reasonable experimental outcomes helped students learn new knowledge and examine prior knowledge
6	• I used the diagram to demonstrate the torque problem	• Students did not proceed with new activity without my instructions • Interrupt the class to clarify to use force instead of mass in calculation	• CY asked a friend to reinterpret the meaning of the problem • Students understood the torque problem differently • Students benefited from the new learning strategy

Table 1-2: Summary of selected events for each narrative relevant to the CLES categories of Student Negotiation and Critical Voice

	Student Negotiation	Critical Voice
1	• Student was honored when be able to respond to my questions	• The atmosphere became more relaxed when a student answered my questions
2	• KL sat away from his partners because of his unfamiliarity with the partner • Same as LL, he visited other groups • LL found that his data was different from that of other groups • Each group member had his/her own roles during the experiments	• The learning atmosphere was more relaxed in the lab than during the lecture • Students solved the instrument problem by arbitrarily turning the knobs on the timer panel • Students often conducted the experiment without consulting the lab manual
3	• Students often exchanged information in the laboratory • SH helped other groups to proceed with the experiment • Students showed respect for partner’s unusual calculation method • Sometimes many groups got the same wrong answers	• Discussion about 200% error revealed 1) the use of improper time precision 2) a bulge at middle incline & 3) dust on the incline
4	• Students shared their shooting experience with friends	• Students did not habitually respond my questions unless they were sure their answer would be correct • Students did not respond the impulse question but happily responded to gun shooting example • While waiting to respond, DS cleaned his glasses, some flipped over the textbook or notes, some just waited for my interpretation • Students had problems in understanding the word form solution, they plugged the numbers into the equation
5	• SH helped other groups to solve the experimental problems • Tacit understandings among group members helped complete the experiment faster • Students have particular roles in proceeding with their task • The relationship improved as the semester proceeded	• I asked the students how to measure the height instead of telling them about the displacement of the pendulum ball
6	• CY had problems in understanding the meaning of the problem and his friend interpreted for him • The group formed by late students were not familiar with one another and this impeded their learning	• I was asked to interpret the meaning of the problem • Student waited until last minute to put their solutions on the blackboard • The atmosphere did not vary when the problem was solved by a volunteer student, which was different from the lecture session

Summary

This research is a case study of how constructivism operates as a referent in my physics-level college classroom. I am conducting a study of both my own practice and my students' learning responses to my teaching. The study was conducted over one semester. Data consist of field notes, observational records, and pre- and post-course student perceptions of the classroom learning environment on the Constructivist Learning Environment Survey (CLES). My analysis consisted of several phases. In the first phase I constructed narrative vignettes of six learning episodes, two lectures, two laboratories and two discussions. In the second phase I conducted an analysis of these narratives to highlight relevant issues. In the third phase I used the subscales of the CLES as theoretical categories to discuss the narratives and the quantitative questionnaire data. Finally, I offered several overarching propositions about the efficacy of the constructivist metaphor in my classroom learning environment, finishing with implications for practice and reflections on the thesis experience.

Chapter 4: Narrative Analysis

In this chapter, I present my six narrative accounts, each narrative consists of a synthesis and representation of data from one of the six lessons. The narratives were analyzed individually and comparatively using a cross-case analysis. The cross case analysis employs the theoretical categories of the Constructivist Learning Environment Survey (CLES) as analytic tools.

Lesson One: Lecture – Vectors and Vector Addition

Narrative

This first lesson of my study, a lecture on the topic of vectors to my class of Electronic Engineering freshman majors, was conducted in early October, three weeks after semester commenced. My Institute is located in a small city called PingTon, in the southern part of Taiwan. At this time of the year in Taiwan, the weather was still very hot; two air conditioners and nine ceiling fans were turned on to cool the temperature. The motors made the classroom very noisy.

At ten minutes after eight in the morning, I walked into the classroom. As usual I had my microphone with me. The class, consisting of forty-nine students (with only six girls), waited for me quietly but sleepy with little interaction. They had graduated from vocational school only two months ago; the majority having studied Electronic Engineering and few had studied printing or art designing. Being early in the semester, they were confronting a new institute, a new educational system, and new classmates. Three weeks was not long enough for them to get used to their new circumstances. They were particularly daunted by the thick, heavy US-English textbooks sitting on top of their desks. These texts, full of complex English and Greek symbols, were to be the basis for this course.

After settling the class, I started by reviewing the content of the previous week. I described a vector as a line whose length represented the magnitude of the vector and the arrow at end of the line represented the direction of the vector. Because vectors are such a basic and fundamental aspect of physics study, I normally start teaching this topic at the beginning of my physics class. After reviewing the previous week, I introduced a new aspect of the topic, vector addition. I asked the class, "What is my location if I drive 40km to the east and then drive 30km to the south?" I first demonstrated how to transcribe the words into a diagram on the blackboard by using 4cm horizontal line representing 40km, and added the arrow sign at right end of the line representing the 40km to the east. I then drew another 3cm line that was followed by the end of the horizontal 4cm line vertically (as per the figure 1. shown below). I added the arrow sign at bottom of the 3cm line, representing how the motion turned south for 30km.

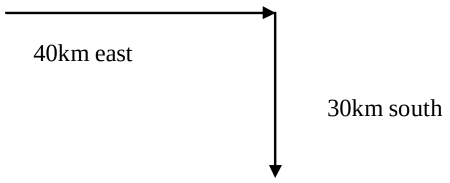

Figure 1. Vector Addition

I asked the class, “Where am I?” “Where should I tell my family if I called them now?” After waiting a moment, I then asked, “Should I say 70km or I should say 50km south of east?” This was followed by, “Is here the position I am now?” I pointed to the end of 3cm line. Waiting for another second or two, I replied to my own question since there was no response from the students. “Should I say 50km south of east by taking the square root of the sum of 40 square and 30 square?” “Yes”, I said, “As the figure showed, I should say that I’m 50km south of east away from home.”

During this sequence I asked several more questions as I was describing the strategies for solving the vector addition problems. I thought that asking questions elicited students’ thinking responses so that problems would be better understood. Sometimes I expected students to respond verbally and sometimes not. In this class, students were sitting and seemed to be listening but no verbal responses were forthcoming. As I proceeded to describe the problem solving strategies, I noticed that many students had their heads down, some of them turning the pages of the textbook to find the example that I was referring to. Some students wrote the notes on the margin of their textbook, and others seemed to pretending that they were listening and thinking.

I asked a further question, “What will that be if I drive to the south 30km first and then 40km to the east?” In order to check whether the context taught was being understood, I invited a volunteer to work up a solution on the blackboard. One of my common teaching strategies was add grade points to students who volunteered in this way. It wasn’t too long before ChongShin, who was seated in the middle front of the room, stood up and walked toward the blackboard. He drew the vector diagram as I did few minutes ago and calculated the correct solution on the blackboard. When ChongShin solved the problem, other students responded in different ways. For example, HuaiChin who seated at middle front of the room concentrated on what was written on the blackboard, and at same time she wrote notes on her notebook. ShinHwa who was seated at middle of the classroom stretched his body and turned to look around the room at his classmates. DonHwa who was seated at the middle right leaned across to talk to the student next to him and passed some material which was obviously not related to the lesson. ChiWei, seated at the back of the room, was leaning on the desk resting.

While ChongShin was solving the problem on the blackboard, I noticed that the learning atmosphere became more relaxed and restful. Only a few students seemed to be paying attention to what was going on at the front. After ChongShin went back to his seat, I explained what he wrote on the blackboard. At this point, the students’ attitude changed; they appeared to sit up after I started to talk and paid attention to the lecture again.

I asked the students, “Is there any difference between moving east first then turning south or moving south first then turning east?” I followed the trace of the diagrams that were plotted on the blackboard and indicated that it did not make any difference which direction was taken first. I referred students to another example from the textbook (Ewen & Schurter, 2002, p. 66),

> *Find the resultant displacement of an airplane that flies 20 mi due east, then 30 mi due north, and then 10 mi at 60^0 of south.*

After reading the problem, I proceeded to tell the students to, “Choose a scale of 1 cm to represent 5 mi so that….”

Analysis

Learning in English

An US-English written textbook was chosen for students’ physics course in their first year of college education. As the vignette shows, given the poor state of students’ basic knowledge of English, using the textbook was a great challenge for them. However, facility in English is a necessary part of students’ experience because they will be required to use English when they are taking future courses at a higher level.

My teaching strategies

Using the examples from everyday life

Vectors are important tools in physics learning. In practical terms, we often experience the theory of vectors frequently without realizing it. The best way to learn new things that we never experienced before is to start from what we already know.

To establish knowledge of vectors and vector additions, I used an example from everyday life that would make it easier for students to understand and help them to remember the concept.

The example of “drive 40km to the east and then drive 30km to the south” is a common expression when directing people to a certain place. The term provided two important vector entities, the quantity of 40km and 30km in directions of east and south respectively. The term also presented two actions — 40km to the east and 30km to the south. The concept of the vector addition was expected to build in students’ mind by imagining my example of taking the action of 40km to the east followed by the action of 30km to the south.

As ChongShin volunteered to solve the problem without waiting long period after my question was raised, in the later session of the class, he demonstrated that the concepts of vectors or vector additions were understood and applied.

Drawing diagrams

I also liked to use diagrams to help my students understand the theories I described in the class. From my teaching experience, I have noticed that verbal description is much more difficult for students to understand than using diagrams. Diagrams display my statements neatly and clearly. For example, the statement “drive 40km to the east and then drive 30km to the south” was much easier to follow by drawing a horizontal line with an arrow sign at right end of the line to represent the motion to the east, then drawing another vertical line at right end of horizontal line with an arrow sign at bottom of the line to represent another motion of toward south. Students seemed to follow my diagrammatic representations with or without understanding my verbal expression.

Asking questions

Another interesting teaching strategy illustrated in this episode was my use of questions, such as “Where am I?” or “What will that be if I drive to the south 30km first and then 40km to the east?” Two reasons I like to ask questions in the lecture, one is because I believe that asking questions will elicit students’ thinking and lead students in the direction that the subject will be taught. Asking questions also offer the opportunity for students to participate in the content that I demonstrated in the class when students are in the process of trying to answer the questions. The other reason is that students’ responses provide me with feedback on how well students understand me and how many of them follow my instructions. In this particular episode, after the questions were asked, I did not wait too long for students to respond to me. In this case, the purpose of asking questions was to elicit students’ thinking.

Remedial strategies for students with poor mathematics background

I also learned that students came from different high schools with various levels of mathematics background. Physics relies heavily on mathematics as a tool to support learning. In this class, a number of students who came from a humanities or an artistic major had difficulty in following me because of a lack of mathematics background. Unfortunately I had to proceed with the class to cover a certain amount of the physics subjects. A sound knowledge of physics is required for those students who intend to major in the Department of Electronic Engineering. As a remedial strategy for those students I strongly encouraged them to study harder and to review the problems after class as well as inviting them to raise questions anytime in my lecture.

Inviting students to solve the problem on the blackboard

The act of "teaching" is often likened to treating knowledge as a commodity. This is particularly so in the lecture mode, when delivering the knowledge from instructor to students without much of feedback from them. In the lecture described in this vignette, I wanted to know how well students understood me and what aspects of my lecture were confusing for them. I used the strategy of asking students to volunteer to solve the problem on the blackboard. The solution that students wrote on the blackboard demonstrated their understanding and their points of confusion. This strategy assisted me to modify my teaching or reinforce my instruction accordingly.

Another reason I liked students to solve the problem in public during the class session was because the solution that students put on the blackboard was written in their "language" even though the solution consisted of several mathematical equations. I called this "students' language" because these equations represented their thinking and ways of communicating with their peers. A subject that could not be understood as a result of my instruction could be better understood in terms of students' own language.

A further advantage of giving students the opportunity to solve problems in public was to provide a break from listening to me, as well as to regain the attention of those students who had lost concentration. The break also gave them time to organize the contents of the lecture by solving the problems. A sense of honor encouraged them to solve the problem in public. To add the extra points that were promised by me to their grade points would be a great help for those of students who did not normally achieve success.

Students' learning attitudes

In this narrative, students did not readily reply to my questions, which is typical of Taiwanese classroom. Answering teachers' questions in front of the whole class takes some courage because students feel somewhat embarrassed if they answer the questions incorrectly. They are well schooled in the art of avoiding embarrassment by habitually not responding to teachers' questions.

Changing the atmosphere

I also noticed that students behaved differently after ChongShin stood up and voluntarily posted his solution on blackboard. In the classroom some students stretched their body and looked around, some talked to their peers about matters not necessarily related to the content of the lesson, others were simply resting. Even those students who looked at what ChongShin put on the blackboard looked relaxed and copied the solution from blackboard. Few students tried to understand ChongShin's thinking. The atmosphere in the classroom became more relaxed, in spite of the initial pressure to share solutions in public. Students had the choice of whether or not they wished to share their ideas on the blackboard. After ChongShin volunteered to solve the problem, the pressure that other students felt was lessened.

Lesson Two: Practical Work –

The Measurement of Coefficient of Friction

Narrative

In my fifteen years of teaching experience, I have found that students are more likely to understand the theories when they had opportunities to conduct practical work in the laboratory. I believe that the idea of “seeing is believing” is especially important in the physics classroom. The second lesson of my study was devoted to the laboratory and was conducted in a large classroom. Nine working tables were arranged in an orderly fashion, each table allowed a maximum of up to eight students. In this particular classroom, there were two groups of three students at each table. The laboratory session was held once each week from 8-11am. Students were organized into sixteen groups at the commencement of the semester and each group was composed of three students. Students were able to select their own group partners to work with throughout the semester.

At fifteen minutes passed eight in the morning, most of students were seated by their table in a relaxed mode and chatting with each other. The apparatus for the experiment of the day was set and laid on the table. Food and drink were not permitted in the laboratory, and so couple of students was still in the hallway rushing to finish their breakfast.

I started the class by briefing them about the experiment, “The objective of this experiment is to measure the coefficient of static friction and coefficient of kinetic friction when object slides down the inclined plane.” I explained, “the coefficient of friction is measured by taking the ratio of the actual force that is expressed in the sliding motion to the ideal force that is attracted by the gravitational force”.

Because the theory of friction had not yet been covered in class, students did not yet know about the coefficient of friction. I introduced the factors that related to the friction force and, on the blackboard, provided the equations that students needed to calculate the coefficient of friction. I did not go through the detail of the principle. I reasoned that, in the laboratory, students normally were busy handling the apparatus or talking to the partners. Therefore, I thought that trying to get students to understand the theoretical principles in the laboratory classroom would be difficult under these circumstances.

I then walked to the near working station and demonstrated how to conduct the experiment. I first showed the students how to adjust the height of the inclined table. Then I raised the inclined plane slowly until the weight, the object in contact with the inclined plane, started to slide. I said, “The tangent of the inclined plane angle is the coefficient of static friction.” After explaining the concept of coefficient of static friction, I continued “the coefficient of kinetic friction is measured by two different methods, first by measuring the time that the weight needs to slide from starter to stopper when the initial velocity (v_0) is zero and then repeating the motion but the initial velocity is not zero this time.”

I showed the students how to connect the photo sensors to the photo-electric timer. The sensors detected the signal when the object passed. I told them that “the timer starts counting when the weight passes the first sensor (starter) and is stopped counting when the weight passes the second sensor (stopper). We record the length between two sensors and record the time that the weight travels between two sensors, these are the parameters of calculating the acceleration of the weight.” I waited a moment for students to observe my demonstration. I explained, “When the v_0 is zero, the weight needs to be placed at starter position without blocking the starter so that the starter will be initiated at the moment weight moves”.

I emphasized the importance of the position of the placement of the weight because, from my experience, I knew that this was a significant cause of the experimental error. Then, I said, “to measure the time when v_0 of weight is not zero, you mark the point where the weight is placed but not at the starter’s position. After you record the time when the weight begins to slide, remove the stopper 20cm further without moving any other apparatus, and put the weight at recorded point that marked at first slide and slides it down again, record the second time.” I spent a long time describe the details of the time measurement for an object on an inclined plane sliding with two different initial speed because, from my experience, that was another major source of experimental error. Finally, I indicated to students how they should calculate the data and where to fill in the data on lab report. Before I finished the briefing, I indicated the mistakes that students normally made when doing this experiment.

In the laboratory Mr. Wu, the laboratory assistant, helped us set up the apparatus. Mr. Wu was new to the job and he needed time to become familiar with the experiment and the equipment. After the experiment commenced, I noticed that some of the apparatus was not prepared properly and I was besieged with requests of help from the students. Mr. Wu and I tried to fix the problem as quickly as possible.

While Mr. Wu and I were busy handling the apparatus problem, students who were waiting for help sauntered around the classroom and observed the other groups, asking questions like “How do you measure the distance?”

Group eight were seated at the front middle table. Two members of the group, ChinSon and LongShin adjusted the height of the inclined plane and tried to measure the time that weight slid down the plane. They experienced a problem measuring the time because the screen of the timer would not glow. Although ChinSon switched the knobs one by one on the panel of the timer, the screen still did not light up. LongShin asked his partner, “Did we connect the sensors right?” He unplugged and then plugged the connection on the back of timer, without success. They quietly worked to find a solution without checking with friends from other groups. ShonYi who was the third partner in the group was seated at the other end of the table, having arrived late. He seemed unconcerned about what was going on with his partners. No matter how ChinSon and LongShin tried to adjust the timer, they failed to get what they want. They finally came to me and asked for help and it turned out that the fuse of the timer was burned out. After the fuse was replaced, the screen that showed the time lit up and the students were able to continue their experiment.

Group one, comprising DonHwa, KaunLi, and LaiLong, was seated at the front, door-side table. DonHwa, was so anxious to start the experiment so that he could not wait for me to finish the briefing. He played with the apparatus as I demonstrated how to use the inclined plane. His two partners did not play with the apparatus at this time however they were also not paying attention during the briefing.

After the experiment commenced, DonHwa and LaiLong started the experiment excitedly. They rapidly collected coefficient of static friction data and connected the photo sensor with timer with no problem. Then they measured the time required to travel a distance when $v_0 = 0$. DonHwa placed the weight on top of the inclined plane arbitrarily and slid the weight down the slope. The time was recorded according to the timer. When DonHwa and LaiLong did the experiment, KuanLi sat alone at the other end of the table and recorded the data provided by DonHwa. KuanLi looked around the classroom but paid little interest to what his partners were doing.

Once in a while KaunLi went to talk to students in other groups to check what they were doing. KuanLi found out the data they collected was different from other groups. For example, other groups found that the time that the weight traveled a distance when $v_0 = 0$ was a lot longer than their result. He came back to the group and told DonHwa and LaiLong. DonHwa said, “What was wrong?”

LaiLong said, “Did we use the timer function right?” They checked with group two, sitting across the table, finding that this group had used the timer with the same function. However, group two placed the weight a lot closer to the starter. LaiLong said, “Where did we place the weight?”

DonHwa said, “I don’t know? I just put it on the inclined plane.”

LaiLong said, “Should we place the weight closer to the starter?” “Not as I know!” “I think we should place the weight closer to the sensor, I remember teacher placed the weight real closed to the sensor when she showed us how to do it” LaiLong said.

DonHwa replied, “No, I don’t think it is necessary.”

It transpired that the students in group one could not agree about where the weight should be placed. And group two could not seem to assist. Finally the students asked for my support.

Analysis

My teaching flow

In laboratory work my teaching flow normally commences with ten to fifteen minutes of briefing, including the objective of the experiment, short summaries of the theories that relate to the experiment, the equations that students need to reach their outcomes, and a demonstration of the experimental procedures. Students then proceed with the practical work, making calculations from the collected data before submitting their laboratory report at end of the session. As was the case in this vignette, the experiment session is normally interrupted several times before the end of session to clear up any confusion, such as mistaken experimental procedures or data manipulation when large scale errors were encountered by a number of students.

My teaching strategies

Allowing students to select their group partners

Laboratory work requires a considerable amount of teamwork and cooperation among group members. In order to reach fruitful experimental results, students need to have good relationship with their group partners, and to mutually agree on the goals of their study. For this reason I encouraged students to select their own group members. However, because this was the first semester of the program, the students did not know other students very well. For most of the time, the groups worked well and the students cooperated on the laboratory task. But I did observe that some groups did not operate very well. For example, KaunLi, in group one, sat at other end of the table away from his partners and had little interaction with his fellow group members. He visited other groups and brought back the news that his group's data was inconsistent with the data collected by other groups. KuanLi seemed more interested in what was happening in other groups than his own. When he did try to relay information to his partners, they did not pay him any attention and continued solving the problem in their own way. These incidents show that when students are not familiar with one another they may not be able to accomplish the task in an effective and cooperative manner.

Helping students collect accurate data

As in this vignette shows, the experimental outcomes provided strong evidence to assist students to understand the theories underpinning the objectives of the experiment. These outcomes offered students the opportunity to reconsider other ideas contradicting the outcomes. The outcomes also offered students the opportunity to build ideas. One of my laboratory teaching strategies, therefore, was to help students collect accurate data rather than emphasize the theories that the experiment displayed. In my experience, it is rather difficult to draw students' attention to a "long speech" about theory when such interesting expensive "toys" were in front of them.

Demonstrating one complete experimental procedure

Students received their laboratory manual before they enter the laboratory classroom. Another teaching strategy was to demonstrate one complete experimental procedure for students before they commenced their task. The demonstrations showed them how to follow the procedures, where to fill in the data and what the data looked like. I also introduced the name of apparatus and how to use it. I knew, from my experience, that most students did not read the instructions even when they had difficulties in proceeding with the experiment. The demonstration was used to reduce the confusion and minimize possible experimental errors. As LaiLong said, “I remember the teacher placed the weight really close to the sensor” when group one tried to solve its problem. Even the student who did not pay attention during my briefing noticed that I placed the weight close to the starter, illustrating that the demonstration helped students with the conduct of their experiment.

Students’ learning attitudes

Anxiety to ‘play’ with the instruments

The narrative highlights that different students came to class with different learning attitudes. For example, at the beginning of the lesson, some students could hardly wait for me to finish my briefing. They played with the expensive toys without seeming to listen to my briefing, as with DonHaw. Their impetuosity helped them become familiar with the instruments that were used, although, they missed some key points about data collecting. Hence, in processing the experiment, they often had to stop in the middle of data collecting or had errors in their data calculation outcomes. For example, as DonHwa and LaiLong proceeded with their experiment they were faced with a strange time measurement. These two students argued about the proper position for the weight to be placed when the time was measured at $v_0=0$. None of their arguments were related to the instructions in the lab manual or any strategy that I might have mentioned to them.

Passive participation in the experiment

Some students acted out their roles in performing the experimental procedures but were not particularly concerned about what they were doing. ShonYi, in group eight, was one example of such a student. He arrived late to class, was uninterested in proceeding with the experiment, and did not question his other two partners’ tacit agreement about how to the experiment should be done. This attitude of passive participation was quite common in my classroom. I can only conjecture that the reason for this attitude was that students did not have a good understanding of the purpose of study beyond obtaining a qualification.

Facing problems

Another interesting attitude was evident in the way that students often came to class without fully preparing for the lesson or anticipating potential problems. When they found something strange, in the procedure or the data, they asked their partners, friends in the other groups, or, as a last choice, teacher. When I graded their lab reports, I, sometimes, found the same aberrant results in several different groups of lab reports which was undoubtedly due to the same mistaken experimental procedures or same mistaken equation applied.

Some students initially tried to solve problems by themselves when proceeding with the experiment. One example of such a problem was when the timer screen did not light up in group eight. The strategies that the group eight adopted when the problem appeared were to switch every knob, one followed by another on the timer panel back and forth, then they checked the sensors’ connection by unplugging and plugging the cables. As a final resort, they sought my support.

DonHwa and LaiLong tackled their problem differently. These students assumed that their data was inadequate when they found out that their time was different from other groups. They reviewed their experimental procedures in their mind first and thought of the possible mistakes in the process. The first thing that occurred to them was whether the function of the timer was set properly (this was a common problem that students encountered in performing this task). They then reviewed the positioning of the weight. One way that these students solved problems was by checking with the people who sat across the table from them. The function that timer was supposed to be set was easily solved. But the positioning of the weight caused some confusion. They could not get the solution from friends. DonHwa and LaiLong talked back and forth to each other about whether the position of the weight should be placed closer or higher to the sensor. They did not asking the opinions of their third group member, KuanLi (who had discovered that other groups had a different answer) nor did they check with the instructions in the lab manual, which indicated the procedures clearly. Finally, they came to ask for my support.

Lesson Three: Group Discussion – Coefficient of Friction Learning

Narrative

The third lesson described in the study follows directly on from the practical lesson described in the second narrative. The experiment conducted in the practical lesson, “The measurement of coefficient of friction” was longer than the normal experiment. While the students worked the task, they were confronted with several new procedures. For example, they were not particularly skilful at using the measuring instrument. Students often forgot to adjust all the functions when collecting their data, resulting in experimental errors. They also faced complicated experimental procedures, meaning it was not easy to identify the different steps in the measurements. Also, the many steps in the calculation led to errors in their results, especially given that students were not familiar with the use of their calculator. All of these problems were particularly challenging in the busy-ness of the laboratory classroom.

In this narrative, I will focus on the discussion following the collection of data. Group four, which was seated at middle edge of the working table, comprised one boy, ChiSun, and two girls, ShuHui and LinYin. The three students each seemed to play a different role in the group. ShuHui played the role of ‘commander’; she sat purposefully on her seat, recording the data that was given by her partners and punching the calculator to calculate the data. She also told her partners what the next step was and what data she needed. ChiSun played the role of ‘manipulator’. He set up the equipment, measured, and passed the data to ShuHui. He also helped ShuHui with the calculations after the measurement was completed. LinYin played the role of ‘helper’ who helped ChiSun to collect data, as well as checking the data with ShuHui. Sometimes she walked across to the other groups to collect extra information when she wanted to query some aspect of the data or the calculation.

After they commenced the experiment, ChiSun spent some time adjusting the height of the photo sensors, because the sensors could not catch the signals when the object passed. He tried different strategies to get it work. During the trial, LinYin passed him a piece of small paper and ChiSun inserted it in between the sensor and supporter, the sensor was fixed. The experiment soon proceeded when they solved this problem. LinYin, as a good helper, stood aside watched and helped ChiSun set up the equipment and gave him suggestions when she had new ideals.

ChiSun passed the data about the distance between two sensors to ShuHui when it was measured. At first ShuHui was not sure where should she should enter the data into the data sheet. She checked with ChiSun, “Did you measure the distance from weight to the stopped sensor?” She pointed the position of the weight before it slid down and the position of the stopper.

ChiSun replied, “No, I measured the distance from starter to stopper.”

ShuHui repeated “from starter to stopper?” with an uncertain voice, because she could not tell the difference between the position of the weight and the position of the starter. “Where should I fill the distance into the data table then?” ShuHui was not sure where the data went. ChiSun and LinYin both leaned forward to ShuHui’s report and looked at it. They pointed to the blank on the data sheet and recommended where she should enter the data. They were at the second stage of finding the coefficient of kinetic friction (μ_k) when $v_0 = 0$. After ShuHui wrote down the number, they proceeded with the experiment.

ShuHui calculated the data while she was waiting for her partners' data. She wrote down each individual calculation step by plugging different numbers into the same equation before she calculated it. After ChiSun and LinYin finished the measurement, they worked together to complete the calculations by following ShuHui's lead. While the experiment proceeded in that group, visitors from different groups came and went. They wanted to know how to measure the length and which data to enter into the equation. ShuHui provided advice to these students.

Students were asked to measure the distance and the time that weight traveled between two sensors so that they could calculate the acceleration. Theμ_k would then be calculated by entering the acceleration of the object and gravity into the equation. The distance they used between two sensors was set around 30cm to 40cm, the time for the weight to travel that distance on a 30 degree inclined plane was about 0.951s or so. The precision of the time calibration was important for such a short time period. I tried to tell students during my briefing about the importance of the precision of the time calibration and its affect on the result of experiment. I suggested a time precision of up to the third digit after decimal point to reduce the measurement error.

At the end of the session, group nine who was seated at the center of the classroom came to me and showed me their 200% error calculation. They wanted to know what was wrong with their experiment. I went back with them to their station, checked their set up and asked how they conducted their experiment. The procedures sounded correct. I looked at the set up carefully and tried to find a clue from their data sheet. I found that the precision of the timer was set at the second rather than the third digit after the decimal point. I said, “The time precision you used would make huge calculation error”. I switched the time calibration knot for them and conducted a calculation for them by adding a third digit of time. After they looked at my result and comparing it with their result, they agreed with my analysis of the problem.

I then asked, “Can you think of the other factors that could affect your results?”

After a moment of contemplation, ChunYi replied, “Could it be because the surface of the inclined plane was not smooth?” The inclined table had an acrylic surface and the table bulged at midpoint because it was supported by a stick. A large error of time measurement would be made by using faulty equipment because the object was assumed to slide on a smooth surface. I observed the equipment and agreed with their analysis of the problem. I was also surprised at their ability to recognize the source of the problem

“Is there other possible reason for this error?”, I then asked. All three students looked at the equipment again.

A moment later, KouKoung replied, “Could it be because the surface of the inclined table was not clean?”, pointing to the dust on the surface of the table. ChunYi, LongChin and I agreed with him.

I replied “Yes, it could affect the frictional force of the sliding objects. Any others?”

“Could it be the distance between two photo sensors?” ChunYi said.

“What do you mean? How did you measure the distance for S_1 and S_2?”, I said.

ChunYi showed me how they measured the distance. Practically, it looked all right. We all looked at the set up and thought of something else which would affect the result of experiment. I noticed that the calculated acceleration of the sliding object when $v_0 \neq 0$ was close to zero. The acceleration was very small compared with what it should be. Then I noticed the recorded distances of S_1 and S_2 were only about 10cm apart. I then told them that “The distances of S_1 and S_2 were so close, a tiny error may cause the results to be quite dissimilar. For instance, it turns out to be a lot difference when you divide the number by 0.05 or 0.054 for the difference of 0.30, 0.35 and 0.302, 0.356.”. I calculated the data to show them the point I was making. When they saw the result displayed on paper, the students agreed with me.

My conversation with group nine was at the end of the experimental session. Consequently, there was no time for the students to rerun the measurement. I suggested that, “You don’t really have time to rerun the experiment; leave the results that you have on the report and next to your result write down the factors that could cause the errors.”

The lesson finished not long after this conversation.

Analysis

Students’ learning attitudes

This vignette highlights several areas of difficulty that students faced when completing the experiment. Students were generally not skillful at using the measuring instrument, they sometimes forgot to adjust the functions of the apparatus properly, they were required to carry out complicated experimental procedures, and many became confused about the calculation steps. As a consequence of these difficulties, I extended the time I used for briefing and demonstration. In the briefing, I attempted to make a fine distinction between the different steps in order to reduce the mistakes that students might make in their data collection process. However, in spite of my explanations, several groups of students came up their results either with (an unlikely) negative acceleration, or very large percentage errors (as with group nine who obtained a 200% error). I mentioned the factors that caused experimental errors in my demonstration, but it appears that these were not taken into account. I infer several reasons that my admonishments were not taken seriously.

The demonstration was held at the commencement of the class session, before students had opportunity to touch the apparatus. The procedures may have been too complicated for them to understand, beyond their experience, and therefore difficult to follow. In addition, many students did not read the instructions listed in the laboratory manual. This meant that they were not well informed about the proper procedures and potential problems. Rather than consult the manual, they exchanged information with other groups. The exchanged information was normally in the form of conjecture about what they heard or what they saw during my demonstration. Unfortunately, this conjecture was not always accurate. Consequently, the outcomes sometimes involved large errors. Group eight, for example, calculated nearly zero acceleration, and group nine obtained an error result of 200%.

Group members respecting one another

Another interesting behavior was demonstrated by ShuHui. She wrote every single equation but entered different numbers on her scratch paper before she calculated the answer. This step took her time to write the same equation using different data. Contrast this to the strategy used by other students of punching the numbers directly into the calculator this strategy used by her was time consuming. In group four, when ChiSun and LinYin finished their measurements, they helped their partner ShuHui to calculate the data by following the equations that were written on the paper. This was an example of group members respecting one another and understanding the actions taken by partners.

Checking experimental results with other groups

Students also liked to examine their data by checking other groups' results. If this strategy were not satisfactory, they would check with me. For instance, when they found that their semi-calculated data did not coincide with their logical understanding, such as negative acceleration, they checked with friends in other groups. If still unsure, they asked for my support.

One example was group eight who showed me the result of nearly zero acceleration in the middle session of the experiment. Group members knew that nearly zero acceleration meant that the object barely moved which was not what they observed. After group eight could not get support from friends, they shared their problem with me. The problem with their calculation was determined after I asked them several questions about their procedures, data processing, and about the equation they used to make their calculations. I also asked them to demonstrate the procedure practically for me. If the problems appeared in more than one group, I interrupted the class and repeated the proper procedures to remind the groups who had same results and about what adjustments to make. This action, of bringing the class together, was used to remedy mistakes and anticipate future problems.

Students' cooperation

Tacit agreement among peers

A good example of cooperation is to be seen in group four, where members soon adopted different roles during the practical work. As highlighted in the previous narrative, we could call these commander, manipulator, and helper. In one scene from this vignette, LinYin passed a piece of small paper to ChiSun and fixed the slippery photo-sensor on the supporter successfully. In the process of fixing, LinYin was stood aside and watched ChiSun; they hardly talked. ChiSun did not ask for the piece of paper, neither did LinYin explain its purpose. They seemed to have a tacit agreement about what was required, even though they had only been working together for four weeks. The most reasonable explanation for their cooperation was that they were both concentrating on their task to the point that LinYin knew exactly what ChiSun needed to solve the problem.

Consulting with peers

In this group, ShuHui played the role of a commander who directed the team, recorded data and calculated it but was not involved in the manipulation of the apparatus. Consequently, she did not always know where to enter the data obtained by her partners. Neither did she always appreciate the distinction between similar but different measurements. On the other side, ChiSun and LinYin who were busy manipulating the apparatus knew what they were doing and what the collected data represented. When ShuHui queried where the data should go, they helped her through discussion. This action not only solved ShuHui’s problem but also helped her to learn about the representation of the data and with the later calculation. Cooperation helped group four proceed through the experiment with success and little delay.

Group four also was a popular group for others seeking consulting. During the lesson, they had frequent visitors who wanted to know about certain procedures and about the calculation of the acceleration. Some visitors wanted to know why they received different answer by plugging the same numbers into the same equations. ShuHui responded when the question was concerned with the calculation; she showed them the equations she used or, sometimes, actually calculated it for them. ChiSun or LinYi described how they manipulated the apparatus when the question was concerned with the procedures. Sometimes the visitors stayed with them for 10 minutes or longer to observe how they conducted their procedures. Or visitors just want to confirm their results with group four to make sure that they were on the right track.

The interaction between instructor and pupils

Group nine came to me at end of the session with their 200% error outcomes. They want to know what was wrong in their experiment. The clue to find the problem that caused their results was in the set up of their station. Students knew their procedure well but could not identify the source of the problem. My role in here was to encourage students' observation skills.

One of their errors, the precision function, was found after I went back with them to their station. The precision error was identified soon after I practically demonstrated the problem by plugging different precision times into the calculation. In my discussion with the group, I explored the other factors that were embedded in their operation or faulty apparatus setups. I asked the members of the group to identify the possible reasons for the errors. In response, they queried whether the bulge in the middle of the inclined plane and the dust on the inclined plane affected the time measurement. I agreed with their assessment. I must say that I was surprised that the students had not identified this as a problem during the experiment. It is likely that the students were not experienced at making adjustments to minimize measurement errors in practical work. This incident demonstrated that students could learn from errors. Without the 200% error, they would not think of the budge and dust was the problem. This is an important skill learned in the early stages of laboratory training.

Lesson Four: Lecture – Impulse and Conservation of Momentum

Narrative

This lesson, in the form of a lecture on the subject of impulse and the conservation of momentum, took place in early December. I remember the maximum temperature that day was 18 degree Celsius, considered by those of us who live in sub-tropical southern Taiwan, as a cold day. At eight o'clock in the morning, the students were sitting on their seats wearing jackets curled around their body in an attempt to keep warm. The windows and the doors in the classroom were closed tightly to keep the cool air out. The lights in the classroom were not turned on yet. Some of the students leaned on the table to catch up on the sleep that they missed for arising early, while others ate breakfast at their seats. The classroom seemed to have a general aura of drowsiness when the bell rang to signify the start of class. As I walked into the classroom, turned on the lights and opened the windows, the students began to wake. I waited for few minutes for them to freshen themselves and prepare for the class.

I started the lesson by addressing the problems that the students had practiced for their homework assignment. LaiShu raised one of the homework problems for me, "page 128, problem 13".

"Please turn to page 128, problem 13." I repeated the problem that LaiShu raised.

> A bullet with mass 60.0 g is fired with an initial velocity of 575 m/s from a gun with mass 4.50 kg. What is the speed of the recoil of the gun?

This was a conservation of momentum problem. The theory of conservation of impulse-momentum was introduced in the previous week. After the question was read I asked the question “What is the impulse?” in order to review the context of previous lecture. There was a moment of waiting as no one responded. I repeated the question one more time and was hoping that someone would answer the question. However, the students replied with silence. Most of students flipped the pages of the textbook or notes to try and find the answer from the textbook. Others looked at me and waited for my answer. While waiting, DonShin cleaned his glasses. To encourage students to answer the question I repeated it one more time. Still, the classroom filled with silence and I was disappointed with the lack of response. “You need to study right after the class, otherwise the theory that we covered in the class would be forgotten very soon,” I said, before proceeding to solve the problem.

“The impulse is to multiply the force that acts on the object by the time that action lasts. Before the moment the bullet is fired, the momentum of the system is zero. That is the momentum of the bullet was same as the momentum of the gun but in opposite direction.”

I then raised another question, “How many of you experienced shooting practice?” About five to six students raised their hands.

“What did you feel at the moment of shooting?”, I asked.

“My shoulder hurt.” ShinLong replied.

“Do you know how could you do to eliminate the hurt?”

“To hold the gunstock tight to my shoulder”, several of students replied.

“Why is that?”, I responded.

“Because it will eliminate the recoil force from gun, the impact on the shoulder would be reduced.” students replied enthusiastically. As I began to talk to them about their shooting experience, the students became more animated. Some students also began to share their experience with their neighbors.

I explained, “The recoil speed of the gun is given by the negative momentum of which balancing the momentum of the fired bullet, the direction of the recoiled gun therefore is opposite to the direction of the fired bullet.” The students seemed to understand my explanation which was drawing on a practical example. “That is the reason why the gun recoiled back to the shoulder.” I continued to explain the problem, “To describe the situation, we say $m\Delta v = F\Delta t$, m is mass of the bullet, Δv is changing the speed of the bullet from rest to the speed when it is fired… ”

While the students’ interest increased as I asked questions about their shooting experience, it soon decreased after we started to solve the problem. The class went back to a quiet and passive environment.

ChiWei who sat at middle rear of the classroom was one of the more responsive students. He raised his hand when I asked the question about whether they experienced the shooting and he also tried to response to my other questions. He also tried to answer my questions but sometimes his answer was incorrect. He also talked to the neighbor at appropriate times about subject matter related to the lecture.

ChiSun who sat at left side of the classroom was busy at working out the solution to the example after I replied to the question. ChiSun missed part of the lecture. In physics we habitually write the symbols (*i.e.* m represents mass, v represents velocity) in the equations instead of numbers. The reason is because the symbols represent the issue of the problem better than using the numbers. Also symbols in the equations omit the careless calculation mistakes better during the process of deduction. But students who used to accept the answers as the numbers could not tolerate the answers as one equation. Some of them plugged the numbers into the equation and calculated it to get a final number after I left the final equations on the blackboard. ChiSun was one of those students who could not wait to finish the problem until after he went home. While he was busy finishing the problem he missed my rest of the lecture until he was satisfied with his answer.

Another student, ShuLin, concentrated on my lecture and for a while twisted her pen habitually. She also copied the notes that I put on the blackboard. She was so intent on coping that I was not sure whether she followed my words, even though I often reminded students that copying was not a good learning strategy. In physics, collecting the hidden information from problems and integrating it into the equation that represents the problem is the most difficult part of learning. I was concerned that students such as ShuLin were not picking up this key part of learning physics.

LuSin sat at a window seat waiting for the class to end without planning to do anything. He talked to his neighbors freely and seemed to enjoy the relaxed atmosphere of the classroom.

During this lesson I noticed that the learning atmosphere in the classroom was weaker as the subject was getting deeper. I felt that students needed to study hard after class in order to understand the context of the lecture through the whole semester. They would be lost if they missed studying just once or twice. The physics classroom could turn to a painful experience. It was painful for me too.

Unfortunately there were more and more students who were giving up on their study as the course went on because they were unable to follow the lecture. Teaching physics for understanding to this class was becoming more difficult as the semester was coming to a close.

Analysis

My teaching strategy

In this class, I tried to use everyday experience to interpret the theory of momentum. I raised two questions in this episode to evoke students' thought. The first question "What is the impulse?" was raised when I tried to find out how well students understood the theory that was taught during the previous week. In my teaching I like to review the theories prior to solving the related problems for the students. However, the theory was reviewed at a different level of detail according to the students' level of understanding. Therefore I asked the question to help me learn how well the students understood the theory. As the narrative shows, after raising the question, I waited a moment for the students to respond. However, after repeating the process of asking the question and waiting for three times there was still no response from the students. I went ahead and reviewed the theory of impulse in detail.

When I raised my first question, I expected to receive a reply from the students. However, instead of answering, they simply flipped the pages of textbook or their notes or waited for me to continue the lecture. This behavior indicated to me that the content covered during the previous week was not understood or recalled or not reviewed by most of the students. While I was discouraged by the lack of response, I tried not to show too much disappointment and continued by explaining the theory of impulse.

The second question was a theory-related example concerned with students' practical shooting experience. I hoped that this example would help students understand the issue of the theory easier and better. When the question "How many of you experienced shooting practice?" was raised students' interest was aroused. Students responded to my question with an excited tone and shared their experience with friends. In this instance, the strategy of using practical experience to introduce the theory was an effective way of capturing students' attention.

After the students showed their interests, I then asked two related questions: "What did you feel at the moment of shooting?" and "How could you do to eliminate the hurt?" Students then proceeded to relate their shooting experiences, and the connection between the impact of recoil action on the shoulder and conservation of momentum.

The students responded "I hold the gunstock tight to my shoulder because it will eliminate the recoil force from gun, the impact on the shoulder would be reduced" This response indicated that students knew how to minimize the impact of recoil action on the shoulder. What I tried to do in this exchange was to relate students' hurt eliminating strategy to the theory and applied their experience to problem solving.

Students' learning attitude

Attitudes towards reviewing the course

The learning atmosphere changed several times in the classroom. When the first question was raised, students' behaviors indicated that while they felt some pressure to respond they did not know how. When the second question, about their shooting experience, was raised the students became more engaged in the lesson. I reasoned that students found it easier to connect to real life examples than to disconnected theories.

My student who majored in electronic engineering and applied science, could not understand why physics was a requirement for graduation. Generally, their perception was that the courses should enhance their professional knowledge directly. Physics was not seen as an electronics related course and in the students' eyes was less important. Although the course was a requirement, it was not always taken willingly. Students told me more than once what they thought of physics: "After all we did not calculate the speed of the car when the car turned on the corner, driving was the issue, experience was what counted. Besides, how could we possibly have time to calculate the speed of the car at that instant!" The responses represented a view about how students had difficulty relating physics to ordinary life. The importance of the course in their judgment affected their learning attitude.

Physics involves problem solving practice and integrates the learning into the theories. Without reviewing and practicing problems, students tend to get lost in the subject. Many of the students in this class had difficulty keeping up their reviewing speed with me resulting in lack of understanding.

Lack of understanding and motivation were the probable reasons why students were not interested in how to integrate their practical experience with the theories in physics. This perception also explained why the atmosphere changed from disinterest to enthusiasm when the shooting experience was raised and the atmosphere changed from enthusiasm back to disinterest again when the learning theories were reintroduced to the lesson.

Change learning habits

A further issue is related to student's preference for 'plugging numbers' to obtain the correct answer. In this lesson, the issue is illustrated by the student, ChiSun, who was busy finalizing the result by plugging the numbers into the equation I wrote on the blackboard. This student represented many others in the classroom exhibiting similar behavior. I had demonstrated two equations on the blackboard, one with symbols only and the other with numbers only, then queried students as to which method was the best way of displaying the equation. I found that more students favored the equation with symbols then the equation with numbers. Yet, in the practical session, students would rather finish the calculation in the classroom.

In other word, they did not consider an equation as an answer, in their mind, only a number was accepted as an answer. I presume that this perception was built up during their middle and high school. They were accustomed to writing every step and filling every single number into calculation on their examination paper and to obtain a number. This was the only way that they could get marks for their response. Also, they wanted to make sure this so-called answer was matched with the answer provided by the textbook. The same answers revealed them that they were on right track and hence gave them confidence about their solution. The students recognized that equations displayed the theories or problems better than a number but they had difficulty accepting an equation as the answer. They would rather finish the calculation than accept my interpretation.

Copying the notes

ShuLin concentrated on copying the contents of the blackboard and so missed part of my interpretation. I often reminded students that what I put on the blackboard were simply the calculation steps that were written in the textbook. What was more important was the phenomenon description that was the essence of the content, and hence was worthy of being summarized in their notes. I also explained that copying the contexts from the blackboard drew their attention away from my interpretation. But I hardly ever saw students write my words in their notes; they always copied whatever I put on the blackboard. I asked students why they did so and they replied to me that copying helped them remember the content. To write my description into notes required an understanding of my interpretation and an ability to transcribe my words in short time.

Lesson Five: Practical Work – The Conservation of Energy

Narrative

The fifth lesson described in my study was a practical activity on the topic of conservation of energy. The practical lesson took place three months after the students commenced their first class. By this time of the year, the students were more skillful at handling the equipment, following experimental procedures, and collecting data than they were earlier on the semester. I found that students conducted their experiment in less time but with better results. They were also less anxious about playing with the 'fancy toys' than they were at the beginning of the semester. The practical component of my teaching was generally running smoothly and I was finding that students were learning from practical work.

On that particular winter's morning, 13 of the students (more than a quarter of the class) arrived late to class. My large classroom looked relatively empty at the start of the lesson. I was confident that these students would arrive because one of my policies was that students would fail the course if they missed classes more then twice in the semester without proper excuse. Yet I knew that their late arrival would disturb the lesson, and they would miss out on my initial briefing to the rest of the students. I decided not to delay and commenced the introduction soon after entering the room.

"The pendulum is the apparatus we use to observe the conservation of energy." I started the briefing by drawing a picture of the pendulum swing on the blackboard. I explained, "The ball is raised to the highest position. At that position, the ball possesses the maximum potential energy (PE) due to gravity and possesses the minimum kinetic energy (KE), which is zero, because it is not moving." I demonstrated the motion of the pendulum swing by using my arms, "The ball is then released from the highest position. We'll notice that the ball will swing to the bottom of the trace and then will rise to the same height as where the ball was released but at other side of the pendulum." I explained further, "The ball possesses the minimum PE, which is zero, but maximum KE which has the same amount of energy as the PE does at highest position when it is at bottom of the swing. That is, transferring the PE to the KE. The energy will transfer from KE to PE again by raising the ball to the other side of the pendulum when it is raised to the top." I then introduced the law of energy conservation by saying, "The total energy, the sum of PE and KE, is not changed at any position of the swing trajectory we called that as conservation of energy. Of course all the theories assume that there is no energy lost to the environment to eliminate the complicated factors at primary learning", I added.

"In this experiment, to get KE we measure the speed of the ball. The speed of the ball is obtained by dividing the diameter of the ball by the time, and the time is obtained by measuring the duration that photo-electronic sensor is blocked by the passing ball." I explained how to measure the speed of the ball. "The speeds at three positions are measured, when the ball is at the top, middle, and the bottom of the swing trajectory." I added, "Be aware, the ball needs to be released at the same position at top of the swing when you measure the speeds at both the middle and bottom of the swing." I finished the briefing by emphasizing, "Remember, the sum of the PE and KE are the same at any point of the ball's trajectory." I then walked to the nearby station and demonstrated how to conduct the experiment. During the briefing, the ten late students came in to the room sporadically.

My impression was that ChaTon and LongTa, members of group fourteen, found the experiment interesting. LongTa, a normal latecomer, arrived on time that morning. Their usual partner, ChonShin, was absent so this morning the group consisted of only two members. ChaTon and LongTa did not wait for me to finish the briefing and played with the apparatus by swinging the ball repeatedly and watching it move back and forth. After my demonstration they started to collect some data. It did not take too long for them to find out that their timer was not working. ChaTon checked the photo-electronic sensor first by looked at the light signal on the timer panel, which indicated the connection between the timer and sensor. They found that the light signal did not spark. He then checked the connection between timer and photo-sensor on the back of the timer by unplugging and plugging to make sure that it was connected properly. This action made the signal light up indicating that the connection was fine. LongTa watched as ChaTon solved the problem before proceeding to collect data once again. At one point they stopped because they did not know which height to measure or how to measure it. Fortunately I was passing by at the time and was able to tell them how to proceed.

Group eleven, TonWhaw, TsiYi and YinSon, worked together very cooperatively, each member adopting different roles in conducting the experiment. TsiYi was in charge of the data recording. He wrote down the time that showed on the timer panel as his partners operated the equipment and ensured that the ball was raised to the correct height. TonWhaw was the operator who conducted the experimental procedures and called out the data. YinSon held the meter stick and was ready for TonWhaw whenever he needed to make a measurement. He also watched the measurement when TonWhaw measured the height to make sure that it was correct. The three students worked effectively and efficiently to conduct the experiment.

When I walked to their station, I noticed that when they pulled the ball to one side, they held the lower end of string rather than the ball itself. That action made the ball hanging down from the holding point and made the height of the ball lower then what it should be. This is a common operational error. I stopped proceedings at this point and called the whole class's attention. I said, "When you pulled the ball to the side, be aware you need to hold the ball itself not the string. Holding on to the string gives your ball a lower height than what you planned to measure and that will give you larger experimental error." I added, "When you measure the time the ball passes the photo sensor be sure that the sensor is blocked by the center of the ball. Because the speed is obtained by dividing the diameter of the ball by the time. An incorrect reading for the diameter of the ball causes a large experimental error in your calculation of speed."

I stayed with group eleven for a little while longer. I noticed that when they measured the speed of the ball they did not measure the height of the sensor. Rather, they measured the speed of whatever the sensor was set to be. I asked, "What the height of the ball's speed are you measuring?" They looked at the sensor tried to answer my question but did not know how to respond.

I said, "To get the total energy of the ball at a certain position you need to measure the speed of the ball at that height. Then what height of the ball speed are you measuring?"

They looked at data sheet and at the apparatus. They realized that they did not know what was the height of the speed they were measuring.

YinSon measured the height of the sensor with the meter stick. This time the sensor did not fix. Whenever TonWhaw set the sensor at a certain height the holder began to slip. After they tried several times, TonWhaw took the sensor off the holder stand and added a piece of small paper that passed from TsiYi automatically to him in between the ring and holder. The sensor stayed at the proper height and the experiment proceeded.

Analysis

My teaching strategy

Eliminating experimental errors

During my experiment demonstrations, I liked to emphasize the details of the procedures so that students might avoid making common mistakes. In each experiment, there were several complicated experimental steps causing students to become confused and make errors. For instance, in this narrative, to obtain the total energy at any point of the ball's trajectory the ball needed to be released at the same height and be measured at the center of the ball. Therefore, in my demonstration, I emphasized the importance of releasing the ball at the same height each time and aligning the center of the ball with the censor. By emphasizing proper procedures I hoped to reduce errors and produce better outcomes in terms of understanding the connection between experiment and theory.

I often interrupted the whole class in the middle of the session and repeated the proper procedures when I found some error operations in one or more groups. I felt that the other groups could apply the same operations. The proper procedures were announced aloud to remind all the groups to check whether they were proceeding properly and enabled them to make the necessary adjustments. In this episode, I interrupted the whole class when I found that some students were holding the ball by the string rather than the ball itself. This action caused inaccuracies in the measurement of the height of the ball. A small unintentional mistake such as this resulted in large error outcomes.

Questioning rather than telling

I also liked to question students when I found something that they were doing improperly. For example, I queried group eleven by asking, “What the height of the ball’s speed are you measuring?” when I noticed that they did not measure the height of the censor. This oversight would mean that the total energy of KE and PE in later calculation was not conserved. I queried students about their procedures instead of telling them directly about their missed measurement. I thought that, in attempting to respond my query, students would find their missed measurement by themselves instead by being told. After my question was raised, students waited for a moment and realized what they had missed.

Students' learning attitudes

In the practical class, we scheduled a different experiment every week. As students proceeded with their experiment they had an opportunity to manipulate different apparatus. Sometimes that apparatus was familiar to them, other times new. At the beginning of the lesson, I noticed that some students eagerly played with the new apparatus as if it was a fascinating toy. They seemed curious about the instruments and interested to learn. When students were in middle and high school, while practical classes were regularly scheduled, sometimes these were replaced by lectures in order to make up for lost lecture time or to catch up with the theory part of the course. Also, sometimes, the experiments were conducted as teacher demonstrations when they were in middle school. So when students had opportunities to conduct their own experiments and manipulate apparatus they were quite excited. Their desire to manipulate the instruments was satisfied in the practical sessions, even though they did not always pay attention to my instructions about proper use of the instruments, experimental proceedings, and the presentation of results.

Lateness to class

About a quarter of the students arrived late to class on this particular day. Student lateness was often because they loitered away their time with friends or played electronic games. By this time of the semester (December), students were used to the environment of the college and established good relationship with classmates. They liked to stay up late to chat with roommates or friends on various websites. Lateness to class was a common phenomena in my college causing many problems. The late students missed part of the teacher’s demonstration interrupted the dynamics of group work. In the lesson described in this vignette, I had to extend my demonstration and repeat the instructions because of the large number of late students.

Student cooperation

After the students practiced practical work for three months, a good level of student cooperation was observed almost in every group. For example, group members would often adopt different roles, such as data recorder, apparatus manipulator, and measurement helper. The data recorder normally was the leader in the group who told the partners what the next step was, the manipulator was in charged in collecting data, the helper mostly was available to obtain equipment and generally assist the others. These roles were played out in group eleven for example, as in other groups. I noticed that the more cooperative groups often finished the task faster then other groups. The groups who finished the task earlier than the others sometimes stayed with their friends in the other groups and shared their experience to help them to complete the work.

The roles played out by group members were not directed by me, but rather played out naturally in the process of completing the task. Cooperation provided group members with the opportunity to learn about their roles, and to solve problems together through discussion. The process of judging the appropriateness of the experimental outcomes not only provided them the opportunity to examine their knowledge of the theories that they practiced but also provided them the opportunity to adjust their knowledge through discussion with their partners.

Training outcomes

The experiment that students completed in this narrative, on conservation of energy, was not considered an easy task but the students finished it on time. For the most part, they submitted a fair lab report demonstrating that, at this stage of the semester, they were becoming more skillful at apparatus operation, procedure management, group cooperation, and data manipulation.

Apart from experimental manipulation, their problem solving ability was improving. One example is provided by group fourteen who displayed their management skills when they found that their instruments and timing system were not functioning properly. They solved the problem in sequence. They firstly checked the connection between the censor and timer by looking at the indicator – a single light that indicated the connection of the timer. The episode illustrates that ChaTon and LongTa did not panic when the problem appeared. Rather, they checked the possible causes systematically to locate and solve the problem. It is interesting to compare this scene with that displayed in my second narrative, about the practical lesson on measuring the coefficient of friction. In this previous lesson, when the timers were not prepared properly, the student did not know what to do, they either looked to other students for answers, waited for me to solve the problem for them, or arbitrarily switching the knob on the timer panel. In the three months between the lessons described in the second and this, the fifth narrative, students appear to have developed a better capacity to solve problems by themselves.

Lesson Six: Group Discussion – Torques

Narrative

As a teaching strategy, small group discussion is not commonly practiced in higher educational classrooms in Taiwan, although it does take place informally in laboratory work as students discuss experimental procedures and data analysis. I was interested to see how my students would respond when I introduced this strategy into my normal teaching. Hence this, the sixth lesson in my study, describes my observation of group discussion in my physics classroom. Prior to the lesson, I introduced the methods and the objectives of group discussion. I came an agreement with students about the organization of the room. To form the discussion groups students were sit with friends with whom they normally had discussions when they had problems. I suggested five to six members in each group and proposed that the students rearrange their study desks, normally placed in orderly rows, into clusters to facilitate the group discussion.

When I entered the room at 8 am, I noticed that the students were sitting at the seats as they normally did. I reminded them that we were going to practice the new learning strategy and waited for them to rearrange the seats. It did not take too long for them to reorganize the desks and sit with their friends. Group numbers ranged from five to nine members. Mostly they sat around the back of the classroom. The late students came in cautiously and joined a small group closer to the entrance. Soon this small group turned to one large group of about ten members. I soon learned that the students had grouped themselves before we started the class, but had not rearranged the desks because of the absence of a leader. They were too shy to make the first move.

I started the class by asking students whether they had any questions from the last session. One student raised the problem from textbook that we solved in the previous class. The problem was related to the equilibrium of the forces and torques. I reviewed the problem for students,

> Two painters each of mass 75.0 kg, stand on a 12.0 m scaffold, 6.00 m apart and 3.00 m from each end. They share a paint container of mass 21.0 kg in the middle of the scaffold. What weight must be supported by each of the ropes secured to the ends of the scaffold? (Ewen & Schurter, 2002, *Physics for Career Education, Seventh Edition*, Upper Saddle River, NJ: Prentice Hall)

I drew a diagram that described the problem on the blackboard and set the pivot point at left end of the scaffold for them. I explained, “The torques in this problem are narrowed down to four when I set the pivot point at the left end were one of the supporting ropes was located, the first torque is from pivot point to first painter which has clockwise direction, the second torque is from pivot point to the paint which has clockwise direction, the third is from pivot point to the second painter which has clockwise direction, and the forth is from pivot point to the right end of supporting rope which has counter-clockwise direction.”

I showed them how to find the direction of the torques by using my arms. “The whole system is at rest in this problem that is the system is both in translational and rotational equilibrium.” I continued, “The translational equilibrium means the sum of the forces are zero and the rotational equilibrium means the sum of the torques are zero. We add all the forces by setting the direction up as positive and down as negative. Same as torque addition, we add all the torques by setting the direction of clockwise as positive and the direction of counter-clockwise as negative." I explained, "The two forces applying on two supporting ropes will be solved from two equations." After explaining the solution to the problem I assigned two practice problems from the textbook, which resembled the reviewed problem. These two assigned problems were to form the basis for the group discussion. As an incentive, I explained that grade points would be added to all the members of the group when one of the group members wrote the correct solution on the blackboard.

Students started by reading the problem. Three minutes later, one of students asked me to translate (or explain) the problem for his group. I knew that one of the difficulties for students in solving problems was to understand the problem. English is difficult for some Taiwanese students to understand. I also appreciated that sorting the data given in the problem was even more difficult for them. In physics problems, the problem information was often hidden in the words. Hence, in order to solve the problems, students needed to identify the hidden information and integrate it into formulas. As I translated the problem I described the picture of the problem for the students.

Here I focus particularly on the interactions of one of the discussion groups. This group consisted of six members. Of the group members, KaunLi, understood me and responded well during my lectures but I found that he did not study much after the class, ChunYi studied hard at home but did not seem to follow me well in the lectures, and DonHwa responded in class when he needed to and studied hard at home. The remaining group members, ShuLin, KouKoung, and ChiSun, normally worked quietly in the normal class, but were not outstanding students. The students sat on two sides of a rectangle table, with two on each side. To locate the seats for each one of them, I name the seats from KaunLi’s side counter-clockwise as A, B, C, D, E, and F, as shown in the Figure 2.

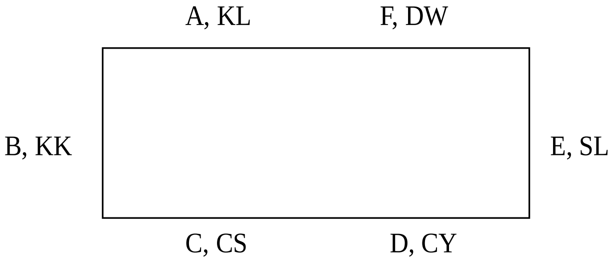

Figure 2. Discussion group seating arrangement

After my translation, ChunYi asked KaunLi

“How do you understand the problem?”

“The scaffold is 12m long, one painter stood 3m from the left end of the scaffold …” KaunLi drew a picture on scrap paper and started to talk for three minutes without interruption. ChunYi, sitting at D, looked to KaunLi and listened to him in a concentrated way. ShuLin, who sat at E, watched their interaction but did not pay attention to the content of their conversation. DonHwa, who sat at F, listened to KaunLi for a short time then turned back to read the problem quietly. KouKoung, who sat at B, twisted his pen and listened to KaunLi for a short time then turned back on his own again.

After KaunLi finished his talk, ShuLin turned to ChunYi and asked, “How do we find the torque of this problem?”

“We should set the pivot point at here (at the left end of the scaffold), the first torque should be clockwise”, ChunYi replied by gesturing with his finger.

“How do you find the direction of the torque?”, ShuLin asked

“We use the four fingers as the direction of the force, and the hand will turn…” ChunYi replied with an uncertain voice because his arm did not show the direction as he said. The reason he could not get the matched direction was because he should use four fingers pointed to the arm of the force not the force itself. Two of the students tried to figure out how to find the direction of the torque. The other members of the group were studying on their own as two of them whispered. KouKoung and DonHwa punched the calculator occasionally and KaunLi tried to solve the problem on scrap paper.

I walked around and checked to see they solved the problem. I noticed that when they added the forces or torques they used mass instead of weight to calculate. I announced out loud, “Don’t forget when you apply the forces or torques you use the weight of the objects not the mass of the objects. The difference between mass and force is to multiply the mass by gravity to get weight, that is force.” After my explanation, students went back to their studies.

After fifteen minutes had passed, the students were still busily working on the task. No volunteers had come forward to solve the problem on the blackboard for the class. Finally TongHwa walked toward to the front of the room and wrote the solution on the blackboard. While he was doing this I told the others to do the next problem if they had solved this one already. Some students looked at the blackboard to find how he solved the problem, several copying what he wrote on the board without knowing whether it was correct or incorrect. TongHwa solved the problem correctly and before the students continued, I interpreted the solution for them.

The first problem took students thirty minutes, before we proceeded to the second. Again, I was asked to explain the meaning of the problem. Based on the experience of the first problem, I thought it probably would take another 15 or 20 minutes to get this one done. But we waited for only about 2-3 minutes before ChaShin walked to the blackboard and wrote the correct solution. ChaShin and TongHwa were in the same group. I soon figured out that they had solved this problem before TongHwa had volunteered the solution to the first problem.

During this lesson, some of the students were practicing group discussion in a serious way, with a good amount of cooperation and joint problem solving. However, other students were just sitting and waiting for the solution to be posted on the blackboard. Interestingly the members of the group formed by the late students (most of whom were not normally friends) were solving their problems in a solitary way with little interaction.

Analysis

My teaching strategy

As the end of the semester approached, I found that students were having more difficulty with the physics content as it became more complex and relied more heavily on prior physics understandings. Students had trouble understanding that the concept of torque requires a basic knowledge of vectors and forces. This was the part that students had difficulty in understanding. As with this narrative, I often used student discussion so that I could observe the interaction between students and the learning that was taking place.

Using pictures to represent the problem

Mechanical physics problems can invariably be represented by pictures. A simple diagram is a clear and neat representation of a problem. And yet students cannot draw the picture unless they understand the problem fully and are able to pick up the messages that are hidden in the problem. Observing whether students can draw a proper picture (if it is suitable) is a good indication as to whether students understand the problems. Good pictures display clear and neat information to assist students to solve the problem. Therefore helping students to find the hidden messages and integrate them into a picture is one of my primary teaching strategies.

Practicing similar problems

Repeatedly practicing similar problems was another of my teaching strategies to help students learn the theories. To find the hidden message and draw pictures to represent the statement of the problem was not an easy job and required practice. As in the narrative, after I reviewed the example taught in the previous week, I selected two similar problems for students to solve. Even though the problems were similar, the students still found them difficult to solve. To find the messages, draw the pictures, determine the direction of the torques, and integrate the information into the equations required repeated practice.

Students' learning attitude in group discussion

The small group discussion provided students with the opportunity to process the theoretical ideas. My experience was that a group size or around six enabled a good sharing of ideas without the group being overlarge and dysfunctional. I observed several additional features of group discussion as outlined below:

Group performance

Often at the beginning, a group's performance was in the forming stage. Some students did not know how to join the discussion and the others did not know how to extract the needs from their discourse. There could be two reasons for this. Firstly, the students' were still in their first semester of their college education, and were unfamiliar with each other's habits. Secondly, the ability to extract the needs from discourse required training. At the beginning of group formation, students would often disengage rather than join a discussion. In the above narrative, KaunLi replied to ChunYi's question. The students were seated at diagonal positions on a rectangular table. DonHaw and KouKoung, both seated in between them, listened to their discourse for a moment before turning back to their own discussion. Another group member, ShuLin, was not paying attention to the discourse. DonHaw did not join the discussion, rather he chose to solve the problem by himself. DonHaw and KouKoung's attitudes revealed that they were not interested in the discourse or they did not know how to join the discussion and benefit from it.

Groups gathering like members

Although students had never formally practiced group discussion, they often used this strategy to raise questions with friends when they did not understand my lectures. After class they would often informally discuss problems with one or two friends. One group, here called group A (not described specifically in the narrative), solved the problems faster than other groups in the discussion session. This group was composed of nine members of which four members had a stronger mathematics and physics background than other members. I noticed that, while solving the problems, these four members discussed the problem in less time, simplified the words that they used and quickly got to the point of the problem. In the problem solving process the other members of the group watched and listened but hardly joined the discussion. In thirty minutes of problem solving the four members solved two problems while the other five were struggling with their first problem. In this case, students who had same level of knowledge background were better able to study together in a group situation.

Lateness impeding group learning

In this narrative, the group composed of students who arrived late to class solved the problems in a solitary fashion with little interaction with their partners. Unfamiliarity with their partners meant that students were reluctant to engage with others hence reducing the power of the group discussion.

To learn students' opinions about group discussion, I suggested that students group themselves for after class study. I felt that meeting regularly would help them review the course, understand the theories and solve the problems. Some students took my advice and were hoping that the group study helped their grades. Other students felt that group discussion was a waste of time, particularly if the content of the discourse was around the subjects that they already knew. They were also concerned about spending too much time helping others rather than reviewing their own work. I learned that it was important to select group partners carefully to ensure successful group interaction. A functioning group did not waste members’ time on meaningless discourse or on helping others to the detriment of the individual.

Group attitude

In thirty minutes of problem solving, the four members of group A solved two problems, while the other members, struggling with their first problem, waited till last the minute to display their solution on the blackboard. Were they too shy to put forward their solution in public? Did they want to leave the opportunity to the others in the class? Or were they were satisfied with and confident about the solution that they worked out? The two problems that were assigned in this session were solved by the same group, group A, and I added grade points to all nine members in the group.

Even though we had prior agreement to practice group discussion in this lesson, the morning of practicing day, students sat in their usual seats until I reminded them about our agreement. Students rearranged their desks and sat with their group partners in short time. Their quick rearrangement indicated that the students were prepared for the group discussion before the class commenced. I suspect that the students were too shy to be first movers and to rearrange the classroom. The attitude of shyness witnessed here was similar to the attitude of being too shy to volunteer to demonstrate a solution on the blackboard. To demonstrate ability requires risk taking and encouragement. Students are often fearful and embarrassed about saying or doing something improper in public. Rather than risk embarrassment, students concealed their talent.

Language impeding learning

In this narrative, two problems were assigned for students to practice in their groups. Both problems were requested for translation by the students, demonstrating that students had difficulties in utilizing English as a tool to learn physics. Some of these issues were magnified by the complexity of the US-English language of the textbook. Normally students became more familiar with the textbook as the semester proceeded, but in this narrative the students were still encountering problems well into the semester.

Learning physics requires a sophisticated ability to translate the message hidden in the words. The translation involves understanding the language of English as well as imagining the words as pictures. In this narrative, many of those students who could not solve the problem were unable to translate the words into meaningful figures.

The language impediment not only existed in the language of English itself, but also in the special scientific terms used in physics, such as velocity, torque, or conservation of momentum. In the classroom, I liked to seek students' help in translating those specialized terms into more meaningful and student-friendly language. I also encouraged students to solve problems for themselves and to explain their strategies to me and to other students.

In this class, ChunYi could not understand the meaning of the torque problem after I interpreted it. He asked KaunLi for help. KaunLi reinterpreted the problem by using the language that they commonly used among themselves and drew the diagram on a piece of paper to assist ChunYi's interpretation. KaunLi's ideas were based on what he had observed in the real world, ChunYi listened carefully but received the messages from his own experiences of the real world. The problem that was interpreted by me in one way and by KaunLi in another was understood differently by ChunYi. ChunYi's uncertain voice while reinterpreting to ShuLin demonstrated that he did not fully receive my message or KaunLi's. The messages of sent and received are not necessarily the same.

Summary

In this chapter, titled Narrative Analysis, I presented narratives of six teaching episodes which occurred at different times across the semester. The narratives were analyzed individually to discuss themes related to my teaching strategies and the students' learning behaviors and attitudes. I found that my teaching strategies relied heavily on the instructions given in the lectures and experiment sessions. I placed great store on receiving "correct" answers from students in responding to my queries. Students were more trusting of the backboarded solutions provided by the teacher than those provided by their fellow students. For the most part my classroom has many of the elements of a teacher-centered classroom where knowledge is treated as commodity that can be obtained and conveyed.

I found that students benefitted from communication with the teacher and with fellow students. Students' learning behavior and attitudes were rather passive, as indicated by late attendance by several members of the class and unconcerned attitudes with regard to what was going on in the classroom. Students often did not see the connection between learning physics and their future career, they did not show persistence in solving difficult problems, and did not show positive self-efficacy with regard to their motivation to learn physics.

In this chapter I have provided the primary analyses of the six episodes in my classroom. In next chapter, titled Cross-case analysis, I will attempt to develop more sophisticated descriptions and complex configurations around each of the CLES categories.

Chapter 5: Cross-Case Analysis

In this analysis, I draw on the data from the six vignettes, and from the CLES questionnaire to examine the learning environment in my physics classroom. The analysis is organized around the five categories or scales from the Constructivist Learning Environment Survey (CLES), which are used as referents to examine students' experiences. The CLES, developed by Taylor, Fraser and Fisher (1997), looks at the extent to which students are co-constructors of knowledge in the classroom. The five CLES scales are:

- Personal Relevance (Learning about World) – the extend to which the teacher relates science to students' out-of-school experience
- Student Negotiation (Learning to Communicate) – the extent to which opportunities exist for students to explain and justify to other students their newly developing ideas and to listen and reflect on the viability of other students' ideas
- Shared Control (Learning to Learn) – the extent to which students are invited to share with the teacher control of the learning environment, including the articulation of their own learning goals, design and management of their learning activities and determining and applying assessment criteria
- Critical Voice (Learning to Speak Out) – the extent to which a social climate has been established in which students feel that it is legitimate and beneficial

to question the teacher's pedagogical plans and methods and to express concerns about any impediment to their learning

- Uncertainty (Learning about Science) – the extent to which opportunities are provided for students to experience scientific knowledge as arising from theory-dependent inquiry, involving human experience and values, evolving and non-foundational, and culturally and socially determined

Quantitative Measures

The CLES questionnaire was used to assess students' perceptions of their physics classroom learning environments. The questionnaire was administered at the beginning of the semester (one week before the first qualitative data were collected) and again at the end of the semester (one week after the last data qualitative data were collected). Class average pre and post scores (1 strongly disagree to 4 strongly agree) and Cohen's effect sizes on each of subscales are provided in Table 2 and Figure 3below. The data indicate that student perceptions on three of the scales — Learning about World, Learning about Science, and Learning to Learn — did not change over the semester. The data also show a slight positive (although not significant) change in students' perceptions on the subscale Learning to Communicate and a slight negative (but not significant) change on the subscale Learning to Speak Out. Overall, students had uniformly positive response to the scales, Learning about Science and Learning to Communicate, than to the other three scales. These results will be discussed further in the following analysis.

Table 2. Descriptive statistics of pre and post-test scores of students' perceptions of their classroom learning environment (on the CLES)

CLES Scales	Mean		Cohen's effect-size
	Pre-test	Post-test	
Learning About the World	2.7843	2.8295	-0.064
Learning About Science	3.3399	3.3485	-0.014
Learning to Speak Out	2.5425	2.4356	0.161
Learning to Learn	2.1471	2.2462	-0.124
Learning to Communicate	3.0131	3.1833	-0.21

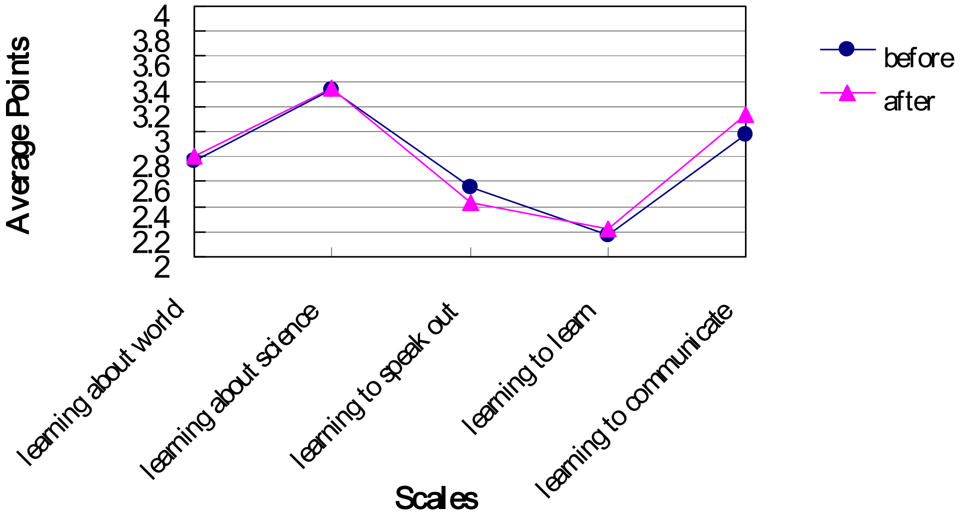

Figure 3. Class average pre- and post-course comparisons of students' perceptions of their classroom learning environment (on the CLES)

Qualitative Analysis

Personal Relevance – Learning about the World

The relatively low average class scores on this CLES subscale indicates that in general terms, my students did not see the physics content as being personally relevant and highly connected to the world outside the classroom. In the following analysis of the vignettes, however, I sought some examples of ways in which personal relevance was part of student experience – relating theories to out-of-school life, touching the world through practical work and analyzing out-of-school experiences.

Relating theories to out-of-school life

Relating physics theories to everyday life assists students to understand and appreciate the theories. Questions relating to everyday life were raised frequently in the classroom. These questions were intended to arouse students' awareness about science from everyday life and to develop their physics knowledge.

For example, in the first vignette, I asked, "What is my location if I drive 40km to the east and then drive 30km to the south?" This question referred to both the quantity and the direction of a vector, and combining the two motions of going east then south was vector addition. The problem, a typical example of vectors and vector additions, was not known by most of the students. Relating vectors to movements in out-of-school life made the theories easier to understand and learn. ChongShin solved the problem in public correctly, demonstrated how a daily life example assisted students to learn vectors.

Another example of relating science to everyday life was the gun shooting example in the vignette four. The shooting experience was referred to during the lesson on momentum and conservation of momentum. Although only a third of the students had shooting experience, the class responded enthusiastically. Most students were aware that the recoiled force of the gunstock caused hurt when the bullet was fired, and that the strategy for eliminating the hurt was to hold the gunstock against the shoulder tightly. But they did not know that the recoil could be explained by the theories of conservation of momentum. The theories of momentum and conservation of momentum were much easier to understand by relating to their own shooting experience.

Touching the world through practical work

“Seeing is believing” was another pedagogical principle used to demonstrate to students that physics theories are applicable to out-of-school life. Chinese students have little chance to manipulate apparatus in the laboratory or repair machines at home. When students first did practical work, the apparatus seemed like ‘toys’. Students were more interested in playing with the apparatus than collecting data.

After a period of practicing (or playing) the students became more adept at manipulating the equipment. For example, in vignette five, group fourteen solved the problem of the timer not functioning properly by tracing the system in an orderly fashion. After three months of practicing in the laboratory, they were able to demonstrate what they had learned in past three months.

Physics theories hold only under certain conditions. However, often students are unfamiliar with these conditions. While experimental procedures are designed for students to proceed under certain conditions, often students are careless about holding to these conditions. Only after revisiting their results do students see the importance of correct experimental technique.

For example, group one from vignette two placed the weight arbitrarily instead of directly in front of the starter on the inclined plane. This showed that the students were unaware of the importance of the condition of zero initial speed for the equation that was specifically set in the calculation. In the case of group eleven, vignette five, students measured the speed of the pendulum but missed the height measurement. I asked them “What is the height of the ball’s speed are you measuring?” instead of telling them directly. They did not respond immediately but after few more questions were raised, the problem was recognized. Students adjusted their measurement accordingly. Students proceeded with their learning after they understood the reasons.

Another example is the 200% error obtained by group eleven from vignette three. In the measurement of the coefficient of friction, they learned that the smoothness of the inclined plane and the cleanliness of the surfaces of the contact plane affected the friction in a practical way. In this way, they also learned about the nature of friction and the factors affecting friction. These examples showed how students touched the world through practical work and by learning physics.

Analyzing out-of-school life experiences

When responding to a students' problem in vignette six, I drew a line to represent a scaffold, several simple lines to show two painters located at each end of the scaffold, and drew a can of paint between the two painters. I used the diagram to help the students understand the problem. I used the diagram to identify the torques that existed in the problem and to identify the direction of the torques in the third dimension by using an arm.

Problem solving is an important aspect of physics learning. Translating a problem into understandable language is one of the difficulties in physics learning. This is because the messages of the problem are hidden in the words and are not easy to identify by simply reading. By representing the problem in another form, in this case a diagram helped the students to see the problems in another way. Moreover, the diagram of the painter on the scaffolding integrated the meaning of the words and out-of-school life experience.

While the above example shows the close connection between physics and everyday life, students remained confused about the connection between the two. The following quote from vignette four illustrates how students differentiated between the physics concepts of speed and centripetal acceleration and their experience of driving a car: "After all we did not calculate the speed of the car when the car turned on the corner, driving was the issue, experience was what counted. Besides, how could we possibly have time to calculate the speed of the car at that instant!"

Student Negotiation – Learning to Communicate

While not statistically significant, the average class scores on the subscale of Learning to Communication were slightly higher at the end of the course than at the beginning. Moreover, scores on this scale were higher than for most other scales. This could be attributed to opportunities being offered to students to share their ideas, listen to others' ideas, and reflect on what other students were saying. In this category, I present three examples of student negotiation — communication among group partners and with friends form other groups, communication without words and communication with other class members who were not friends.

Communication among group partners and with friends from other groups

In vignette six, where the emphasis was on group discussion (a new experience for students), two problems were assigned for students to practice the theory of torque. One student, ChunYi, did not understand my interpretation of the problem and asked KaunLi, "How do you understand the problem?" KaunLi explained to ChunYi by using the local language and drew a picture on scrap paper to explain. Later, after KaunLi's explanation, another group member, ShuLin, asked ChunYi "How do we find the torque of this problem?" This question was the first step towards solving the problem and was covered in KaunLi's explanation. ShuLin joined their conversation at first but did not finish. Was it because the subject matter in KaunLi's talk did not match to ShuLin's needs or because ShuLin was not patient enough to listen? ChunYi replied to ShuLin's question.

Very soon ChunYi found that he was not sure whether he knew how to find the torque. Because the direction of the torque did not match the direction of his right hand (a ‘rule of thumb’ for finding the direction of torques), ChunYi’s sounded uncertain and tried to find what the problem was. The discussion helped ChunYi solve the problem through understanding.

Discussions also were observed frequently in the practical work. Students talked to each other when they did not know how to collect data, where to enter the data on data sheet, how to calculate data, and what the results were. The discussions usually took between the partners of the group, with the group who sat across the table, or with visitors from other groups. LuanLi (vignette two), who did not interact much with his partner, visited his friends in other groups. He brought back some information to show that their result was different from others. In order to find why their time measurement for the sliding object was different, they discussed the results with each other, as well as with the group who sat across the table. They checked whether they had used the apparatus properly by questioning themselves “Did we use the timer function right?” They found that they had placed the weight in a different starting point. Disputes between DonHwa and LaiLong about the positioning of the weight with respect to the starter lasted for few minutes, “I think we should place the weight….” “No, I don’t think it is necessary.” When agreement could not be reached, as a final resort, they asked for my support. The proper positioning of the weight was clarified through this communication.

In group four from vignette three, ShuHui, the group leader, did not know where to enter the data into data sheet because she did not know how the distance was measured. Also she could not tell the difference between the measurements. ShuHai asked, “Do you measure the distance from weight to the stopped sensor?”

"No, measure the distance from the starter to stopper.", said her colleagues, ChiSun and LinYin, as they leaned forward to ShuHai's data sheet and pointed to the blank space where the data was to be entered. After ChiSun and LinYin explained the procedure to ShuHui, she understood how the data should be entered and how they were collected.

Group four, who cooperated well in their practical work, had many visitors during the session. Visitors wanted to know how group four processed the data collection, where the data were placed in the data sheet, and how calculations were performed. ShuHui replied to the visitors patiently or, if she did not know the answer, asked for her partners' help.

Communication without words

Practical work requires a high degree of team work. Groups who finished experiments early were often highly cooperative. In these groups, there was a high degree of tacit agreement about the roles of group members. Group eleven (vignette five), for example, could not hold their photo-sensor on the stand. TsiYi tried several ways to fix it, but failed. Without speaking, TonWhaw passed a small piece of paper to TsiYi. TsiYi knew what was meant and placed it in between the photo-sensor and supporting stick and solved the problem. Similarly, in group four, in vignette three, LinYin passed the paper to ChiSun without words. ChiSun knew what was intended and proceeded to conduct the experiment.

Communication among students who were unfamiliar with one another

Although the students selected their own experimental partners, I often observed unproductive discussions in groups were members did not know each other very well. In vignette six, for example, the group sitting near the entrance consisted with the students who came in late but did not want to disturb others in the classroom. This large group of about ten members comprised of mostly of students who were unfamiliar with each other. Whole group discussion was rarely observed, with most members of this group sitting alone and working by themselves.

In another example, KaunLi from group one (vignette two) sat alone at other end of the table with little interaction with his partners. He seemed more interested in what other groups were doing, and constantly looked around the classroom. This is another example of the importance of group members being familiar with one another and having well defined roles.

Shared Control – Learning to Learn

Chinese teachers and students do not have a history of shared control of teaching and learning. Low class average scores on this CLES scale indicate that students did not (or did not know how to) share control of their leaning. However, here I present some examples of how I attempted to modify my pedagogy in response to student needs. These modifications include adjustments to my teaching strategies to respond to student confusion about concepts and procedures, and the consequences of students' late arrival to class.

Adjusting my strategies to clear up students' confusion

When I raised questions in the middle of a lecture, I often posed a problem for students to solve voluntarily on the blackboard. When students showed their workings on the blackboard, I read the solution as a code to understand how well they understood the new material. This also helped me identify the problems that students might have in their learning processes, whether the solutions were correct or not.

ChongShin solved the vector addition problem in vignette one in same way that I had done a few minutes earlier. This showed me that he understood the material that was recently taught. Contrast this incident to vignette four when I asked a question about impulse. No one responded after the question was raised and the question was repeated three times. The students' silence indicated to me that they did not understand or could not recall the meaning of impulse. This lack of response indicated to me that I needed to revise the topic in an explicit way. Thus student responses helped me decided what to do and how to proceed with the class.

Student questions also influenced my pedagogical decisions. In vignette four and six, students raised problems about the assigned homework from the previous week. In response, at the end of the session I held up the planned schedule to help students solve the problems. Students' learning activity was thus affected by questions raised in the classroom.

Adjusting my strategies to attend to students' improper experimental procedures or calculations

During the practical work, I often demonstrated the experimental procedures and showed them the calculation equations so that they could collect sound data and obtain reasonable results. I would often interrupt the class several times in the middle of the session when several different students asked me the same question repeatedly, or when I found that students were using improper procedures or mistaken calculation methods. In vignette two, a practical on measuring the coefficient of friction, students often placed the weights arbitrarily on the inclined plane instead of directly in front of photo-sensor. This action, caused by student unfamiliarity with the procedure, resulted in large experimental errors. When I found that there were many groups of students making the same mistake while I walked around the classroom, I stopped the whole class and reminded of the proper position to place the weights. Similarly, in vignette five, I stopped the whole class in the middle of session, to remind them that they should hold the ball itself, not on the string of the pendulum. After the announcement, students adjusted their actions accordingly, and were able to obtain reasonable results.

In vignette six, I also found myself interrupting group discussion when I found that many students calculated the conservation of momentum by applying mass instead of force. The announcement interrupted students' concentration on the task at hand but helped them rectify their procedures or problem solving to good effect.

Lateness to class affecting students' learning

Students who came late to class often had difficulty in adjusting their learning. Students needed time to settle and pick up the lesson content since they missed part of the lecture. In vignette six, a group discussion, several students came into the classroom late and embarrassingly joined the group sitting near the entrance. This ad hoc group of late students did not normally sit together. There was a lack of discussion in this group, caused by unfamiliarity with each other and the fact that members had missed vital introductory parts of the lesson. There was a similar problem with student lateness in the practical lesson. Late students missed my briefing and the demonstration about experimental procedures. They sought guidance from friends who came earlier but their explanations were sometimes inadequate. Lateness to class directly affected the learning of those involved as well as the learning of other students.

Critical Voice – Learning to Speak Out

Chinese culture teaches children that teachers always are right and that whatever teachers do is beneficial to students. Teachers are treated as the authority figure. Consequently, the act of querying a teacher's methods or even responding to a teacher's question is a challenge for students, often requiring great courage. It is, therefore, unsurprising that the average class scores on this CLES scale were lower than for most other scales. Average scores also dropped slightly over the course of the semester (although not significantly), perhaps indicating students were finding the physics content to be more difficult as the semester proceeded. This aspect of the learning environment — learning to speak out — is evident when students displayed their confusion and made suggestions about how they wished to be taught.

Students displaying their confusion

The atmosphere in the laboratory classroom — as students conducted experimental procedures, used the data to make calculations, and chatted with friends — was quite relaxed. At same time students had many problems to overcome, such as how to manipulate the instruments, undertake experimental procedures, perform calculations, and judge the rationality of the results. In the easy atmosphere of the laboratory, the students' were less nervous about seeking the teacher's support to overcome their problems. This is illustrated by group eight, in vignette two. When the students faced the problem of the burnt out fuse in the timer, they switched the knob on the timer panel one by one until they had no other way to solve the problem. At this point the students asked for my assistance. Group one checked with their neighbor first to solve their time measurement problem before they sought my support. Group nine, in vignette three, sought my help to explain the 200% error in their experimental results. Students' help-seeking behavior demonstrated their desire to clear up any confusion about the learning activity. Before they asked for my support, however, they tried hard to solve the problem on their own.

Students expressed their ideas more freely in the experimental classroom. In the discussion about finding reasonable factors causing the 200% error, ChunYi and KouKoung responded to my question, “Can you think of other factors that could affect your results?” with suggestions such as “bulged at midpoint of inclined plane” and “inclined table was not clean”. ChunYi also expressed his ideas about the reason for the large error. The discussion was held pleasantly with no pressure and with showing their students' desire to learn.

In the lecture situation, students also raised questions about the problems they encountered when trying to understand the material or solve the problems. In vignette four and six, students asked me to solve one of the homework assignments. In vignette six, students also requested that I interpret the meaning of one of the problems assigned during the class. Students asked for my translation when they could not follow the meaning of the problem.

I liked to raise questions in the classroom because I thought that students could respond in the language that they customary used among friends. This kind of communication helped the others in the classroom who had difficulty understanding the lecture. Yet, students did not respond to the teacher's questions unless they were sure that their answers were correct. They did not want to be embarrassed in front of their friends. In the first vignette, I raised several questions such as "Should I say 70km or I should say 50km south of east?" or "Is here the position I am now?"; as well as "What is the impulse?" in vignette four. While my aim in asking these questions was to provoke students' thinking, I received few responses. An exception was in vignette four, when I asked students "How many of you experienced shooting practice?" In this case, students responded enthusiastically. When ChongShin, in vignette one, or TongHwa and ChaShinin, in vignette six, solved the assigned problem on the blackboard voluntarily, they demonstrated their willingness to share their ideas with their fellow students.

Students experienced pressure when I offered students the opportunity to solve the problem in front of their peers. In vignette six, for example, students were at first reluctant to place their solutions on the blackboard. However, when TongHwa and ChaShin displayed their solutions, this helped the other students to learn. In another example from vignette one, the learning atmosphere became more relaxed when ChongShin voluntary solved the problem on the blackboard. Students were pleased that one of their peers was able to solve the problem. The pressure was relieved when one student volunteered or was chosen.

In summary, asking for the teacher’s support or responding to the teacher’s questions requires considerable learning motivation and courage on the part of students.

Students suggesting which way they preferred to be taught

In physics, we habitually use symbols to represent a solution. After I worked out a solution represented by symbols, ChiSun indicated that he could not accept a symbol as an answer. ChuSun was not the only student who accepted only numbers as answers. There were several other students who agreed with ChiSun. Students demonstrated to me the way that they liked me to teach, by plugging the numbers into the symbols to get the final number. Even though I explained that the solution was represented as symbols and that the students were expected to practice the new expression, the students had difficulty getting used to this new procedure.

Students also liked to copy solutions from the blackboard. However, sometimes, as in vignette four, they missed parts of my interpretation about the theories. I suggested that they should spend time writing down my interpretation because that was the most important part in physics learning. However, students insisted on copying my solutions from the blackboard as they had done previously. In doing so, they demonstrated to me the way they liked to be taught, in a method that was the acceptable to them.

Uncertainty – Learning about Science

Average class scores on this CLES subscale were considerably higher (and uniform across the semester) than for the other four subscales, indicating that students perceived that their classroom offered considerable opportunities to learn about science (interpreted I suspect as learning the content of science). Under this referent, I highlight three aspects of students' learning about the uncertain nature of science – how knowledge of science varies according to prior experience and value systems, how science cannot provide perfect answers, and how different people use different science procedures.

Science varying in accordance with the environment and values

During discussion students exchange ideas or share their thoughts about how to solve physics problems or about the proper procedures for completing experimental tasks. Students often adjust their understandings when exposed to new ideas which prove to be effective. For example, in vignette six, KaunLi and I used different explanations when interpreting the torque problem to ChunYi. KaunLi also had to interpret the problem to ShuLin. I explained the problem based on my training and my conjecture about how students could understand. But the students received the messages based on what they already had in mind and how they looked at the world. The messages of sending and receiving are not necessarily the same. We each understand the same scientific phenomena in different ways based on our background and experience.

The discussion between DonHwa and LaiLong in vignette two about where to position the weight was based on their understanding of how to measure the elapsed time for zero initial speed of weights sliding differently. The two students had different interpretations about what they heard during the briefing, what they saw during the procedure demonstration, and what they previously understood about zero initial velocity. These differences provided students with motivation to think and inquire. Knowledge of science varies from person to person.

Science not providing perfect answers to problems

Students liked to check their problem solutions and experimental results with friends to make sure that their answers were correct. They also checked the solutions that I left on the blackboard after the problem was solved so that they could make sure that the solutions were correct. In vignette four, ChiSun was so eager to make sure that the solution on the blackboard was correct that he missed the following lecture as he was busy working out the solution. For me, answers represented by symbols highlight cause and effect relationships. To students, the most acceptable solution was a number. This preoccupation with obtaining the correct answer had been instilled in students from an early age.

Group nine, in vignette three, obtained a 200% error, and wanted to know what caused the error. Through our discussion we identified several rational reasons for the error. I demonstrated to them how the precision of the timer influenced the calculation; and the way they collected data and the small difference in the distance between S_1 and S_2, could also cause a huge mechanical error. The students pointed out how a bulge on the inclined plane influenced the time elapse for the sliding object; and how the cleanliness of the inclined plane affected the coefficient of friction between object and plane. The discussion demonstrated to them that there was no perfect coefficient of friction. It could be affected by many factors. In vignette two, group one, KaunLi wondered over to his neighbor to share information and found that they had collected different data. When he brought these data back to his group, they spent time deciding which data were reasonable and which were not. The behavior of checking the solutions demonstrated that there were no perfect answers for problem.

Difference science procedures used by different people

Vignette three illustrates how ShuHui calculated the data in a different way from her peers. She wrote every single calculation step by plugging the numbers into a formula before she calculated it. Most of the other students in the laboratory punched the numbers into the calculator directly without writing the steps. After her partners, ChiSun and LinYin, finished their data collection they helped ShuHui by following the steps that were already written on her scrap paper. They did not question her about why she used such an uncommon strategy. The behavior of not questioning demonstrated how her partners showed respect for ShuHui. Different scientific procedures were used by different people.

In another example, during the topic of conservation of momentum, students shared their shooting experience with their friends. When the question of “How many of you experienced shooting practice?” was raised, the atmosphere in the classroom became more enthusiastic. Students chatted with each other in delighted voices. Each person had his or her own unique experience of this science-related phenomenon.

Summary

In this cross-case analysis, I have drawn from the six narrative vignettes and the class average pre- and post-course CLES scores. The analysis uses a critical lens to examine the learning environment of my college-level physics classroom, by using the theoretical frameworks of the six subscales of the Constructivist Learning Environment Survey.

Chapter 6: Propositions, Implications, and Reflections

Propositions

This study employs the framework of a constructivist learning environment to examine my own science teaching in a Taiwanese school. I have employed the five categories of the CLES to analyse six vignettes of my practice. In this chapter, I revisit these analyses to construct several overarching propositions about the study. These propositions serve as tentative assertions, highlighting those issues that may have applicability beyond the boundaries of this study.

Proposition 1: The teacher plays a central role in establishing the overall classroom learning environment

The six narratives described in previous chapter show the teacher playing a central role in the lecture and in the laboratory classroom. In the lectures, for example, I interpreted the content of the physics theories and, for the most part, the students sat and listened with little querying. In the lessons described in narratives one and four, for example, I used several practical experiences as examples to refer to vectors, vector addition, and the conservation of momentum. Among those subjects some are easier to follow but some require a high level of reasoning ability. Instead of trying to understand the theories, student listened quietly and copied the words on the blackboard without too many questions. Typically, they displayed their uncertainties in silence or stared at the blackboard at the point where they had a problem. Students did not habitually interrupt the class when they could not understand my interpretation.

In confronting student’s attitude of learning, my strategy to probe their understanding was to raise questions to provide opportunities for students to display their queries. However, in responding my queries, a certain amount of pressure was observed. When my questions were answered by the students, the atmosphere in the classroom seemed more relaxed. But when no one responded to my queries the climate was less comfortable. During these times, students would sit on their seats, and flip through the textbook or their notes, while waiting for my solution. The students seemed to experience considerable pressure if they did not know how to respond to my questions.

In the laboratory, I demonstrated the procedures of the experiments. While students followed my demonstration, they often encountered problems in experimental operations and collected unreasonable data. I attribute this to poor reading of the laboratory manual, as illustrated in narratives two and five. At this moment, when I observed a major problem in the conduct of the experiment, as in narrative five, I interrupted the whole class and emphasized the proper procedures or the proper data manipulations. I also played an important role in group discussion. For example, in the lesson described in narrative six, students did not facilitate the formation of group discussion until I instructed them to do so.

However, my classroom offered the opportunity for students to raise questions if they encountered difficulties with problems. In vignette four, for example, students asked me to reinterpret how to solve the problem that was covered in previous week; and in vignette six, they asked for help to solve the problem that was assigned as home work. Students also asked me to translate the meaning of the problem since it was written in English. These kinds of queries, raised in different classrooms, indicated that the students' experienced a comfortable learning classroom conducive to raising questions.

Students also demonstrated their concerns about their own learning in the laboratory. In vignette three, for example, members of group nine sought my support to solve their unreasonable 200% error. I saw my role in this situation as a guide and probed them about possible sources of error. ChunYi reasoned that the error could be due to the bulge on surface of the inclined plane, KouKoung reasoned that it could be due to the dusty surface, and ChunYi asked, "Could it be the distance between two photo sensors?" I suspected that the small distances between two sensors caused great calculation disparity. Bulging and dusty surface would not have been mentioned unless suspected by students. Yet they were not certain enough to avoid those factors in their experimental procedures. The concept of the coefficient of friction was clarified further through discussion between me and the students.

Another example of dialogue between teacher and students is in vignette five when I found that group eleven did not measure the height of the sensor. Instead of telling them directly about the proper method, I asked, "What is the height of the ball's speed are you measuring?" This question threw them into confusion. I followed by suggesting, "To get the total energy of the ball…" Students then realized that there was a part of the measurement missing. During that period, only a few words were used, but those words caused students to think about the solution to their problem. Students developed a better meaning of total energy and of conservation of energy as a result of making and correcting their original error. Students' physics theories learning were developed through student-teacher or teacher-student discussions.

One of the important parameters in observing a constructivist learning environment is the opportunity that student are offered to participate in the control in the classroom. For example, in narrative one, the textbook that students used for the course was selected by me before the class commenced. The US-English written textbook was rather difficult for students but was arranged for their future study purposes. Student did not participate the decision making about the use of the text. The course content and the selection of the textbook were each determined by me. Student did not have many opportunities to participate the decision making of what they wanted to learn, although on one occasion, I consulted with students about the minor subjects they wished to cover, such as heat or optics.

On the other hand, the class schedule was adjusted according to student's demands. For example, the class schedule was adjusted when students could not respond to my question, as in narrative four. The original class schedule was delayed as I reinterpreted the meaning of conservation of momentum. Similar actions were observed in the laboratory classroom, or in group discussion. Even so, the decision to reschedule the class was mine.

The average class pre- and post-topic scores on the CLES scales of Shared Control and Critical Voice were comparatively low. These results are a further indication of the lack of opportunity for my students to share control in the classroom, and express their critical voice. To summarize my proposition, there is strong evidence that mine was a teacher-centered classroom.

Proposition 2: Student group dynamics are important in the classroom learning environment

In a constructivist learning environment, students’ interaction is an important consideration. In my classroom, students were grouped in the laboratory classroom and in the group discussion session. Students were offered the opportunities to share their thoughts with their peers, and groups were asked to answer questions and justify their thinking.

In vignette two, KaunLi found out the time data that his group collected was different from the time data collected by another group. KaunLi’s group started to trace possible sources of error in the experiment. The students investigated this anomaly by checking the function of the timer and comparing their technique with the group who sat across the table from them. They found that group two positioned the weight in a different manner. After discussion they realized that they did not know the proper position for the weight and eventually consulted with the instructor. In this process, the group members shared their thoughts, exchanged the data with other groups, and discussed the method of measuring the time with peers from other group and with the partners in same group. Overall, ideas about data collection were shared and examined for their viability.

In the lesson described in vignette six, the subject of torque was introduced, reinterpreted, and examined through problem solving. However, there remained some confusion on the part of group members. In group discussion, ChunYi asked KaunLi once again “How do you understand the problem?” and listened to ChunYi’s interpretation carefully. Then he responded to ShuLin’s query “How do we find the torque?” but could not continue because his explanation conflicted with the direction of his right hand thumb which indicated the direction of torque. His uncertain voice indicated that he was still confused about the idea of torque. After the dialogue, ChunYi then sat quietly, seemingly engrossed in his study for a period of time. At the same time, KaunLi and ChunYi were questioned by others and responded to questions by ChunYi and ShuLin. The viability of their thoughts was also examined through sharing and critically examining ChunYi’s ideas.

It is interesting to note that some of the more able students were not interested in the learning strategy of group discussion. They argued that they could not benefit from group discussion because the other members of the group could not help them but hold them back. They would rather use the time that was spent on discussion to study on their own.

In this study, familiarity among group members affected learning. In laboratory work, for example, the students tended to perform a certain role to complete the group task. In the lesson described in vignette three, ShuHui adopted the role of ‘the commander’, ChiSun, ‘the manipulator’, and LinYin, ‘the good helper’, played important individual roles, contributing to the joint effort to complete the task. LinYin and ChiSun seemed to have good tacit understandings. For example, LinYin passed ChiSun a small piece of paper without requesting an explanation. They had known each other for only two months but their classroom relationship had a natural feel. I contributed this relationship to their positive learning attitude, and conscientious manner.

Group members also demonstrated their respect for each other's work when ShuHui analyzed the data on behalf of others. The attitude of serious respect was a sign of harmonious collaboration, resulting in neat and serious reports. At the beginning of the semester, I noticed that this group completed its tasks at about the speed as the other groups in the classroom, but at the end of the semester it usually finished its tasks faster than the others. The good collaboration relationship among group partners was also found in the group eleven, described in vignette five, when TsiYi quietly passed a small piece of paper to TonWhaw to support the photo-censor on the stand. This group accomplished their experiment in a serious and effective manner.

In the lesson described in vignette two, KaunLi, a member of group one, sauntered around the classroom and sat alone at the end of the table. Then he exchanged information with other groups and shared the exchanged information with his partners. But, again, he sat alone on the other end of the table with little participation with his peers. In the following session of the experiment he became more involved with his partners' task, but overall I conclude that his unfamiliarity with his partners impeded him in participating in the group's work.

Studies by van Zee and her colleagues (2001) and Roth and Bowen (1995) show that students share their thoughts in a constructivist classroom and the knowledge is elaborated during their discussion. In the current study, students were provided opportunities to express their opinions, share thoughts, to query their problems with peers or be queried by peers. To some extent at least, this demonstrates that students were provided with a comfortable learning environment in both laboratory and group discussion session.

On the other hand, there is also evidence of students who were not as involved in joint discussions. In vignette six, in the group discussion session, very little interaction was observed among the group of students who arrived late to class. Most students in that group studied by themselves or pretended to be engaged. Their lateness not only prevented them from joining the group discussion but also impeded the group dynamics among the original members in the group. Student lateness also impeded task completion in the practical sessions. ShonYi, in vignette two, arrived late and could not join the group operation because he did not know how to proceed with the experiment. The same issue was observed in vignette five. ShonYi's lateness meant that the group was effectively operating as a group of two rather than three. This delayed the completion of the task and reduced the effectiveness of the discussion.

Proposition 3: The central role of content often works against the establishment of a constructivist classroom

Physics theories are induced from daily life and are deeply involved in everyday life. Yet relating the physics theories to practical experience or relating the practical experience to physics theories is one of the major difficulties for students in learning the subject (Roth et al., 1997). It seems that experience is experience and theory is theory, and the thread connecting the experience and the theory is not easy to recognize.

In the classroom, I used examples from students' experience to interpret physics theories and drew the simple diagram to display a picture of the problem. In vignette one, I used the motion of going from A, as city A, to B, as city B, to relate the mathematical operation of vectors and vector additions. One student, ChongShin, solved the assigned problem on the blackboard similar to the way I interpreted it, indicating that he understood my explanations. This is one example of a student learning by using everyday experience.

The same strategy was applied in narrative four. I used the gun shooting experience to demonstrate the theory of conservation of momentum. The positive response from the students indicated that the gun shooting example was well received. However, this time students became confused about the meaning of momentum and the conservation of momentum. The thread that connected the theory (of momentum) and the experience (of the gun shooting) was not found.

In vignette six, ChunYi responded to ShueLin's queries with an uncertain voice. This response indicated that he had a misconception about the idea of torque or the method of finding the direction of torque. The theory of torque is everywhere in our daily life and is related to the everyday experience. However, as described in the vignette, the theory was explained at least three times before ChunYi reinterpreted for ShueLin, but ChunYi remained confused about the concept. His unsuccessful interpretation demonstrated that he could not identify the number of torques in the problem and could not distinguish how to find the torque. He was able to draw a picture of the problem, indicating that he transcribed the problem into 'real life' form. This indicates that even though the theory of torque is widely seen in everyday life, it is not an easy task for students to understand and accept.

Crawford, Krajcik and Marx (1999) reported that when classroom discussions were related to the students' own experience students were more cognitively engaged. In my own study, the students had no problem learning when the subject was at a basic level but were less success when the subject involved advanced level thinking and processing. While students' out-of-school experiences were used occasionally to help teach theoretical ideas, I found that extra efforts of study are needed for students to learn effectively and successfully. A fluent skill of interpreting the theories also is required to facilitate students' thinking. As described in analysis four, students disagreed with me about the possibility of calculating the speed of car when it turned a corner. This exchange indicated that the knowledge that student learned from physics classroom was not practically transferable to their daily life needs.

In a study by Roth and his colleagues (1997), the teacher, Mr. Sparks demonstrated how the conservation of angular momentum works by sitting on a frictionless stool and holding a rotate-able bicycle wheel. However, many students failed to grasp the subject matter. The authors reason that several factors impeded students' learning on this occasion. While physics is developed from everyday phenomenon, simply relating the everyday experience to the physics theories in the constructivist classroom is insufficient to support students' learning. Skillful understanding of the theories and their mutual interaction is required to facilitate students' physics learning.

Proposition 4: Cultural factors play a large role in determining the constructivist nature of the classroom

In Taiwan the education system is largely examination oriented. Assessments generally consist of multiple choices questions with the answers marked by a computer. The students' learning attitude is therefore oriented towards obtaining the "right answer" rather than cognitive reasoning. This system fosters students memorizing formulas without necessarily promoting understanding. The students' primary goal is to receive a high score and they are trained to believe that numbers are the only answers to be accepted as solution. In narrative four, ChiSun tried to work out the solution that I left on the blackboard, in the form of words. He could not decode whether or not it was correct, even though it was presented by the instructor. At the commencement of the course, I discussed with the students the option of using words or an equation instead of a numerical answer. I explained that these alternatives were neither superior nor inferior to a number but simply an alternative. However, ChiSun was conditioned to accept a numerical solution as being superior to words. His reaction demonstrated that accept a new learning strategy is a matter of habit changing or concept changing. Old habits are often deeply embedded and developing new habits take time.

Similar behavior was observed when the students copied my notes from the blackboard. Normally the words that are written on the blackboard are easy to read but the underpinning phenomena and trajectory of the thinking are complicated to write. These underlying principles can only be explained by oral description. Understanding the underpinning phenomena is the key point of learning physics and

I urge my students to “Concentrate on my oral description. Understanding is the most important part of learning, don’t worry about the notes on the blackboard”. Yet the students continued to copy the words, and in doing so, missed my oral interpretation. This was still was the majority behavior even as the end of the semester approached. In vignette four, for example, ShuLin, continued to copy the words from the blackboard and missed part of my interpretation. In vignette six, some students copied the solution that TongHwa put on the blackboard even without understanding whether the content was correct. This behavior demonstrates that students are trained to habitually copy notes without understanding the underlying concepts. Similar behavior was observed in Mr. Sparks’ classroom (Roth et al., 1997). Students explained to me that they copied down whatever was written on the blackboard “in case” it was needed when they reviewed the context. They said that they felt insecure if they did not have a complete set of copied notes.

In my classroom I often tried to find out how well students understood the content. In vignette one, for example, ChongShin volunteered to solve the assigned problem and in vignette four I raised the question, “What is the impulse”. I repeated the question several times but received no response. Inviting students to solve the problem on the blackboard or to respond my queries was not unusual in my classroom. My invitation normally would be accepted if responding student knew how to solve the problem because I promised additional grade points if the solution was correct. Students in the laboratory classroom liked to finish their report and submit it early. Many students of those who handed in early reports stayed in the classroom to help others who had not yet accomplished their task. These early finishers appeared to be happy and seemed honored to assist others. While students required some courage to post their thoughts in public, accomplishing the task provided them with honor and increased confidence.

These findings are similar to those reported by Chang and Bell (2002) who asserted that “students’ perceived learning barriers were mainly in the area of their learning habits, which included ineffective learning methods and insufficient learning commitments” (p. 87). In my own class, ineffective learning methods included memorizing the formula without understanding, and insufficient learning commitments included skipping and coming late to classes.

Students did not always consult the laboratory manual when faced with difficulties while conducting their experiment. Instead they sauntering around the classroom and consulted with the members of other groups. In vignette two, members of group one consulted with the members of group two to find where to properly place the weight. Instead of reading about the procedures in the laboratory manual, students shared and passed around information without judging its worth. These findings are consistent with Roth and Bowen’s (1995) conclusion that the message spreads around in the classroom. This phenomenon explains why sometimes I received some bizarre reports at the end of the lesson and this same bizarre outcome was present in many group reports.

At the beginning of the course, students often treated the laboratory equipment as interesting fancy “toys”. Students could not resist their curiosity to play with those toys before I finished the experimental briefing. They also played with the equipment in a more or less random fashion when faced with a problem. In vignette two, for example, when the students encountered the timer problem, they switched the knobs one by one to try their luck. Contrast this scenario to the scene of a similar problem three months later. After the experiment was conducted (described in vignette five), the students checked the cable connection on the back and front panels in an orderly manner. These two different behaviors indicated that after three months of working with the experiment their experimental ability improved considerably. This is an example of how experimental work provides students with the opportunity to elaborate their scientific knowledge through practical operation and develop experimental procedural skills.

Proposition 5: Language plays an important role in the construction of the learning environment

Language includes the words that instructor uses to interpret phenomena and the symbols or diagrams or pictures used to represent statements. However, what the student receives and understands is not necessarily the same as what the speaker tries to convey. Such misunderstandings are due the different interpretations of language, caused by divergences in ages, cultural backgrounds, gender, etc. In the group discussion, for example, I reinterpreted the concept of equilibrium of torque to students in the classroom by using certain terms and representations. These representations were different from those that KaunLi used to explain the phenomenon to ChunYi. Different representations were also used when ChunYi provided an explanation to ShuLin.

In the lesson described in the first vignette, the class was using a textbook written in US-English. However, the language used was often unfamiliar to the students and interpretation required further assistance from me. In vignettes four and six, students asked me to translate the meaning of the problem that they were asked to solve. The language of the textbook was one of the factors impeding their understanding of the meaning of the problem. A further issue lies in the difficulty of physics language itself. Even when the problem is written in the mother language of Chinese, I was often requested to translate the meaning of the problem. Students have problems in transcribing the meaning of the words into some kind of understandable picture. They cannot interpret the word messages because they are hidden in the semantics. Difficulties, therefore, are encountered by the language of the textbook (for example, English) but also by the semantics of the subject itself.

Learning is also affected by students' difficulty in understanding of the meaning of terms used in physics that are not used in everyday life. Sometimes, such words are beyond the scope of everyday life (Fang, 2006). For example, we use velocity instead of speed; force instead of strength or violent actions; reflection instead of bouncing back; similarly with the terms torque, vector, and momentum. Velocity, known as speed in everyday experience, is the conjuncture of the speed and the direction of the motion in physics. When students work on a problem, they often omit the direction dimension because of their everyday experience. Hence, their everyday use of the meaning of speed alienates the incoming knowledge. Furthermore, the new knowledge confuses the knowledge that one already has.

A further issue is that physics originated and was developed in western countries. The procedures of logical thinking, and observing and describing phenomena are explained in the terms that are used in western countries. When introduced into countries of other cultures the everyday experience, the logical thinking, and the terms are not necessarily applicable (Akatugba & Wallace, 1999). In Chinese, for example, the terms momentum or torque never appear in daily life, or the concepts of equilibrium or conservation are terms that were adapted in recent years from the conservation of energy.

In summary, cultural factors, students' learning habits, previous experience and language are important factors affecting the construction of the learning environment

Proposition 6: Students' learning attitude affected the classroom environment

Many of the students in my classroom were motivated to succeed. They actively raised questions that were assigned as homework if they had problems with the solution. They also consulted with me in the laboratory classroom when they had problems with the operation of the equipment or with manipulation of their data.

Notwithstanding this observation, however, students tend to show a passive attitude to teaching and learning. Chang and Bell (2002) suggest three factors contributing to passive learning attitudes among Taiwanese students, the pressure of preparing for the university entrance examination and its narrow focus on grades (compared with the freedoms experienced at university level), students' satisfaction with pass grades (contributing to a lack of self-expectation), and the prevalent adoption of rote learning (leading to a lack of cognitive reasoning ability). These factors were also prevalent among the students in my college.

In my classroom it was not difficult to find students who were not actively participating in the lessons. For example, LuSin (vignette four), instead of paying attention to the lecture, he talked to his neighbor and waited for the recess. He did not appear to show concern about what was going on in the lesson. In vignette two, ShonYi, a member of group eight, sat alone at the other end of the table, apart from his partners, with little concern for what his partners doing. Some of the students in my class appeared unprepared for the quiz and simply recited the formulas. They did not know which formula was applicable to the problem or they applied a non-related formula to the problem. Several students were regularly late to class. Some tried to catch up on material discussed before they arrived. Other late students did not participate in any meaningful way and appeared to be simply waiting for the recess break.

The reasons for these behaviors are manifold. Many students in my career college thought that technical skill training was more important than subject knowledge. They seemed more concerned with techniques than basic physics knowledge in supporting their future study. They frequently asked, “Why do I need to take this course? I want to learn more techniques that support my future employment not the physics that I’ll never use.” Many students judged the importance of the course by relating the content to their future job prospects. As the course went deeper and more effort was required, these students seemed to become more reluctant to participate and more discouraged.

To summarize the learning environment in my classroom, it is a largely teacher-centered arrangement. Typically, as the teacher I offered my interpretation of the physics theories in the front of the classroom. Students sat and listened without too many queries. However, there were some opportunities for more open inquiry. On these occasions, there was more student-teacher interaction, contributing to a more constructivist learning environment. These more open interactions were observed mostly in the laboratory classroom and group discussion. In the formal lecture situation, students were reluctant to offer their views. Speaking up in these settings, required courage and students wanted to avoid the impression of challenging the teacher's authority. The data show that there were not many opportunities for students to share control of the content or procedures of classroom with the teacher, although I did make occasional adjustments to the schedule in response to students' requests and behaviors. While there is some evidence of my trying to connect the physics theories to students' everyday experiences, they did not always receive the knowledge in the way that I intended. While students were offered opportunities to express their thoughts, and to listen on others' ideas, they did not always do so for reasons explained earlier.

Implications

I was educated in a teacher-centered system, and saw my role as a teacher as imparting my knowledge to my students. For much of my career, I concentrated on making my explanations of physics theories more understandable and interesting to my students. I put less effort into other aspects of my pedagogy, such as tapping into students' prior knowledge and experiences. While I paid some lip service to students' experiences, I was discouraged by their failure to fully understand my theory related interpretations. My interpretations and my student's understandings seemed to be two parallel lines that did not meet. However, I found that my responses to student initiated queries helped me to bring these two lines together. Student queries not only stimulated students to think but they also helped me to learn what they were thinking. I also found that responding to a student's queries honored the student involved. Appropriate timing of when to listen to a query and when to provide the solution for the student, that is, “to tell or not to tell” (Krueger, Loughran, & Duit, 2002) is critical in supporting students’ learning.

I also found that students were more motivated when theoretical ideas were related to their practical experience. My students enjoyed sharing their experiences with their peers and with me. But when the theories went beyond a simple recounting of experience, student became confused and their interest diminished. Students also learned from practical work in the laboratory classroom. The course provided student the opportunities to experience the phenomena that were described in the lectures or textbook. The outcomes from the practical work or problem solving challenged and inspired student to learn.

In conclusion, students learned from divergent fields and diverse settings as long as they “wanted” to straighten out their confusions. Therefore in student learning, learning motivation or career goals play an important role in determining whether students are likely to confront and overcome difficulties, apply themselves in class, attend regularly and on time, participate in group work, complete homework etc. Learning motivation helps the student set and strive for goals. I believe that this was one of the major challenges for my students who had a history of low academic achievement. How to induce such students to establish their career goals, and engage in active and meaningful learning, is an important issue for further study.

In the classroom, an open learning atmosphere allows student to present their experience and discuss their ideas with others; evokes student’s reasoning ability and make theories more reasonable; and releases the teacher’s power to increase students’ involvement in the classroom. Yet, such openness requires time to proceed, often impeding the course schedule. Too much power released may put the student in a maze situation, having to learn without the necessary direction from the teacher.

Teacher-centered and student-centered classroom have their advantages and disadvantages. Some kind of balance is clearly required, and the nature of that balance depends on the context, the subject matter, the teacher and the student.

Reflections

Before I commenced this study, I was puzzled as to why my students could not understand my deliberate and well thought out explanations of physics theories. I presumed that, if I persisted, they would eventually adopt my knowledge as their own. In spite of my efforts, however, I found that students were still not responding as I had hoped. After I began exposed to the theory of constructivism, I realized that students would only adopt my ideas when those ideas made sense to them. Over time, I tried to modify my instruction to find out what was causing my students to become confused, and to take more time to make my explanations more acceptable. I also realized that it was pointless to introduce a new theory when students could not understand the previous one. I became a more popular teacher among students because I valued and accepted their opinions, and focused on their understanding.

A constructivist referent for teaching helped me understand the importance of a more open learning atmosphere and good relations with my students. However, the success of such an approach depends on the comfort level of students, parents and other stakeholders. For example, in traditional Chinese society, children learned by memorizing articles and poems without interpretation. Children were expected to wait until they were older and had more experience of life before offering opinions and interpretations of their own. It is interesting that these two approaches — which I will call constructivist and traditional — were each implemented in different worlds and at different times, and were each successful in their own way. There is no single absolute theory of education. The positive aspects of each much be selected according the context, kept in balance and implemented with care.

REFERENCES

Akatugba, A. H., & Wallace, J. (1999). Sociocultural influences on physics students' use of proportional reasoning in a non-western country. *Journal of Research in Science Teaching, 36*(3), 305-320.

Aldridge, J. M., Fraser, B. J., & Taylor, P. C. (2000). Constructivist learning environments in a cross-national study in Taiwan and Australia. *International Journal of Science Education, 22*(1), 37-55.

Aldridge, J. M., Laugksch, R. C., Seopa, M., & Fraser, B. J. (2006). Development and validation of an instrument to monitor the implementation of outcomes-based learning environments in science classrooms in South Africa. *International Journal of Science Education, 28*(1), 45-70.

Anderson, C. W., Holland, J. D., & Palincsar, A. S. (1997). Canonical and sociocultural approaches to research and reform in science education: The story of Juan and his group. *The Elementary School Journal, 97*(4), 359-383.

Beichner, B., Bernold, E., Burniston, P., Dail, P., Felder, J., Gastineau, J., et al. (1999). Case study of the physics component of an integrated curriculum. *Physics Education Research, Am. J. Phys. Suppl., 67*(7), s16-s24.

Bentley, M. L. (1998). Constructivism as a referent for reforming science education. In M. Larochelle, N. Bednarz & J. Garrison (Eds.), *Constructivism and education* (pp. 233 - 249). Cambridge: Cambridge University Press.

Bodner, G. M. (1986). Constructivism: A theory of knowledge. *Journal of Chemical Education, 63*(10), 873-878.

Brill, J., Kim, B., & Galloway, C. (2007). Cognitive apprenticeship as an instructional model [Electronic Version]. *http://projects.coe.uga.edu/epltt/index.php?title=Cognitive_Apprenticeship*,

Chang, W. (2005). The rewards and challenges of teaching innovation in university physics: 4 years' reflection. *International Journal of Science Education, 27*(4), 407-425.

Chang, W., & Bell, B. (2002). Making content easier or adding more challenge in year one university physics? *Research in Science Education, 32,* 81-96.

Cho, J. (2002). The development of an alternative in-service programme for Korean science teachers with an emphasis on science-technology-society. *International Journal of Science Education, 24*(10), 1021-1035.

Chung, S.-H. (1998). 論小學數學科建構式教學的普遍適用性〔Discussion on the suitability and prevalency of the elementary constructivist mathematics〕*研習資訊, 15*(2), 43 -55.

Cobb, P. (1996). Where is the mind? A coordination of sociocultural and cognitive constructivist perspectives. In C. T. Fosnot (Ed.), *Constructivism: Theory, perspective, and practice* (pp. 34 - 52). New York and London: Teachers College Press.

Coe, R. (2002). It's the effect size, stupid: What effect size is and why it is important [Electronic Version]. http://www.leeds.ac.uk/educol/documents/00002182.htm

Costa, A. L., & Liebmann, R. (1995). Process is as important as content. *Educational Leadership, 52*(6), 23-24.

Crawford, B. A., Krajcik, J. S., & Marx, R. W. (1999). Elements of a community of learners in a middle school science classroom. *Science Education, 83*, 701-723.

Desautels, J., Garrison, J., & Fluery, S. (1998). Critical-constructivism and the sociopolitical agenda. In M. Larochelle, N. Bednarz & J. Garrison (Eds.), *Constructivism and education* (pp. 253-270). Cambridge: Cambridge University Press.

Dorman, F. P. (2001). Associations between classroom environment and academic efficacy. *Learning Environments Research, 4,* 243-257.

Driver, R., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Research, 23*(3), 5-12.

Duit, R., & Treagust, D. F. (1998). Learning in science - from behaviourism towards social constructivism and beyond. In B. J. Fraser & K. G. Tobin (Eds.), *International handbook of science education* (pp. 3-25). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Erickson, F. (1998). Qualitative research methods for science education. In B. J. Fraser & K. G. Tobin (Eds.), *International handbook of science education* (pp. 1155-1173). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Ewen, D., & Schurter, N. (2002). *Physics for career education*. Upper Saddle River. NJ: Prentice Hall.

Fang, Z. (2006). The language demands of science reading in middle school. *International Journal of Science Education, 28*(5), 491-520.

Fosnot, C. T. (1996). Constructivism: A psychological theory of learning. In C. T. Fosnot (Ed.), *Constructivism: Theory, perspectives, and practice* (pp. 8 - 33). New York and London: Teachers College Press.

Fraser, B. J. (1998). Science learning environments: Assessment, effects and determinants. In B. J. Fraser & K. G. Tobin (Eds.), *International handbook of science education* (pp. 527-564). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Fraser, B. J. (2001). Twenty thousand hours: Editor's introduction. *Learning Environments Research 4*, 1-5.

Geelan, D. R., Wildy, H., Louden, W., & Wallace, J. (2004). Teaching for understanding and/or teaching for the examination in high school physics. *International Journal of Science Education, 26*(4), 447-462.

Grbich, C. (2007). *Qualitative data analysis: An introduction*. Thousand Oaks, CA: Sage.

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics. *American Journal of Physics*, *66*(1), 64-74.

Hardy, M. D., & Taylor, P. C. (1997). von Glasersfeld's radical constructivism : A critical review. *Science and Education, 6*, 135-150.

Helldén, G. F., & Solomon, J. (2004). The persistence of personal and social themes in context: long- and short-term studies of students' scientific ideas. *Science Education, 88*, 885-900.

Jang, S.-J. (2007). A study of students' construction of science knowledge: talk and writing in a collaborative group. *Educational Research, 49*(1), 65-81.

Jonassen, D. H. (1994). Thinking technology: Toward a constructivist design model. *Educational Technology, 34*(4), 34-37.

Jonassen, D. H., & Duffy, T. M. (2000). Revisiting activity theory as framework for designing student-centered learning environments. In D. H. Jonassen & S. M. Land (Eds.), *Theoretical foundations of learning environments* (pp. 89-121). Mahwah, NJ: Lawrence Erlbaum Associates.

Julyan, C., & Duckworth, E. (2005). Constructivist perspectives on teaching and learning science. In C. T. Fosnot (Ed.), *Constructivism: theory, perspectives, and practice* (pp. 61-79). New York: Teacher College Press.

Kim, H.-B., Fisher, D. L., & Fraser, B. J. (1999). Assessment and investigation of constructivist science learning environments in Korea. *Research in Science & Technological Education, 17*(2), 239-249.

Krueger, B., Loughran, J., & Duit, R. (2002). Constructivism. In J. Wallace & W. Louden (Eds.), *Dilemmas of science teaching: Perspectives on problems of practice* (pp. 191-204). London and New York: RoutledgeFalmer.

Larochelle, M., & Bednarz, N. (1998). Constructivism and education: Beyond epistemological correctness. In M. Larochelle, N. Bednarz & J. Garrison (Eds.), *Constructivism and education* (pp. 3-20). Cambridge: Cambridge University Press.

Lee, L. S. (2000). *Technological and vocational education in Taiwan.* Paper presented at the Japan Academic Society for Industrial Education (JASIE), ED 441 956.

Lerman, S. (1996). Intersubjectivity in mathematics learning: A challenge to the radical constructivist paradigm? *Journal for Research in Mathematics Education, 27*(2), 133-150.

Marra, R. (2005). Teacher beliefs: The impact of the design of constructivist learning environments on instructor epistemologies. *Learning Environments Research, 8,* 135-155.

Meltzer, D. E., & Manivannan, K. (2002). Transforming the lecture-hall environment: The full interactive physics lecture. *American Journal of Physics, 70*(6), 639-654.

Merriam, S. B. (1998). Qualitative research and case study applications in education. In *Analytic techniques and data management* (2nd ed., pp. 155-177). San Francisco: Jossey-Bass.

Mintzes, J. J., & Wandersee, J. H. (1998a). Reform and innovation in science teaching: A human constructivist view. In J. J. Mintzes, J. H. Wandersee & J. D. Novak (Eds.), *Teaching science for understanding : A human constructivist view* (pp. 30-58). San Diego: Academic Press.

Mintzes, J. J., & Wandersee, J. H. (1998b). Research in science teaching and learning: A human constructivist view. In J. J. Mintzes, J. H. Wandersee & J. D. Novak (Eds.), *Teaching science for understanding: A human constructivist view* (pp. 60-94). San Diego: Academic Press.

Murray, M. (2004). Narrative psychology. In J. A. Smith (Ed.), *Qualitative psychology: A practical guide to research methods* (pp. 111-131). Thousand Oaks, CA: Sage.

Novak, J. D. (1978). An alternative to Piagetian psychology for science and mathematics education. *Studies in Science Education, 5,* 1-30.

Novak, J. D. (1998a). *Learning, creating, and using knowledge*: Mahwah, NJ: Lawrence Erlbaum Associates.

Novak, J. D. (1998b). Theoretical and empirical foundations of human constructivism. In J. J. Mintzes, J. H. Wandersee & J. D. Novak (Eds.), *Teaching science for understanding: A human constructivist view* (pp. 3-29). San Diego: Academic Press.

Pintrich, P. R., Marx, R. W., & Boyle, R. A. (1993). Beyond cold conceptual change: The role of motivational beliefs and classroom contextual factors in the process of conceptual change. *Review of Educational Research, 63*(2), 167-199.

Polkinghorne, D. D. (1995). Narrative configuration in qualitative analysis. In J. A. Hatch & R. Wisniewski (Eds.), *Life history and narrative*. London: The Falmer Press.

Roth, W.-M. (1993). Construction sites: Science labs and classrooms. In K. Tobin (Ed.), *The practice of constructivism in science education* (pp. 145-170). Mahwah, NJ: Lawrence Erlbaum Associates.

Roth, W.-M. (1998). Teacher-as-researcher reform: Student achievement and perceptions of learning environment. *Learning Environments Research, 1,* 75-93.

Roth, W.-M., & Bowen, G. M. (1995). Knowing and interacting: A study of culture, practices, and resources in a grade 8 open-inquiry science classroom guided by a cognitive apprenticeship metaphor. *Cognition and Instruction, 13*(1), 73-128.

Roth, W.-M., McRobbie, C. J., Lucas, K. B., & Boutonne, S. (1997). Why may students fail to learn from demonstrations? A social practice perspective on learning in physics. *Journal of Research in Science Teaching, 34*(5), 509-533.

Stake, R. E. (2006). *Multiple case study analysis*. New York: The Guilford Press.

Taylor, P. C. (1996). Mythmaking and mythbreaking in the mathematics classroom. *Educational Studies in Mathematics, 31*, 151-173.

Taylor, P. C., Dawson, V., & Fraser, B. J. (1995, 22-25 April, 1995). *A constructivist perspective on the monitoring classroom learning environments under transformation.* Paper presented at the annual meeting of the National Association for Research on Science Teaching, San Francisco, CA.

Taylor, & Fraser, B. J. (1991). *Development of an instrument for assessing constructivist learning environments*. Paper presented at the annual meeting of the American Educational Research Association, Chicago, IL.

Taylor, P. C., Fraser, B. J., & Fisher, D. L. (1997). Monitoring constructivist classroom learning environments. *International Journal of Educational Research, 27*, 293-302.

Taylor, P.C., Fraser, B.J., & White, L. (1994). *The revised CLES: A questionnaire for educators interested in the constructivist reform of school science and mathematics.* Paper presented at the annual meeting of the American Educational Research Association, Atlanta, GA.

Tobin, K. (1990). Social constructivist perspectives on the reform of science education. *The Australian Science Teachers Journal, 36*(4), 29-35.

Tobin, K. (1998). Sociocultural perspectives on the teaching and learning of science. In M. Larochelle, N. Bednarz & J. Garrison (Eds.), *Constructivism and education* (pp. 195-212). Cambridge: Cambridge University Press.

Tobin, K., & Tippins, D. (1993). Constructivism as a referent for teaching and learning. In K. Tobin (Ed.), *The practice of constructivism in science education* (pp. 3-22). Mahwah, NJ: Lawrence Erlbaum Associates.

Tsai, C.-C. (1999). "Laboratory exercises help me memorize the scientific truths": A study of eighth graders' scientific epistemological views and learning in laboratory activities. *Science Education, 83*, 654-674.

Tsai, C.-C. (2000). Relationships between student scientific epistemological beliefs and perceptions of constructivist learning environments. *Educational Research, 42*, 193-205.

van Zee, E. H., Iwasyk, M., Kurose, A., Simpson, D., & Wild, J. (2001). Student and teacher questioning during conversations about science. *Journal of Research in Science Teaching, 38*(2), 159-190.

von Glasersfeld, E. (1993). Questions and answers about radical constructivism. In K. Tobin (Ed.), *The practice of constructivism in science education* (pp. 23-38). Mahwah, NJ: Lawrence Erlbaum Associates.

von Glasersfeld, E. (1995). A constructivist approach to teaching. In L. P. Steffe & J. Gale (Eds.), *Constructivism in education* (pp. 3-15). Hillsdale, NJ: Lawrence Erlbaum.

von Glasersfeld, E. (1998). Why constructivism must be radical. In M. Larochelle, N. Bednarz & J. Garrison (Eds.), *Constructivism and education* (pp. 23-28). Cambridge: Cambridge University Press.

Wallace, J., & Louden, W. (1998). Curriculum change in science: Riding the waves of reform. In B. J. Fraser & K. G. Tobin (Eds.), *International handbook of science education* (pp. 475-478). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Wilkinson, S. (2004). Focus groups. In J. A. Smith (Ed.), *Qualitative psychology: A practical guide to research methods* (pp. 184 - 204). Thousand Oaks, CA: Sage.

Wu, Y.-T., & Tsai, C.-C. (2005). Development of elementary school students' cognitive structures and information processing strategies under long-term constructivist-oriented science instruction. *Science Education, 89*, 822-846.

Wu, C. S. (2006). 台灣教育改革的檢討與策進: 1994-2006 年〔Review and planning the innovation of Taiwan education: year 1994-2006〕. *教育資料集刊第三十二輯 - 教育變革與發展*

孫仲山, & 吳思達. (2006). 技職教育政策檢討與策進 〔The review and planning of Taiwan career education〕. *教育資料集刊第三十一輯 -- 教育政策專輯*.

翁秉仁. (2005, 4/10/2005). 談建構數學 〔Discussion the constructivist mathematics〕. 1. Retrieved 3/21, 2003

APPENDIX

Chinese Version of CLES

關於學校外世界的學習	從來沒有	很少如此	偶而如此	經常如此	總是如此
1. 我學到校外世界的知識。	1	2	3	4	5
2. 當我要學新的單元時 , 都由校外世界有關的問題開始。	1	2	3	4	5
3. 我學到如何將所學的科學應用到日常生活上。	1	2	3	4	5
4. 我更了解校外世界。	1	2	3	4	5
5. 我學到有關校外世界裡有趣的事。	1	2	3	4	5
6. 我所學習到的與我校外日常生活無關。	1	2	3	4	5

關於科學的學習	從來沒有	很少如此	偶而如此	經常如此	總是如此
7. 我學到“科學不能對問題提供十全十美的答案”。	1	2	3	4	5
8. 我學到“科學隨時間而改變”。	1	2	3	4	5
9. 我學到“科學會受人們的價值觀和意見的影響”。	1	2	3	4	5
10. 我學到“不同文化的人們所使用的不同科學”。	1	2	3	4	5
11. 我學到“現代科學與古代科學是不同的”。	1	2	3	4	5
12. 我學到“科學是創造理論的:。	1	2	3	4	5

學習“說出來”	從來沒有	很少如此	偶而如此	經常如此	總是如此
13. 我能問老師“我為什麼必須學這個”等問題。	1	2	3	4	5
14. 我能問老師“為什麼要這樣學法？”。	1	2	3	4	5
15. 我能對使我產生混淆的學習活動表示抱怨。	1	2	3	4	5
16. 我可對任何阻礙我學習的事情表示抱怨。	1	2	3	4	5
17. 我可表達我的意見。	1	2	3	4	5
18. 我可為我的權益發言。	1	2	3	4	5

關於如何學習	從來沒有	很少如此	偶而如此	經常如此	總是如此
19. 我幫助老師規劃我所要學習的內容。	1	2	3	4	5
20. 我幫助老師評定我學習的進步情形。	1	2	3	4	5
21. 我幫助老師決定最適合我的學習活動。	1	2	3	4	5
22. 我幫助老師決定讓我花在學習活動上的時間。	1	2	3	4	5
23. 我幫助老師決定我所要改進的學習活動。	1	2	3	4	5

24. 我幫助老師評估我的學習狀況。	1	2	3	4	5
關於如何溝通	從來沒有	很少如此	偶而如此	經常如此	總是如此
25. 我有機會和班上同學談話。	1	2	3	4	5
26. 我與班上同學談論“如何解題”。	1	2	3	4	5
27. 我向班上同學說明我的想法。	1	2	3	4	5
28. 我要班上同學說明他們的想法。	1	2	3	4	5
29. 班上同學會要我向他們說明我的想法。	1	2	3	4	5
30. 班上同學向我說明他們的想法。	1	2	3	4	5

English Version of Constructivist Learning Environment Survey (CLES)

Learning about the world	Almost Never	Seldom	Sometimes	Often	Almost Always
1. I learn about the world outside of school.	1	2	3	4	5
2. My new learning starts with problems about the world outside of school.	1	2	3	4	5
3. I learn how science can be part of my out-of-school life.	1	2	3	4	5
4. I get a better understanding of the world outside of school.	1	2	3	4	5
5. I learn interesting things about the world outside of school.	1	2	3	4	5
6. What I learn has nothing to do with my out-of-school life.	1	2	3	4	5

Learning about science	Almost Never	Seldom	Sometimes	Often	Almost Always
7. I learn that science cannot provide perfect answers to problems.	1	2	3	4	5
8. I learn that science has changed over time.	1	2	3	4	5
9. I learn that science is influenced by people's values and opinions.	1	2	3	4	5
10. I learn about the difference sciences used by people in other cultures.	1	2	3	4	5
11. I learn that modern science is different from the science of long ago.	1	2	3	4	5
12. I learn that science is about creating theories.	1	2	3	4	5

Learning to speak out	Almost Never	Seldom	Sometimes	Often	Almost Always
13. It's OK for me to ask the teacher "why do I have to learn this?"	1	2	3	4	5
14. It's OK for me to question the way I'm being taught.	1	2	3	4	5
15. It's OK for me to complain about teaching activities that are confusing.	1	2	3	4	5
16. It's OK for me to complain about anything that prevents me from learning.	1	2	3	4	5
17. It's OK for me to for me to express my opinion.	1	2	3	4	5
18. It's OK for me to speak up for my rights.	1	2	3	4	5

Learning to learn	Almost Never	Seldom	Some-times	Often	Almost Always
19. I help the teacher to plan what I’m going to learn.	1	2	3	4	5
20. I help the teacher to decide how well I am learning.	1	2	3	4	5
21. I help the teacher to decide which activities are best for me.	1	2	3	4	5
22. I help the teacher to decide how much time I spend on learning activities.	1	2	3	4	5
23. I help the teacher to decide which activities I do.	1	2	3	4	5
24. I help the teacher to assess my learning.	1	2	3	4	5
Learning to communicate	Almost Never	Seldom	Some-times	Often	Almost Always
25. I get the chance to talk to other students.	1	2	3	4	5
26. I talk with other students about how to solve problems.	1	2	3	4	5
27. I explain my understandings to other students.	1	2	3	4	5
28. I ask other students to explain their thoughts.	1	2	3	4	5
29. Other students ask me to explain my ideas.	1	2	3	4	5
30. Other students explain their ideas to me.	1	2	3	4	5