ABSTRACT

Title of Dissertation: STUDENTS' ACHIEVEMENT EMOTIONS IN CHINESE CHEMISTRY CLASSROOMS

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Achievement emotions are critical for students' academic performance and career choices. The previous literature has focused on one specific type of achievement emotions – test anxiety – in Western contexts and neglected other various emotions experienced in different occasions such as attending classes. The present study aims to address the research gap by examining students' achievement emotions in a specific cultural and subject context – Chinese high school chemistry classrooms. Subjects were 103 16 or 17-year-old eleventh-grade students (45 female and 58 male) from two chemistry classes in the same high school in China. The qualitative and quantitative data was collected from four sources: pre- and post-surveys, open-response questions, classroom observations and teacher/student interviews.

This dissertation examined Chinese students' achievement emotions from both theoretical and practical perspectives. First, it theoretically investigated the

dimensions of Chinese students' achievement emotions in traditional chemistry classrooms and how these dimensions were related to its antecedent (i.e., chemistry self-efficacy) and effect (i.e., classroom engagement). The factor analysis indicated two distinct factors emerged from Chinese students' emotions: *positive emotions* and *shame* (one specific type of negative emotions). The structural equation modeling showed that both chemistry self-efficacy and *positive emotions* were significant and positive predictors of students' classroom engagement. Chemistry self-efficacy also significantly and positively predicted students' *positive emotions* while predicting students' perceptions of *shame* negatively. However, the path from *shame* to classroom engagement was not significant after controlling for positive emotions.

Second, it practically explored how one specific pedagogical strategy of integrating the computer simulation – a visualization tool to review content knowledge – influenced students' perceptions of achievement emotions and related affective variables (i.e., chemistry self-efficacy and engagement). Independent sample t-tests showed that the computer simulation significantly increased students' chemistry self-efficacy beliefs and positive emotions. In contrast, its effects on negative emotions and classroom engagement were not significant. By scrutinizing qualitative data from different sources, I provided explanations for the computer simulation's role in influencing the above four affective variables.

STUDENTS' ACHIEVEMENT EMOTIONS IN CHINESE CHEMISTRY CLASSROOMS

by

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Dissertation submitted to the Faculty of the Graduate School of the
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Dedication

This dissertation is dedicated to my family:

Jianwen Gong and Meifeng Jiang, my parents

Xiaowei Gong, my sister

Xiaodong Gong, my brother

Thank you for your support along my life journey. Your love always motivates me to become a better person.

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List of Abbreviations

NGSS (Next Generation Science Standards)

PhET (Physics Education Technology)

Achievement Emotions Questionnaire (AEQ)

Achievement Emotions Questionnaire – Mathematics (AEQ – M)

Introduction

“Why are science lessons so boring? Why is science so difficult for me?” These questions are frequently asked when Chinese students express their feelings in science classes. As individuals’ emotional experiences are substantially influenced by cultural and value norms (Tsai, Knutson, & Fung, 2006) defined within specific educational environments, researchers should first theoretically understand what kinds of emotions are commonly experienced and how they function in such science classroom environments. Therefore, in my dissertation, the first section investigates: (1) what are the dimensions of Chinese students’ achievement emotions in high school chemistry classrooms? (2) How do different dimensions of achievement emotions relate to the antecedent (i.e., chemistry self-efficacy) and effect (i.e., classroom engagement) based on control-value theory?

A better understanding of Chinese students’ emotional experiences in traditional chemistry classrooms can help researchers further explore what intervention strategies are effective for enhancing students’ positive perceptions. In other words, what can teachers do to improve students’ confidence and enjoyment in learning science? The consideration of this question reminds me of those enjoyable moments in one of my undergraduate chemistry classes where the professor utilized computer simulations to describe the complicated structure of inorganic molecules. This was the first moment that I realized the power of technology to demonstrate scientific concepts (e.g., molecular symmetry) and transform science learning experiences by allowing students to operate molecules in various ways (e.g., rotate and flip) and to visualize molecular structures. Based on the above personal experience, the second section of this dissertation examines: (3) how does one specific computer simulation influence students’ affective perceptions in Chinese high school chemistry classrooms when it is integrated as a visualization tool to review content knowledge?

Science Education in Eastern Contexts

Before exploring the above three research questions, it is important to understand the context of this study – Chinese high school science classrooms. Science was imported into China at the beginning of the nineteenth century (Abd-El-Khalick, 2004). As science has evolved from Western cultures, teaching and learning science in Eastern contexts is a complex undertaking. Baker and Taylor (1995) argued that the simplified attempt to replicate and implement Western science curriculums appeared to be ineffective due to its mismatch with students' world views and learning needs in non-Western countries. As a consequence, the format and process of science education in Eastern contexts is quite different from those in Western contexts due to the influence of cultural values or norms defined in such environments.

Two dominating cultures – Confucianism and Collectivism – delineate the public's perceptions about responsibilities of teachers and students in Chinese school settings. As Confucian cultures emphasize the education's function of achieving a higher social economic status and developing moral characteristics, a tradition of deep respect for teachers has been established among student populations (Ma, 1999). Teachers, who are usually called as "engineers of the soul", are authority figures second to parents (Wang, Wang, Zhang, Lang, & Mayer, 1996). The old saying that "once my teacher, forever my parents" is commonly used to educate students to respect teachers. In turn, teachers should fully support students in acquiring content knowledge and getting high scores in school examinations. Due to the emphasis on knowledge transmission, student academic performance is regarded as the most important indicator for evaluating a teacher's effectiveness.

Under such cultural and value norms, the Chinese education system is highly centralized with national academic standards, textbooks and examinations. The regular science instruction is lecture-dominated and supplemented with demonstration experiments and videos. Teachers usually interact with students in the format of choral responding. There are few opportunities for students to interact with each other during class periods. Students heavily rely on teachers' explanations to understand scientific knowledge and seldom interrupt teachers' lectures to ask questions, which may take away time for the whole class. As classroom activities are teacher-directed, student engagement in Chinese classrooms refers to the continuous retainment of attention towards teachers' directions and explanations. In contrast, Western classroom learning environments are more participatory and active where students can ask the teacher questions directly in whole-class instruction. Students are also encouraged to interact with classmates in the format of classroom discussion and small-group activities. The difference in classroom environments (independence VS. collaboration) potentially influence students' emotional expressions. Based on this assumption, I will specifically examine Chinese students' achievement emotions in Section 1.

At present, there is increasing criticism on the over-emphasis of content knowledge, which leads to passive rote memorization and decreased interest of learning science. To improve this situation, the Ministry of Education (2016) suggested reforming the traditional lecture-based instruction and advocated holistic education by publishing six *Core Literacies of Chinese Students,* including scientific spirits, humanistic heritages, abilities of learning, healthy livings, social responsibilities, and practices and innovations. Specifically, scientific spirits emphasize the development of critical thinking and the application of scientific knowledge and skills during the problem-solving process. The ultimate goal is to promote humanistic development and the scientific literacy of the whole population. As existing research in Western contexts shows that technology tools such as computer simulations bring promises to develop students' scientific practices comprehensively, it is worthwhile investigating the possibility of using computer simulations to transform the traditional lecture-based instructional format within performance-oriented cultures and highly structured environments. In Section 2, I will explore the influence of integrating computer simulations on Chinese students' achievement emotions and related affective variables.

In summary, this paper is comprised of six sections. The introduction and context show the overall structure and background of this dissertation. Section 1 and Section 2 investigate different research questions with the same group of subjects but with different sources of data and methods of analysis. The concluding remarks discuss how results of Section 1 and Section 2 are related and provide thoughts about future directions.

Section 1: The Dimensions and Functions of Chinese Students' Achievement Emotions

Introduction

Students can experience various affective states in academic settings. Enjoyment, hope, pride, relief, anxiety, shame, hopelessness, anger, frustration, and boredom are commonly occurring emotions in student populations (Pekrun, Goetz, Titz, & Perry, 2002a). As one critical predictor of academic performance and career choices (Schutz & Pekrun, 2007), students' affective dimension is not just a simple catalyst, but a necessary condition for learning to occur (Perrier & Nsengiyumva, 2003). Investigating the dimensions, source, and effect of achievement emotions is especially worthwhile in STEM fields where students are often reluctant to pursue STEM majors and careers after graduating from high schools (Maltese & Tai, 2011). Existing research in Western contexts has shown that achievement emotions are multifaceted and linked with academic self-efficacy (Marchand & Gutierrez, 2012; Putwain, Sander, & Larkin, 2013) and engagement (Walker, Greene, & Mansell, 2006). Yet whether such multiplicity or relations are similar in non-Western contexts is an open question.

Culture substantially shapes students' emotional perceptions (Tsai, Knutson, & Fung, 2006) through values or norms being emphasized with specific education environments. In Eastern contexts, classroom values or norms are developed based on Confucian cultures and collectivistic cultures. Traditional Confucian cultures greatly value the role of education in developing an individual's personality and attaining a higher socio-economic status. Academic success is one important way for individuals and families to seek recognition. Admission from top universities is not only a self-advancement but also the fulfillment of parents' expectations, which brings glory or face to the community. Face, defined as “the confidence of society in the integrity of ego’s moral character” (Hu, 1944, p.45), is closely associated with one’s sense of dignity and reputation in Chinese society. In contrast, poor performance or expulsion from school leads to feelings of shame and loss of family face (Gow, Balla, Kember, & Hau, 1996), which makes it impossible for individuals to function properly within the community (Hu, 1944). The awareness about potential results of academic success or failure prompts students to take responsibility for their own learning and respect the teacher as an authority figure. Simultaneously, collectivistic cultures encourage individuals to view themselves as parts of the whole group. Students in highly structured large classrooms are prompted to constrain expressions of intense emotions (e.g., anger) as one means of maintaining in-group harmony. In contrast, Western contexts where individualistic cultures are valued, emphasize the independence and uniqueness of the student self. As a consequence, the classroom structure is less hierarchical, which encourages open and direct expressions of personal feelings (Oyserman, Coon, & Kemmelmeier, 2002).

Students’ different ways of expressing emotions across cultural contexts have been supported by previous empirical findings. For example, Mesquita and Karasawa (2002) found that Asian students were more likely to report “no emotions” than American peers. However, this study generally compared undergraduate students’ everyday emotions, and it is unknown whether such phenomenon is applicable to high school students’ class-related emotions. What is more, it is unclear whether cultural differences influence the way different achievement emotions relate to each other and to the corresponding antecedent and outcome. Therefore, the current study aims to address these gaps by examining the dimensions of achievement emotions in Chinese chemistry classrooms and investigating how achievement emotions are related to self-efficacy (as an antecedent) and engagement (as an outcome). A better understanding of Chinese students' emotions can increase knowledge about the role of culture in regulating students' class-related emotions and further inform researchers and teachers about how to develop emotionally supportive classroom learning environments across cultural contexts.

Theoretical Framework

Pekrun's (2006) control-value theory provides an integrative framework for examining students' emotions within academic settings. Achievement emotions, the central construct of control-value theory, are defined as emotions directly related to academic activities (e.g., enjoyment or boredom of receiving lecture-based instruction) and outcomes (e.g., sadness of getting low grades). As students can experience various affective states, researchers usually use three dimensions (i.e., *the degree of activation, valence,* and *object focus*) to describe the multiplicity of achievement emotions. Based on the *degree of activation*, achievement emotions are grouped into activating emotions (e.g., joy, frustration) and deactivating emotions (e.g., relaxation, sadness). Based on its *valence*, achievement emotions are divided into positive emotions (e.g., gratitude, pride) and negative emotions (e.g., shame, anger). Based on the *object focus*, achievement emotions are classified into activity-related (e.g., enjoyment, anger) and outcome-related (e.g., pride, anxiety). The three-dimensional taxonomy of achievement emotions is outlined in Table 1.

Since students can experience similar or different emotions in different situations, Pekrun, Goetz, Frenzel, Barchfeld and Perry (2011) developed a measurement instrument called Achievement Emotions Questionnaire (AEQ) to assess students' various emotions experienced in three situations: attending classes, doing homework, and taking tests. They collected data from 389 Canadian undergraduate students and conducted confirmatory factor analyses to examine internal component structures of the scale. The results showed that the two-facet emotion × setting model fitted better than the one factor model and nine-emotion factor model (enjoyment, hope, pride, relief, anger, anxiety, shame, hopelessness, and boredom). The variation in the model-fitting suggests that "the relationships between different achievement emotions can be best explained by taking into account both the differences between discrete emotions and the differences between emotions that occur in different achievement settings" (p.44). In addition, the Achievement Emotions Questionnaire - Mathematics (AEQ-M) was translated from German to Chinese and tested with 312 Germany and 579 Chinese 8th grade students to examine the cross-cultural comparability and convergent validity. The results showed that the Chinese version of the AEQ-M was valid for cross-culture research.

Table 1.

A Three-Dimensional Taxonomy of Achievement Emotions (Pekrun, 2006)

Object Focus	Positive		Negative	
	Activating	Deactivating	Activating	Deactivating
Activity Focus	Enjoyment	Relaxation	Anger Frustration	Boredom
Outcome Focus	Joy Hope Pride Gratitude	Contentment Relief	Anxiety Shame Anger	Sadness Disappointment Hopelessness

Besides defining the central construct, control-value theory also outlines two key assumptions about the antecedent and effect of achievement emotions (Pekrun, 2006). The first assumption is that control-related beliefs predict students' perceptions of achievement emotions. Students usually experience enjoyment when feeling in high control of achievement activities and frustration when feeling out of control. At present, researchers have defined different constructs (e.g., self-concept, self-efficacy, and academic control) to evaluate students' control-related beliefs. As students' judgments of capabilities differ across different subjects, Bandura (2006) suggest that self-efficacy is more appropriate for evaluating control-related beliefs due to its specific, situational and malleable nature (Linnenbrink & Pintrich, 2003), In the current study, I focus on self-efficacy – judgments of one's capability to organize and execute courses of action required to attain designated types of performances (Bandura, 1986) – as the representation of control-related beliefs.

The second assumption in control-value theory is that achievement emotions influence students' academic engagement, which refers to the effort, attention, and persistence during the initiation and execution of learning activities (Skinner, Furrer, Marchand, & Kindermann, 2008). Now researchers pay increased attention to this construct because student engagement is presumed to be malleable and is regarded as a proximal indicator of students' academic retention, achievement, and resilience (Skinner et al., 2008). Based on control-value theory, I hypothesize that students' self-efficacy beliefs and classroom engagement serve respectively as the antecedent and effect of achievement emotions. These theoretical assumptions provide the basis for constructing the tested model in this study. In addition, control-value theory postulates that students' emotional experiences are situated within specific education environments. In the following section, I will first review how different cultures regulate students' expressions of emotions and then present empirical findings about its relationships with self-efficacy and engagement.

Literature Review – Cultural Differences in Achievement Emotions

The Central Construct – Achievement Emotions

Cultural values and norms regulate students' emotional reactions to the same situation through the conceptualization of the student self. Oyserman, Coon and Kemmelmeier (2002) postulated that the comparison between individualistic cultures and collectivistic cultures is a useful way to examine how overall cultural differences influence the development of the student self. In individualistic cultures (e.g., Western), the student self is perceived to be independent and unique from others. Students are expected to pursue individual goals and express personality patterns. In collectivistic cultures (e.g., Eastern), the student self is perceived to be interdependent and cannot be separated from others. Students are encouraged to fulfill their social obligations, maintain harmony with others, and support the goals of others who are related in social relationships (Eid & Diener, 2001). In addition, Confucian cultures in Eastern contexts emphasize the stable social order and the deep respect for teachers who are authority figures through defining students' appropriate forms of conducts in classrooms.

The variance in social expectations for the student self across cultural contexts prompts the individual to express achievement emotions in different ways. Students in individualistic cultures are more likely to express various emotions as independent selves. As social relationships and group harmony constitute the core of the student self in collectivistic cultures (Hsu, 1971), students are more likely to express culturally desirable emotions and constrain undesirable feelings on their own initiative. For example, shame is an elaborate emotion in Chinese cultures (Li, Wang, & Fischer, 2004). There are a large set of related vocabularies for the perception of shame (Russell, & Yik, 1996). Wilson (1981) defined a verbal scale of shame in Chinese, ranging from the least to the most intense feelings: unease or shyness (害羞), embarrassment (不好意思, 尴尬), losing face (丢脸), deep shame (惭愧), and extreme shame (无耻, 不要脸). The incitement of shame, which is usually associated with individuals' self-evaluation of failing to meet specific standards, is a social control technique in Asian countries that emphasize personal responsibilities (Marsella et al., 1974). Shaver, Wu and Schwartz (1992) reported that Chinese children started to understand shame or shyness by the age of 2.5 years.

Within classroom environments, Chinese teachers often announce each student's grades and class rankings after school examinations to incite the feeling of shame if they fall behind. Such phenomenon is also supported by previous evidence that Chinese high school students are reported to experience more shame but less anger in mathematics than German peers (Frenzel, Thrash, Pekrun, & Goetz, 2007).

At present, most cross-cultural studies focus on the differences in the frequency and intensity of achievement emotions and ignore interrelations of various emotions. Pekrun, Goetz, Titz and Perry (2002a) reported that four clusters emerged when examining interrelations of nine achievement emotions in Western contexts: (a) enjoyment, hope, and pride; (b) relief; (c) anxiety, shame, and hopelessness; (d) anger and boredom. However, it is unknown whether the above four clusters are applicable in Eastern contexts. Some researchers argued that culture norms potentially shape the association between positive emotions and negative emotions (Bagozzi, Wong, & Yi, 1999; Schimmack, Oishi, & Diener, 2002). Western students perceive positive emotions and negative emotions as oppositional: one is either happy or sad but not both. In contrast, Eastern students, who do not equate oppositional with contradictory, are less likely to provide opposite ratings for positive and negative emotions. Based on above evidence, it is worthwhile investigating the dimensions of various achievement emotions in Eastern contexts. What is more, little research has examined relationships between achievement emotions and other variables (i.e., self-efficacy and engagement) in Eastern contexts and whether these relationships differ from Western contexts. As Pekrun (2006) suggested that causal mechanisms of achievement emotions follow general principles, in the following sections, I mainly review findings of previous research conducted in Western contexts and propose three theoretical questions when examining these relationships in Chinese chemistry classrooms.

Relationships between Achievement Emotions, Self-Efficacy, and Engagement

Self-Efficacy and Emotion

As self-efficacy refers to individuals' perceptions of their capabilities to perform a context-related task successfully (Bandura, 1986; Pajares & Miller, 1994), students with higher self-efficacy beliefs are expected to appraise the situation as manageable, perceive higher likelihood of success and thus maintain positive emotions (e.g., enjoyment). In contrast, students with low self-efficacy beliefs are more likely to perceive the situation as a threat and the anticipation of failure increases negative emotions (e.g., anxiety) (Bandura, 1997; Zimmerman, 2000). This theoretical assumption has been confirmed by a series of empirical studies among university students. For example, Pekrun et al. (2004) examined Germany undergraduate students' achievement emotions in situations of taking exams and tests. They found that academic self-efficacy was positively related to positive emotions (i.e., joy, hope, and pride), whereas the correlation for negative emotions (i.e., anger, anxiety, shame, and hopelessness) was negative. Marchand and Gutierrez (2012) reported that American graduate students' self-efficacy was a negative and moderate predictor for frustration and anxiety. Putwain, Sander and Larkin (2013) identified that the academic self-efficacy of United Kingdom undergraduate students predicted more positive emotions and less negative emotions. In summary, existing studies in Western contexts indicate that self-efficacy beliefs significantly predict students' positive and negative emotions in opposite directions.

What is the relationship between self-efficacy beliefs and achievement emotions in Chinese classrooms? Previous research has compared students' general or math self-efficacy at different age levels across cultural contexts and found that students in Eastern cultures reported much lower levels of self-efficacy than peers in Western cultures (Klassen, 2004; Lee, 2009; Scholz, Dona, Sud, & Schwarzer, 2002). Asian students tend to underestimate their abilities because the construct of the student self in Eastern cultures is developed differently from Western cultures (Zusho & Pintrich, 2003). Specifically, Chinese students are encouraged to be modest and make self-effacing responses (Bond, Leung, & Wan, 1982), which is supported by the proverb saying that "modesty helps one to go forward, whereas conceit makes one lag behind." Considering the lower level of self-efficacy in Eastern contexts, I propose the first question – do Chinese students' self-efficacy beliefs significantly predict their positive and negative emotions in chemistry classrooms?

Self-efficacy and Engagement

Self-efficacy affects the individual's learning behavior by regulating the quantity of expended effort and the willingness to persist in tasks (Bandura, 1997). Students with high self-efficacy beliefs are expected to persist and spend more effort in the face of difficulty while students with low self-efficacy beliefs are more likely to doubt themselves and give up easily when confronting challenges (Linnenbrink & Pintrich, 2003). Existing studies have examined how self-efficacy predicts student engagement along with other variables. Schunk (1989, 1991) reported that self-efficacy predicted students' effort and persistence over and above prior content knowledge. Students who possessed requisite knowledge but had low self-efficacy were less likely to persist in the task. Walker, Greene and Mansell (2006) found that American undergraduate students' self-efficacy uniquely predicted the meaningful cognitive engagement after controlling for other variables such as intrinsic motivations and academic identification.

What is the relationship between self-efficacy beliefs and engagement in Chinese classrooms? Previous research has shown that differences in classroom structure and size often influence students' classroom behaviors related to engagement. As Chinese teachers prefer whole-class instruction, whereas American teachers more often use small-group or individual instruction (Stigler & Perry, 1988), classroom engagement is defined differently across Eastern and Western cultural contexts. Chinese teachers emphasize the individual's paying attention and concentration during class while Western teachers focus on cooperation and discussion among group members. Chinese teachers' perceptions of students' most frequent and troublesome misbehaviors are daydreaming, being inattentive, sitting there and never answering questions while Western teachers' perceptions are talking out of turn (Ding, Li, Li, & Kulm, 2008). Based on such cultural differences, I propose the second question – do Chinese students' self-efficacy beliefs positively and significantly predict their engagement in chemistry classrooms?

Emotion and Engagement

Regarding the relationship between achievement emotions and engagement, researchers have proposed different theoretical assumptions. Schwarz (1990) noted that positive affective states inform individuals that the current situation is safe and satisfactory, and decrease their willingness to engage in effortful information seeking. Negative affective states signal that the situation is a threat and thus increase engagement for changing the situation. Conversely, Fredrickson (2004) proposed that experiences of positive emotions prompt individuals to persist and engage with environments and activities by broadening one's momentary thought-action repertoires and building enduring personal resources. The inconsistency of theoretical assumptions about the relationship between achievement emotions and engagement might result from the fact that researchers usually differentiate achievement emotions based on the single dimension – valance – and ignore the second dimension – the degree of activation.

The interplay between valance and activation of achievement emotions produces four basic categories of emotions (i.e., positive activating, positive deactivating, negative activating, and negative deactivating emotions), which exert different effects on student engagement. For example, positive activating emotions (e.g., enjoyment, hope) are reported to be positively related to students' self-reported effort, whereas negative deactivating emotions (e.g., boredom and hopelessness) show the opposite pattern (Pekrun, Goetz, Titz, & Perry, 2002a; Pekrun, Goetz, Frenzel, Barchfeld, & Perry, 2011). However, the linkage between negative activating emotions (e.g., anger, anxiety and shame) and engagement is more ambivalent. Despite overall negative effects, negative activating emotions can increase student engagement in some situations (Pekrun & Linnenbrink-Garcia, 2012). For example, perceived anxiety might stimulate students to invest more effort to avoid failure and thus increase engagement. The complex relationship between achievement emotions and engagement encourages researchers to conduct more investigations in different cultural contexts. Therefore, I propose the third question – do positive and negative emotions significantly predict student engagement in Chinese chemistry classrooms?

Research Questions

As students' achievement emotions are dependent on subject domains and classroom contexts, I investigated these questions in a specific cultural and subject context – Chinese chemistry classrooms. In this section, I addressed two research questions: (1) what are the dimensions of Chinese students' achievement emotions in high school chemistry classrooms? (2) How do different dimensions of achievement emotions relate to chemistry self-efficacy beliefs and classroom engagement? Based on above theoretical assumptions and empirical findings, I hypothesized that:

- Students' achievement emotions had different dimensions and these dimensions may differ from existing findings in Western cultures;
- Students' self-efficacy beliefs and achievement emotions were directly related to their engagement in classrooms (see Figure 1 for the tested model);
- Achievement emotions served as a mediator for influencing the relationship between control-related beliefs and classroom engagement (see Figure 1 for the tested model).

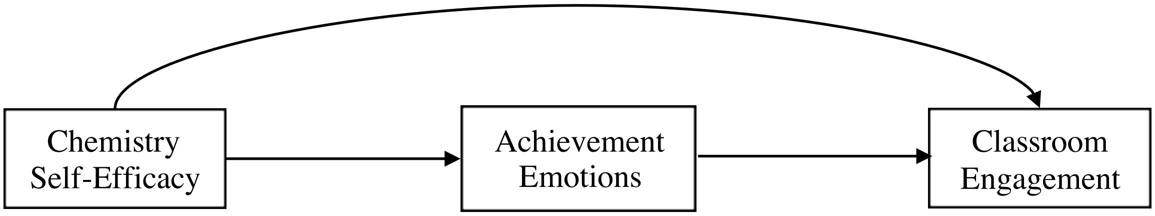

Figure 1. The Proposed Theoretical Model

Methodology

Context and Data Collection

The study was conducted in an exemplary high school located at the capital city of a northern province in China. According to student performance in college entrance examinations, this two-campus high school ranked fourth in the located city. Among 580 16 or 17 years old eleventh-grade students, 103 students (45 females, 58 males) from two classes participated in this study. They were from families with middle socioeconomic status. As the two classes were equivalent in the average performance, the classroom effect was ignored and participants were treated as a single sample.

Under the same centralized curriculum standards, textbooks, and teaching materials, classroom environments were highly structured with an average class size of 50 students. School teachers usually covered 3-year curriculum content in 2 to 2.5 years so that students could use the remaining time to prepare for the college entrance examination. As academic study was the most central task, students spent a great amount of time in school. They usually arrived at school at 7:20 AM and finished the last class at 6:00 PM. After a 90-min self-study session, students left school at 8:20 PM. There were four chemistry classes in each week and each class period lasted 45 minutes. Students stayed in one classroom to take different courses while teachers traveled between different classrooms. In each classroom, students sat row by row with limited free spaces (Figure 2). During the typical chemistry instruction, the teacher usually stood on the platform and conducted activities such as lecturing, demonstrating chemistry experiments, and showing images or videos. The relative position between the teacher and students suggested that the classroom was a hierarchical unit, where students were expected to follow teachers' directions.

In this study, students were first asked to complete a questionnaire that consisted of three measures: chemistry self-efficacy, achievement emotions, and classroom engagement. All responses were indicated using a 5-point Likert scale, anchored at 1(strongly disagree) and 5 (strongly agree). Survey items that measured chemistry self-efficacy beliefs and classroom engagement were translated from English to Chinese by the author, and then back-translated by one chemistry teacher, who verified the match with the original version.

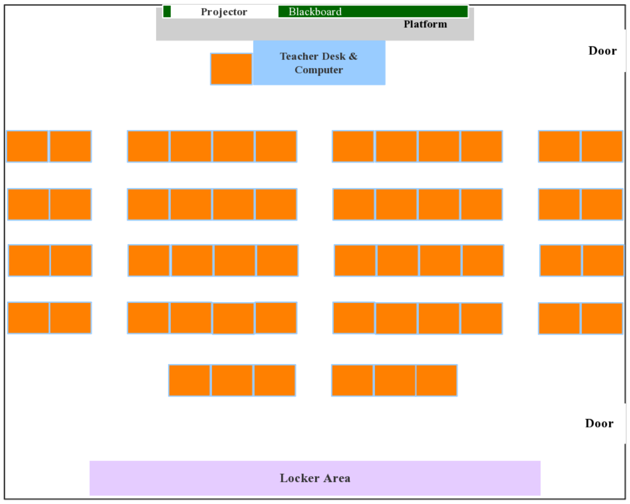

Figure 2. The Chinese Classroom Structure

Measures

- *Chemistry self-efficacy:* I translated Dalgety, Coll, and Jones's (2003) chemistry self-efficacy scale into Chinese (Part 1 in Appendix A). The scale consisted of 16 items ($\alpha = .942$). An example item was: "I can convert the data obtained in a chemistry experiment into a result."
- *Achievement emotions*: The original Chinese language version of achievement emotion questionnaire – mathematics (AEQ-M; Pekrun, Frenzel, Goetz, & He, 2005) measures students' emotions in three occasions: attending classes, doing homework, and taking exam. In this study, I focused on the situation of attending chemistry classes and used the subset of the questionnaire (Part 2 in Appendix A). The validation has been conducted for the German and Chinese language comparison. The scale consisted of 14 items ($\alpha = .794$). An example item was: "I look forward to my chemistry classes."
- *Classroom engagement:* I translated Skinner et al.'s (2008) engagement scale to

measure students' engagement in chemistry classes (Part 3 in Appendix A). The scale consisted of 10 items (α = .896). One example item was: "when I'm in chemistry class, I think about other things [reverse coded]."

All student (N = 103) filled out the survey. In addition, seven students (4 males and 3 females) volunteered to attend semi-structured interviews (Appendix B). As the whole interview covered different topics, students' entire statements that described general feelings in traditional classrooms were selected and translated.

Methods

Two types of quantitative methods were used to test hypotheses on structures and functions of achievement emotions. First, I conducted exploratory factor analysis (SPSS Version 22) to answer the first research question, which aimed to identify dimensions of achievement emotions in the sample. Factor analysis is a data reduction technique used to find underlying factors for a large number of variables (Williams, Onsman, & Brown, 2010). Since different types of achievement emotions are latent variables that are assumed to correlate with each other, I used principal axis factoring with a direct oblimin rotation. Second, I conducted path analysis to answer the second research question, which tested how achievement emotions related to its antecedent (i.e., chemistry self-efficacy) and outcome (i.e., classroom engagement). Path analysis provides researchers with a comprehensive means for specifying and assessing direct or indirect causal relations of theoretical constructs (Anderson & Gerbing, 1988). I used absolute, parsimonious, and incremental indices to evaluate the data-model fit, including the model χ^2 statistic, the standardized root measure squared residual (SRMR), the root mean squared error of approximation (RMSEA), and the comparative fit index (CFI). I adopted Hu and Bentler's (1999) suggested values for retaining a model – RMSEA below .06, SRMR below .08 and CFI above .95. In addition, students' interview data were transcribed and reviewed to provide explanations for quantitative analyses.

Results

1. **What are the dimensions of Chinese students' achievement emotions in high school chemistry classrooms?**

Prior to the extraction of the factors, two tests were used to assess whether the respondent data were suitable for factor analysis. Both the Kaiser Meyer Olkin (KMO) measure of sampling adequacy (.777) and the Bartlett's Test of sphericity (χ^2 =477.78, *df* = 91, *p* < .001) showed that factor analysis was an appropriate method to analyze the dimensions of achievement emotions. I determined that a two-factor solution, which explained 40.26% of the variance, was preferred based on examination of the screen plot, eigenvalues, and pattern matrix. The descriptive statistics of 14 items and factor loading matrix for the final solution are presented in Table 2. One item (item 9), which had weak cross loadings (< .4) on both factors, was excluded from the analysis. All other items had moderate to strong loadings (>.4) on a single factor and no cross loadings (< .4). Specifically, Factor 1 included five strong-loading items (item 1, 2, 3, 6, and 10) and five moderate-loading items (item 4, 5, 7, 8, and 14). Factor 2 included two strong-loading items (item 11 and 12) and one moderate-loading item (item 13).

Table 2.

Descriptive Statistics and Factor Loading Matrix of Items in the Achievement Emotion Scale

Achievement Emotion Scale Items	M	SD	Factor 1	Factor 2
E2 - I enjoy my chemistry classes.	3.60	.73	.833	
E1 - I look forward to my chemistry classes.	3.47	.78	.728	
E3 - The material we deal with in chemistry is so exciting that I really enjoy my classes.	3.32	.82	.706	
E6 - I am annoyed during my chemistry classes.	2.20	.83	-.683	
E10 - When thinking about my chemistry class, I get nervous.	1.98	.74	-.630	
E4 - I enjoy my class so much that I am strongly motivated to participate.	3.44	.74	.589	
E14 - I think I can be proud of my knowledge in chemistry.	3.82	.76	.587	
E5 - I am proud of my contributions to the chemistry class.	3.70	.85	.578	
E7 - I am so angry during my chemistry class that I would like to leave.	1.62	.78	-.501	
E8 - I get angry because the material in chemistry is so difficult.	2.38	.96	-.431	
E12 - My face is getting hot because I am embarrassed that I cannot answer the teacher’s questions.	2.43	1.01		.754
E11 - When I say something in my chemistry class, I can tell that my face gets red.	2.23	.95		.627
E13 - I am ashamed that I cannot answer my chemistry teacher’s questions well.	3.16	1.12		.561
E9 - I worry if the material is much too difficult for me.	3.14	1.05		

Note: Factor loading < .4 are not shown.

By examining the content of fourteen items, I found that Factor 1 included four items about feeling enjoyment (item 1, 2, 3 and 4), two items about feeling proud (item 5 and 14), three items about feeling angry (item 6, 7 and 8) and one item about feeling anxious (item 10). Six items about positive emotions (i.e., enjoyment and pride) loaded positively on Factor 1 while four items about negative emotions (i.e., anger and anxiety) loaded negatively on Factor 1. Therefore, I labeled this factor as *positive emotions*. Factor 2 included three items with positive loadings about shyness, embarrassment, and losing face (item 11, 12 and 13). As above terms were covered in Wilson’s (1981) verbal scale of shame in Chinese contexts, I labeled Factor 2 as *shame*. In sum, I concluded that there were two distinct factors in Achievement

Emotions measure with this sample of Chinese students in chemistry classrooms: *positive emotions* and one specific type of negative emotion – *shame*. Reliability analysis yielded satisfactory Cronbach's alpha value for two factors: α = .87 for *positive emotions* (N = 10) and α = .68 for *shame* (N = 3) (Table 3).

To better illustrate emotional components of two factors, I organized diverse types of emotions in Table 3 and calculated descriptive statistics of positive emotions and negative emotions under each factor across scale items. It showed that the intensity of students' emotional perceptions differed across two factors. Students reported higher positive emotions (i.e., enjoyment and pride) (*M* = 3.56, *SD* =. 59) than shame (*M* = 2.60, *SD* =. 80) and anger/anxiety (*M* = 2.06, *SD* =. 63).

Table 3.

Descriptive Statistics of Two Factors in Achievement Emotions

Two Factors	Cronbach's α	Valance	Categories	*M*	*SD*
Positive Emotions	.87	Positive	Enjoyment (E1, E2, E3, E4) Pride (E5, E14)	3.56	.59
		Negative	Anger (E6, E7, E8) Anxiety (E10)	2.06	.63
Shame	.68	Negative	Shame (E11, E12, E13)	2.60	.80

The lower intensity of negative emotions under two factors might result from students' avoidance of openly expressing their negative emotions, as demonstrated in the interview data. The underlined portions of the transcript showed that seven students (A - G) described their class-related emotions in different ways. Two students (C and G) explicitly used words with positive (e.g., happy, interested) and negative attributes (e.g., annoyed, angry). The other five students reported a lack of obvious feelings (D and F) or negative feelings (A, B, E).

A: I like chemistry classes. I am interested in those elements in reactions. I do not have those feelings that I do not want to attend.

B: (I) take it quite easy without burden. Chemistry is relatively easier than other science subjects. When taking physics classes, I am very strained and have to carefully listen what teachers say about this or that. I do not have such feelings in chemistry classes.

C: I am very happy when taking chemistry classes. I have liked science since I was a small kid. But if the content is difficult, I might be a little annoyed. In this situation, I would not get stuck there but still listen to teachers. I might explore this question with teachers after class. As long as the new content is not very difficult, I am very interested and engaged.

D: I do not have obvious feelings. I am happy, just the general feeling not that much. My feelings do not change much.

E: I like chemistry. Chemistry classes do not make me anxious. But I am not very happy either. I am happiest when I play in PE classes. I am happy when I understand (the content). I am depressed when the content is difficult.

F: Not bad. The goal is to grasp (the knowledge). I get used to it.

G: I am very angry only when I cannot keep up with the teacher and understand these scientific ideas.

2. How do Chinese students' achievement emotions relate to their chemistry self-efficacy beliefs and classroom engagement?

Based on the RQ1, I examined how two distinct factors of achievement emotions related to chemistry self-efficacy beliefs and classroom engagement. Prior to path analysis, preliminary multivariate analyses of variance (MANOVAs) was conducted to detect classroom effects. The results revealed that there were no significant differences between the two classrooms with respect to the four affective variables in the path model, F (4, 84) = 1.901, p = .118 > .05; Wilk's $\Lambda = .917$, partial $\eta^2 = .083$, which confirm the previous assumption that classroom effects can be neglected. The correlations between four affective variables are presented in Table 4. Model fit indices demonstrated the model fitted the data well (χ^2 [1] =.975, p = 0.324, SRMR = 0.028, RMSEA < 0.001, CFI = 1.000). The model accounted for significant amounts of variance in classroom engagement (34.7%) but non-significant amounts of variance in *positive emotions* (11.5%) and *shame* (8.9%). Figure 3 outlines the path analysis model with only significant path coefficients and residual variance of dependent variables while Table 5 presents a decomposition of all effects. Of all path coefficients in the proposed model, chemistry self-efficacy had a statistically significant, positive association with *positive emotions* ($\beta = .338$), and a statistically significant, negative association with *shame* ($\beta = - .298$). Chemistry self-efficacy had two statistically significant and positive associations with classroom engagement: one was direct ($\beta = .268$) and the other was indirect through positive emotions ($\beta = .152$). Between two factors of achievement emotions, only positive emotions had a statistically significant and positive path to classroom engagement ($\beta = .449$). Based on Suhr's (2008) criteria, all direct path coefficients ranged from medium to large. Viewed alongside the factor analysis, these findings showed that respondents perceived *shame* as distinct from other negative emotions but *shame* did not explain unique variance in engagement.

Table 4.

Descriptive Statistics and Bivariate Correlations

	1 (PE)	2 (S)	3 (SE)	4 (CE)	Descriptives	
					M	*SD*
1. Positive Emotions (PE)	-				3.70	.55
2. Shame (S)	-.122	-			2.60	.80
3. Self-Efficacy (SE)	.390**	-.203*	-		3.32	.65
4. Classroom Engagement (CE)	.542**	-.144	.409**	-	3.67	.68

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

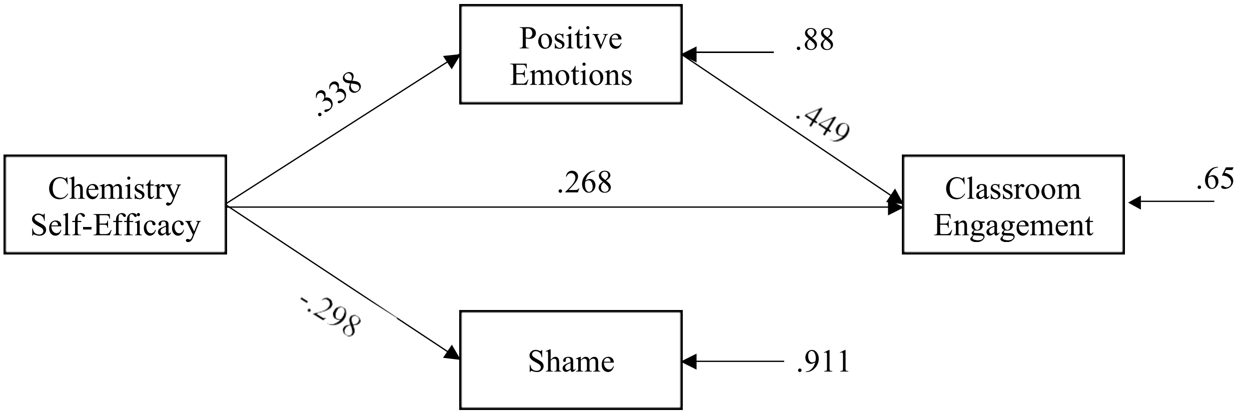

Figure 3. The Path Model

Table 5.

Maximum Likelihood Parameter Estimates

Parameter	β	S.E.	Est./S.E.	*p*
Direct Effect				
Chemistry Self-Efficacy → Positive Emotions	0.338	0.098	3.437	0.001
Chemistry Self-Efficacy → Shame	-0.298	0.105	-2.834	0.005
Chemistry Self-Efficacy →Classroom Engagement	0.268	0.090	2.995	0.003
Positive Emotions → Classroom Engagement	0.449	0.083	5.440	< .001
Shame →Classroom Engagement	0.038	0.089	0.430	0.667

Indirect Effect				
Chemistry Self-Efficacy →Classroom Engagement	0.152	0.054	2.820	0.005
Residual Variance				
Classroom Engagement	0.653	0.079	8.284	< .001
Positive Emotions	0.885	0.067	13.286	< .001
Shame	0.911	0.063	14.579	< .001

Discussion

This study examined the dimensions of achievement emotions in a specific cultural and subject context – highly structured Chinese chemistry classrooms – and how two factors of achievement emotions related to chemistry self-efficacy beliefs and classroom engagement. I focused on how Confucian and collectivistic cultures shaped students' emotional perceptions and their relationships with other variables in control-value theory. Such effort informs researchers about how to utilize emotional resources to effectively engage students in Eastern chemistry classrooms.

The Two-Factor Model of Achievement Emotions

Regarding the first research question, I found that Chinese students' achievement emotions in chemistry classes had two distinct factors: *positive emotions* and *shame*. In other words, students' five class-related achievement emotions were not discrete and isolated. The first factor – *positive emotions* – refers to high levels of enjoyment and pride while low levels of anger and anxiety. My classification using factor analysis is different from the theoretical assumption and empirical finding that *shame* might be in the same category with other negative activating emotions such as anxiety (Pekrun, Goetz, Titz, & Perry, 2002a; Pekrun, 2006). Actually, previous research often differentiates achievement emotions based on the single dimension – valance. For example, Putwain, Sander and Larkin (2013) combined scales for learning-related enjoyment, hope, pride into an aggregated measure of positive emotions and scales for anger, anxiety, boredom, hopelessness and shame into an aggregated measure of negative emotions. The comparison of existing findings in different contexts shows that shame is a separate category of emotions for Chinese whereas it is part of the sadness category along with other negative emotions in Western cultures (Shaver, Wu, & Schwartz, 1992). Such conclusion suggests that Chinese high school students' perceptions of anger and anxiety are more closely associated with enjoyment and pride rather than the feeling of *shame*. Positive emotions (i.e., enjoyment and pride) and specific negative emotions (i.e., anger and anxiety) might constitute opposite ends of a bipolar spectrum (Pekrun et al., 2011).

Why does *shame* stand out as an independent factor of Chinese students' emotions in chemistry classes? Why is the mean of *shame* (Factor 2) higher than means of other negative emotions in Factor 1? One possible explanation is that *shame*, a social emotion caused by students' beliefs about the failure to meet others' expectations, is more salient and unique to Chinese students than other types of negative emotions. The stronger feeling of *shame* than anger in Asian population might result from the student self that is defined and developed in Eastern contexts. Confucian cultures, which highlight the value of academic accomplishments and attribute personal responsibility for failures, create initial conditions for perceptions of shame (Turner & Waugh, 2007). Simultaneously, Collectivistic cultures, which emphasize the harmony of the whole group, expect students to carefully control specific negative emotions (e.g., anger) that might influence their relations with others negatively. As a consequence, students in collectivistic cultures are more likely to express shame, which emphasizes relationships with others, rather than anger, which emphasizes distance from others (Kitayama, Markus, & Kurokawa, 2000). Negative emotions such as anger, which are accepted in individualistic cultures, are more likely to be avoided in collectivistic culture (Frenzel, Thrash, Pekrun, & Goetz, 2007).

The weaker anger and stronger shame among Asian students (Mesquita, Boiger, & De Leersnyder, 2017) are also related to their corresponding social functions or demands in Eastern contexts. Wong and Tsai (2007) suggested that shame is perceived as a more appropriate response than anger in specific contexts. In some situations, schools use pedagogical or management methods to trigger *shame* in students (Monroe, 2009). For example, in some Chinese classrooms, there is one special student seat located near the teacher desk to help the troublemaker regulate his or her classroom behaviors (Figure 2). Teachers often ask one student to stand up to answer questions if he or she is inattentive. The special attention from teachers and classmates incite the feeling of shame due to the failure of meeting classroom standards. Despite the fact that the feeling of *shame* is negative in the valence, such perceptions are also activating, which might lead to positive results such as motivating students to spend more effort. What is more, since collectivistic and Confucian cultures emphasize individuals' responsibilities to keep harmony and accomplish academic goals, the failure of living up to others' expectations (e.g., cannot answer teachers' questions) indicates the individual does not fulfill the obligation towards others as part of the classroom community. Therefore, feeling *shame*, which is viewed as a positive, valued and appropriate response to failures in collectivistic cultures (Wong & Tsai, 2007), is more commonly experienced, salient or threatening for Asian students (Heine, 2001).

The tendency of restraining specific intense emotions (e.g., anger) is further supported by qualitative interview evidence. When describing their emotions in chemistry classes, two students reported the lack of obvious feelings. This phenomenon is consistent with the previous argument that Asians are less likely to express or even notice their emotions (Heine, 2001;

Mesquita & Karasawa, 2002). The lack of obvious feelings suggests that students who described their emotions with nonnegative terms might perceive such classroom environments as positive, which explains why most negative emotions were classified in the same category as positive emotions but negatively correlated. In addition, five students reported the absence of negative emotions. One possible explanation is that the head teacher in Chinese classrooms usually set clear rules about expectations for student behaviors in order to manage large size classrooms effectively. Students are expected to behave or express accordingly for retaining harmonious classroom order or at least not to interrupt others during classroom instruction. Under the above classroom norms, students are not encouraged to express anger in public classroom environments. Students' perceptions of anger are outcome-directed that mainly arise from the failure of understanding content knowledge (see Quotes from student G).

Relationship with Self-Efficacy and Engagement

Regarding the relationship between achievement emotions and the antecedent – chemistry self-efficacy – I found that students' judgments about their capabilities to learn chemistry related in significant ways to two factors of achievement emotions. Specifically, chemistry self-efficacy beliefs significantly and positively predicted *positive emotions* while significantly and negatively predicted *shame*. In other words, students with higher chemistry self-efficacy beliefs were expected to report higher positive emotions and lower feelings of shame in chemistry classes. The result is consistent with findings of previous research conducted in Western settings, which examined how each category of test-related emotions (e.g., joy, pride, shame, anxiety and anger) were related to academic self-efficacy (Pekrun et al., 2004). Overall, the functional linkages of positive emotions and negative emotions with self-efficacy beliefs appear to be universal across cultural and subject contexts.

Regarding the relationship between achievement emotions and their effect – classroom engagement – we found that only *positive emotions* significantly and positively predicted student engagement in chemistry classes. Students with higher level of positive emotions reported being more engaged in chemistry classes. However, feelings of *shame* could not predict the engagement level, which reflects the previous argument about the complex relationship between negative activating emotions (e.g., shame) and engagement. This result is consistent with prior findings in Western contexts that positive emotions (e.g., enjoyment, hope) positively related to students' self-reported effort, but differs from prior research in that *shame* did not have a significant negative relationship with effort (Pekrun et al., 2004), no matter before or after controlling for positive emotions. However, it is consistent with one study conducted in China that reported little association between negative emotions and student engagement (Lam, Wong, Yang, & Liu, 2012). The different patterns of results between these studies suggest that cultural norms might shape the relationship between negative emotions and student engagement. As mentioned above, in Eastern contexts, the perception of shame can serve as a double-edged sword for regulating the following actions: students who feel moderate amounts of shame might experience increased motivation to spend more effort and process information more carefully so that they can avoid situations of losing face and maintain the self-value for others. However, excess shame might be a real emotional threat, which results in task-irrelevant thinking (Pekrun et al., 2004) and decreases engagement in classrooms.

In addition, the path model also showed that students' chemistry self-efficacy predicted classroom engagement in both direct and indirect ways. Positive emotions mediated the effect of chemistry self-efficacy on classroom engagement. This finding is consistent with prior research indicating the unique contribution of self-efficacy to classroom engagement when controlling for other variables (Walker, Greene, & Mansell, 2006). It also suggests that teachers can more effectively engage students in chemistry classrooms if pedagogical strategies (e.g., using technology) can promote students' self-efficacy beliefs and positive emotions. Therefore, in the next section, I will discuss how the integration of computer simulations influences these affective variables.

Conclusions, Limitations, and Implications

Achievement emotions are critical for students' academic achievement and personal development (Linnenbrink-Garcia & Pekrun, 2011). This study examines the dimensions, antecedent and effect of achievement emotions in a specific cultural and subject context – Chinese chemistry classrooms. The combination of quantitative surveys with qualitative interviews contributes to capturing Chinese students' patterns of class-related emotions more accurately. Since previous research paid more attention to test anxiety, my research contributes to the psychological literature on achievement emotions in the following two aspects.

First, it increases theoretical knowledge about students' achievement emotions experienced during class periods and how Eastern cultures shape students' emotional patterns. Our findings indicated that one specific negative emotion – *shame* – was perceived differently than other types of negative emotions. The unique status of shame might result from cultural norms in Chinese classrooms that emphasize social relations with others and value the function of shame for motivating students to spend more effort. Second, we tested theoretical assumptions of control-value theory in a unique cultural and subject context. The results showed that both chemistry self-efficacy and positive emotions were significant predictors of student engagement in Chinese high school classrooms. Chemistry self-efficacy also significantly predicted students' perceptions of positive emotions and shame in opposite directions. The non-significant path from shame to engagement suggests that different types of negative emotions might exert different influences on student engagement in different cultural contexts. As shame is negative but activating in nature and is more salient to Chinese students, it is worthwhile investigating the mechanism how shame influences students' following learning behaviors or strategies in the future.

However, these findings are accompanied by limitations. The path model was proposed based on theoretical assumptions of control-value theory, there may exist other models with equivalent or better fit. For example, Bandura's (1986) social cognitive theory assumes that psychological arousal (e.g., anxiety) is one important source of perceiving self-efficacy beliefs. What is more, the path model in this study only tested unidirectional relationships among various affective variables. Based on above limitations, I suggest that researchers can collect various data from different time points with a larger sample, examine the reciprocal relationships between affective variables, and compare the model fitting of different path models.

Together, the results of this study will appeal to researchers who are interested in investigating the variation of student emotions across cultural contexts with different values and educational systems. Understanding functional linkages of achievement emotions in highly-structured Chinese classrooms also encourages future research to investigate how teachers can develop effective pedagogical strategies (e.g., using technology) that nurture positive emotions and engage students in such environments.

Section 2: The Impact of Computer Simulations on Chinese Students' Affective Perceptions

Introduction

Computer simulations, defined as computer generated dynamic models of the real world and processes (Smetana & Bell, 2012), are regarded as one potential and promising approach to transform teaching and learning in science classrooms. They provide students with new learning opportunities such as interacting with dynamic model systems, visualizing representations of physical phenomena, and receiving animated feedback (Van der Meij & de Jong, 2006). Despite the above potential, the effectiveness of using computer simulations is strongly dependent on teachers' pedagogical practices of integration within specific classroom contexts (Hsu & Thomas, 2002; Smetana & Bell, 2012). At present, few studies have explored the feasible pedagogical strategy and corresponding influence of integrating computer simulations into highly structured Chinese classrooms. The present case study aims at filling this research gap by observing how two Chinese teachers implemented computer simulations in their chemistry classrooms and collecting survey and interview data to examine students' affective perceptions in simulation-integrated environments. Such effort can increase the knowledge about expanding the application of computer simulations across classroom contexts.

Pedagogical Strategies and Impacts of Using Computer Simulations in Western Contexts

Computer simulations are now used worldwide in a variety of educational environments such as lecture, laboratory, recitation, homework, and informal settings (Finkelstein, Adams, Keller, Perkins, & Wieman, 2006). Despite the wide application, integrating computer simulations into classroom instruction is a complex undertaking. Classroom teachers, as the main decision maker of the entire process, play critical roles in aligning the use of computer simulations with curricular objectives and student needs in specific classroom contexts (Hennessy Deaney, & Ruthven, 2006). Manfra and Hammond (2008) pointed out that teachers' pedagogical aims dominate their pedagogical strategies of integrating technology. For example, some science teachers who emphasize content understanding might use computer simulations as a visualization tool to present information. In contrast, other teachers who focus on developing students' scientific practices outlined in the Next Generation Science Standards (NGSS) might use computer simulations as an inquiry tool to perform exploration tasks. How do the two different pedagogical approaches of integrating computer simulations influence students' science learning experiences? To answer this question, I will first review findings of previous research conducted in Western contexts.

Using Computer Simulations as an Inquiry Tool

Computer simulations vary in their degrees of immersion. As some computer simulations can embed science content within highly immersive virtual environments, education researchers recommend using them in a student-centered approach where students can develop scientific inquiry skills and construct conceptual understanding on their own. For example, Ketelhut (2003) and her colleagues implemented an interactive simulation – *River City* – for engaging middle school students in collaborative scientific inquiry and developing 21st century skills over three weeks. Students visited virtual environments six times to familiarize with the interface, complete mini-tasks, and test hypotheses. The results showed that the problem-solving process of engaging virtual experimentation increased academic self-efficacy of students in the experiment group (Ketelhut, 2010). This conclusion is further supported by qualitative interview data:

students who found the regular science class boring or had low feelings of self-efficacy were reported to persistently figure out the presented problem in virtual environments and enjoy the science class more (Clarke & Dede, 2005). Accordingly, computer simulations are suggested to effectively engage middle school students in learning science and “act as a catalyst for change in students’ self-efficacy” (Ketelhut, 2007, p.99). Meluso, Zheng, Spires and Lester (2012) corroborated the above argument with the evidence that fifth-grade students' science self-efficacy and science content learning significantly increased after interfacing with a simulation microworld called *Crystal Island* across a series of four days. In their study, students completed an online tutorial to get familiar with the controls and character movements on the first day, then interacted with the computer simulation either on a single-player condition or a collaborative playing condition for 40-50 min on the following three days. Both studies indicate that computer simulations can potentially increase students’ self-efficacy, positive emotions (e.g., enjoyment), and engagement in learning science.

Despite the above benefits, it is difficult to generalize the student-centered pedagogical approach to specific science classrooms where class time and technology equipment are limited. To solve this problem, other researchers have explored the possibility and influence of demonstrating computer simulations in a teacher-directed approach. It should be noted that such pedagogical approach does not necessarily prohibit inquiry opportunities. Instead, computer simulations can be useful tools for interactive lecture demonstrations, which support whole-class inquiry practices (McKagan et al., 2008). For example, Rutten, van der Veen and van Joolingen (2015) systematically described how one Dutch secondary school physics teacher integrated computer simulations to support the “predict-observe-explain” cycle (Hennessy et al., 2007), which is one important principle in the majority of inquiry approaches (Bell, Urhahne, Schanze,

& Ploetzner, 2010). Specifically, students first predicted how scientific phenomena would develop, then observed and described the actual phenomena, and finally explained why phenomena developed in certain ways. The results showed that using computer simulations as an interactive demonstration tool enhanced students' attention focus, enjoyment, interest and science knowledge. However, researchers also reported that students in large classes were less convinced that teaching with computer simulations contributed to their motivation. In other words, the large class size might counteract the positive effect of computer simulations on students' affective perceptions. Such an issue provides the rationality of conducting the current study: if computer simulations are integrated in large Chinese high school classrooms, what is the influence on students' affective perceptions?

Using Computer Simulations as a Visualization Tool

Using computer simulations as an inquiry tool requires science teachers to reform their regular teaching strategies. Due to various contextual challenges and pedagogical aims, many science teachers are reluctant to adopt the inquiry-based approach and prefer to integrate computer simulations as a visualization tool. In this situation, students are asked to observe the demonstration and provide or listen to explanations for scientific phenomena. There are two different ways of using computer simulations as a visualization tool. Some science teachers use computer simulations as an alternative to traditional textbook-based instruction. For example, Kiboss, Ndirangu and Wekesa (2004) replaced textbooks with computer-mediated simulations in the secondary biology course over a 3-week period. During these lessons, students were presented with animated color graphics and short notes with factual information on cell division. The results showed the experiment group reported significantly higher gains in positive perceptions of classroom environments and feelings towards the biology course than the control group. Such positive effects were attributed to students' active interactions with the simulation, which simplified “mystic” concepts in science discourse.

Other teachers use computer simulations to supplement the traditional classroom instruction. For example, Jimoyiannis and Komis (2001) examined the effects of one computer simulation – *Interactive Physics* – on high school students’ understanding of basic kinematical concepts concerning simple motions through the Earth’s gravitational field. In the computer lab, the physics teacher used the computer simulation to display simple kinematical phenomena and analyze the free fall laws. The results showed that students in the experiment group exhibited significant improvement of achievement for the tasks concerning the concept of acceleration. Similarly, Stern, Barnea and Shauli (2008) investigated how a dynamic software simulation – *A Journey to the World of Particles* – influenced middle school students’ conceptual understanding of the kinetic molecular theory. The experiment group, who observed the consequences (e.g., trace of an individual particle) of modifying parameters (e.g., temperature and pressure), scored significantly higher than students in the control group. However, the average performance of both groups was low and long-term learning differences were negligible.

In summary, most existing studies that examined effects of using computer simulations as a visualization tool have focused on students’ content understanding while ignoring their affective perceptions. It is unknown whether such pedagogical approach is also productive for improving students’ affective perceptions (e.g., self-efficacy, positive emotions, and engagement in learning science), especially in large Chinese classrooms. By answering the above question, this study can provide empirical evidence for informing the decision making of integrating computer simulations within similar classroom contexts. As mentioned earlier, any discussion about the positive effects of computer simulations should be accompanied by a discussion about teachers' pedagogical strategies of integration within specific classroom contexts. Before exploring whether such positive effects are still applicable in Chinese large chemistry classrooms, I will first describe how Chinese teachers implemented computer simulations as a visualization tool.

Pedagogical Strategies of Using Computer Simulations in Chinese Contexts – a Visualization Tool

Many studies that examine learning effects of computer simulations are conducted in experiment conditions and disregard ecological validity of real classroom environments. The current study aims to fill the research gap by avoiding interfering with teachers' practices of using computer simulations. In this study, I introduced one specific computer simulation called "Reaction & Rate" (Figure 4) from the Physics Education Technology (PhET) project, which covers content knowledge about the reaction rate, related influencing factors, and chemical equilibrium (https://phet.colorado.edu/en/simulation/reactions-and-rates). It should be noted that PhET simulations are different from game-based simulations in the interface design. The former allows students to adjust variables and observe dynamic animations while in the latter, students can manipulate the character to navigate within the 3D immersive virtual environments.

Before the classroom implementation, the two Chinese teachers first explored the PhET simulation and evaluated how different simulation features functioned to represent curriculum contents. Taking the richness of simulation information and the realities of classroom contexts (e.g., large class size, heavy curriculum task, limited class time, and technology equipment) into consideration, they proposed that the feasible and effective strategy of integrating computer simulations was to use it as a visualization tool to review related content knowledge in one class period. Such instruction decision is consistent with the Western phenomenon that science teachers are more likely to initiatively integrate computer simulations as a visualization tool. Specifically, the teachers adjusted the system variables (e.g., temperature, concentration) in the computer simulation while students observed and connected animated phenomena with curriculum knowledge. It should be noted that the computer simulation was not integrated to replace traditional experiments that demonstrated chemical phenomena at macroscopic level (e.g., how water bath heating influences the decomposition rate of hydrogen peroxide). Instead, they were used to supplement the traditional chemistry instruction and elaborated the molecular movement at the microscopic level. The process of using the simulation in the two chemistry classes was videotaped.

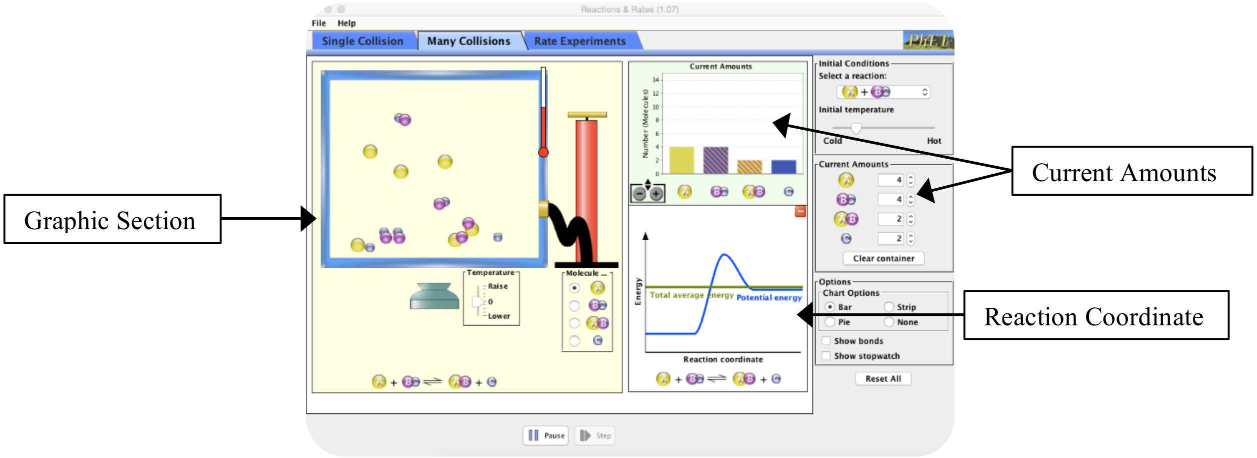

Figure 4. Screenshot of the PhET simulation

Detailed descriptions about what happened in these Chinese chemistry classrooms can help researchers and practitioners comprehensively understand teachers' pedagogical strategies of integrating the computer simulation, and how teachers interacted with students in real classroom contexts. Since the two teachers cooperated to make instructional decisions of integrating the computer simulation, their pedagogical strategies were similar. In this section, I transcribed one of the videotapes as the example and narrated the classroom story how the chemistry teacher implemented the computer simulation to review related content knowledge.

During the simulation-integrated chemistry class, the conversation between the chemistry teacher and students occurred in the format of choral responding. All dialogues were translated from Chinese.

At the beginning of the simulation-integrated class, the chemistry teacher first reviewed the topic (i.e., the reaction rate and influencing factors) by asking a series of questions. The teacher first asked, “What physical variables can influence the reaction rate?” Students responded with different answers such as surface area, temperature, pressure, concentration, and catalyst. Then the teacher connected curriculum contents with industrial examples and asked, “What can be done to increase the surface area of ore in industrial production?” Students provided different methods such as crush, dissolution, and stir. Subsequently, the teacher started to help students review how other physical variables influenced the reaction rate, which could be demonstrated with the computer simulation.

Teacher: How do temperature, pressure, and concentration influence the reaction rate?

Students: (Some students) The pressure influences the distance between molecules or atoms.

(Other students) The concentration influences the number of molecules per unit volume.

At this moment, the teacher displayed the interface of the computer simulation on the projector. Students broke into cheers and said “wow.” The teacher then asked some guiding questions and explained simulation features before the demonstration, which are recommended practices of using computer simulations (Hsu & Thomas, 2002).

Teacher: The occurrence of chemical reactions requires molecules to collide [with each other]. How do different factors influence the reaction rate through microscopic collisions? How does temperature influence the reaction rate?

(Pointing to the chemical reaction at the bottom of the graphic section)

Here is the example: if A reacts with BC, [which] consists of B element and C element, and produces AB and C. [This is] one simple replacement reaction. How does temperature influence the reaction rate? Let's add 30A and 30BC.

(Pointing to the graphic section)

Here we can see the container is fixed. We can change the number of A and BC to change the concentration, right? (Pointing to the slider) We can find the "initial temperature" [here]. We can adjust to show whether the temperature is high or low.

(Pointing to the graphic section again)

We can also increase or decrease temperature at the bottom of the container during the reaction process.

(Pointing to the right side of the interface)

We can control the concentration here. The initial temperature is here. Let's observe how molecules collide to react.

When the teacher clicked the "start" button, students started to observe molecule movements in the container and wondered with the sound of "wow" again. Simultaneously, the teacher elaborated how students could connect between different sections of the computer simulation to generate a relationship between temperature and reaction rate.

Teacher: The yellow one is A. The purple and gray one is BC. If we want to see clearer whether new substances are produced, (Pointing to the diagram section) we can observe the [current amounts] coordinate, which shows current molecular amounts of A and BC. We can see [the numbers of] products are increasing. So how does temperature influence [the reaction rate]? Now let's increase the temperature and observe how it influences the reaction rate. Is reaction rate increased?

Student: Yes.

As the temperature increased, container molecules gradually moved very fast and students started to laugh. One student said to her neighbor, "these balls are flying." Then the teacher guided students to connect the observed phenomenon with the "reaction coordinate."

Teacher: Have you noticed any changes in the "reaction coordinate" when I increase the temperature?

Students: The total energy increases.

Teacher: So how does temperature influence the reaction rate?

Students responded to the question with various answers. The teacher summarized students' ideas, "If temperature increases, molecules move faster and this increases the collision frequency. We can see the energy line also increases. It shows the [total] reactant energy of A and BC. What is the result? More general molecules become activated molecules. Then [higher temperature] increases the percentage of activated molecules and the final reaction rate."

After clarifying the microscopic mechanism how temperature influenced the reaction rate, the chemistry teacher moved to the third factor – concentration – and started to demonstrate the second experiment. In this process, she followed students' strategy of increasing the concentration and asked students to observe and compare the reaction rate. In addition, she connected between different factors and explained that fourth factor – pressure – influenced the reaction rate through changing the concentration.

Teacher: Let's observe the concentration. Now we have 30A and 30BC. The container volume is fixed. How can we change the concentration?

Students: (One student) Press the container. (Other students) Add more A and BC.

Teacher: How many do we add?

Students: 100A.

Teacher: (Following the suggestion) OK. Let’s increase the concentration of A, add 100A.

As the container was full of molecules, students were excited with the sound of “yay.” Simultaneously, the teacher guided students to generate a relationship between the concentration and reaction rate. Based on students’ explanations, she provided further information and used the energy line in the “reaction coordinate” to correct students’ misunderstanding.

Teacher: There are so many A. They cannot avoid colliding with BC. If BC moves around, they meet A. Then it is quite possible to react. So how does concentration influence the rate?

Students: (Some students) Change the number of molecules in per unit volume.
(Other students) Change the number of activated molecules.

Teacher: (Pointed to the reaction coordinate) Are there any changes in the energy diagram?

Students: No.

Teacher: We did not change the number of activated molecules. Only increased the number of molecules.

After demonstrating two experiments using the computer simulation, the teacher asked how the last factor – the catalyst – influenced the reaction rate. Students responded with the answer, “Change the activation energy.” One student murmured, “Let me try it.” The teacher commented, “The computer simulation does not include the function of adding catalyst. It should be improved in the future.”

Research Question

> How does one PhET simulation influence students’ affective perceptions (i.e., chemistry self-efficacy, achievement emotions, and classroom engagement) when it is integrated as a visualization tool for reviewing content knowledge in a traditional Chinese classroom setting?

Methodology

Procedure and Data Collection

Participants who attended the second study were the same as in the first study: one hundred and three 16 or 17-year-old eleventh-grade students (45 female and 58 male) from two chemistry classes in the same high school. As described in the first study, students first responded to the pre-survey in which they answered questions about three affective perceptions (i.e., chemistry self-efficacy beliefs, achievement emotions, and classroom engagement) with respect to regular chemistry classes. After the classroom implementation of the PhET simulation, students filled out the post-survey, which included the same items as the pre-survey, to report their perceptions in the simulation-integrated session. Almost all students from the two classrooms filled out pre- (N = 103) and post- surveys (N = 101).

In addition, the two teachers and nine of the students volunteered to participate in semi-structured interviews, which asked questions about their perceptions of using PhET simulations in chemistry classes (Appendix B). All interviews were audiotaped: the two teachers were interviewed together while the students were interviewed individually in a private office. Sixty-one students (nearly half of the sample) including six of the students who were interviewed also volunteered to respond to eight open-response questions, which asked about their learning experiences in simulation-integrated classroom environments (Appendix C). Two example interview and open-response questions were: "How do you feel about simulation-based chemistry class? What is the influence of using the computer simulation on your perceived confidence of learning chemistry?"

Methods

Since the study was exploratory in nature and examined students' various affective perceptions in real classroom contexts, I adopted a case study approach to answer the research question. First, such an approach can be of value where the research aims to investigate a complex phenomenon embedded in the real world, and where the scope is difficult to define and can only be understood within context (Yin, 2003). Second, the case study is suitable to uncover interactions of inseparable variables that are elements of the phenomena being studies (Yin, 2003). The quantitative and qualitative data were collected from four sources: 5-point Likert scale surveys (Appendix A), classroom observations, open responses (Appendix B) and teacher/student interviews (Appendix C). The multiplicity of data sources revealed the complex phenomenon from different perspectives and strengthened the convincement of results.

Regarding the post-survey data, Cronbach's alphas for 16 chemistry self-efficacy and 14 classroom engagement items were .965 and .925, respectively. As few students explicitly described their feelings of shame in interviews and open-responses, I followed the most commonly used strategy and categorized achievement emotions scale items into 6 positive emotion items (α = .843) and 8 negative emotion items (α = .736). Then I conducted independent sample t-tests to compare means of the four affective variables in the pre- and post- surveys because student identification information was not available for dependent t-tests. Regarding qualitative data, I identified units from about how and why computer simulations influenced four affective perceptions (open-coding), and finally grouped these related units under different categories (axial coding) (Strauss & Corbin, 1990). My interpretations about the impact of the computer simulation are presented below.

Results and Discussion

The purpose of the present study was to examine Chinese students' affective perceptions when a PhET simulation was integrated as a visualization tool to review content knowledge. Such effort increase the knowledge about how to improve students' science learning experiences in Chinese classroom contexts through integrating computer simulations. In this study, the quantitative survey data outlined the overall impact of the computer simulation on students' four affective variables (i.e., chemistry self-efficacy beliefs, positive emotions, negative emotions, and classroom engagement) (Table 6) and qualitative data provided more details about individuals' diverse perspectives behind the scene. Interview quotes that are related to four affective variables are listed in in the third column of Table 7 with different numbers (e.g., S1, S2… S14) and other quotes are embedded in paragraphs with brackets. In the following sections, I will discuss the effects of the computer simulation along each affective variable.

Chemistry Self-Efficacy Beliefs

The first conclusion is about how the computer simulation influenced students' chemistry self-efficacy beliefs. The independent samples t test showed that the PhET simulation significantly and positively increased students' chemistry self-efficacy beliefs (*t* [202] = -2.38, *p* = .018) (Table 6). Based on Cohen's (1988) rules of thumb, the effect size for this analysis (*d* = .34) was small to medium. Such significant result reflects the dynamic and malleable property of self-efficacy beliefs, which can be experimentally augmented in a short period of time upon receiving contextual information (Bong, & Skaalvik, 2003). Among 61 open responses to Q5 in Appendix C, 23 students (37.7%) reported a higher level of confidence in learning chemistry (e.g., S1, S2, and S3 in Table 7) while 29 students (47.5%) reported the lack of a big influence (e.g., S4, S5 and S6 in Table 7). In other words, the survey data indicated an overall positive effect while qualitative data implied that the change of chemistry self-efficacy beliefs were perceived differently based on students' interpretations of the results of simulation-integrated classroom activities.

Why did some students perceive higher chemistry self-efficacy beliefs in simulation-integrated chemistry classes? When answering this question, 15 students ascribed to the power of technology in representing microscopic scientific processes in a vivid manner, which reduced the difficulty of understanding the same content (e.g., S1 and S2 in Table 7). Such explanation is consistent with Bandura's (1997) theoretical assumption that students' self-efficacy beliefs are reciprocally and recursively related to cognition. The progress in cognitive understanding prompts students to perceive higher levels of self-efficacy beliefs. Even though students did not have computers at their disposal, the whole-class demonstration facilitated them to effectively connect between visualized animations and content knowledge under teacher guidance. These colored animations, which provided additional situational resources through visualizing unobservable microscopic phenomena (e.g., S8), reduced students' cognitive loads and allowed them to develop an intuitive understanding of how scientific processes operated and attain a sense of familiarity (Laurillard,1992). The unique affordances of the computer simulation effectively complemented traditional lectures and potentially benefited students who were disadvantaged in classroom environments with pure linguistic descriptions (e.g., S9 and S10). Interview quotes from three students (S8, S9, and S10) are listed below:

> *S8: "it gives life to molecules, I feel more relaxed and no longer have the feeling of seeing the world in the smoke and mirrors."*
>
> *S9: "I can intuitively observe the reaction process. In the old lecture-based class, I can only figure out on my own. Sometimes it is difficult to imagine how the [molecular] movement becomes faster or slower."*
>
> *S10: "computer simulations can help those who want to learn and spend effort but cannot learn. If the difficulty is decreased, I can understand the same knowledge more easily. For example, I can understand 30% [of content] in old classes but now [I can] understand 50% and get more information."*

Besides cognition processes, interview data indicated that the sense of self-efficacy beliefs associated with students' goal orientations unexpectedly. Individuals hold either a learning goal orientation or a performance goal towards academic tasks (Dweck, 1986). A learning goal orientation describes a desire to master materials and enhance competence or knowledge. In contrast, a performance goal orientation reflects a desire to maximize favorable evaluations of competence (Wigfield & Cambria, 2010). Previous research has shown that learning goal orientation was positively related to self-efficacy, whereas performance goal orientation was negatively or not related to self-efficacy on an academic task (Bell & Kozlowski, 2002; Phillips & Gully, 1997).

The difference in goal orientations might provide explanations for students' different opinions about the effect on chemistry self-efficacy beliefs. In this study, the computer simulation was integrated to review previously learned knowledge. Students with a learning goal orientation (e.g., S1 and S2) valued the computer simulation's function of deepening conceptual understanding and maintaining long-term memory. As one student said,

> *"The computer simulation can help our memory last longer. Teachers' words are easily forgotten. But after using the computer simulation, maybe I cannot recall what teacher said after two weeks, but the image lingers in my mind. It reminds me what happened at that time."*

One chemistry teacher also supported the computer simulation's role of promoting long-term conceptual understanding because students could apply similar mechanistic knowledge in different contexts:

> *"I think the good thing is that abstract things are more intuitive. The software can represent microscopic formats. Though students might collect less information at the moment, they can extend [in the future]. Chemistry is from microscopic to macroscopic level, then from macroscopic to microscopic level. If [students are] clear about microscopic things, then they can easily understand the macroscopic level. If they thoroughly understand this microscopic thing, then the other microscopic thing is easy. For example, we can say the concentration increases collisions. We can say temperature also increases collisions. If I teach [how] the consternation [influences collisions] clearly, then [how] the temperature*

[influences collisions] is easy to explain. I think this is the advantage. This is like giving [students] one example, they draw other inferences."

In contrast, students with a performance goal orientation (e.g., S4 and S5) disvalued the computer simulation's benefits of promoting deeper understanding of scientific mechanisms or processes because they cared more about performing well in standardized tests, which included questions about a series of factual information. The failure of acquiring new knowledge information might interfere with students' perception about the change of chemistry self-efficacy beliefs (e.g., S3, S4 and S5). Even though the computer simulation have deepened student mechanistic understanding between influencing factors and reaction rate, whether it is counted as worthwhile knowledge is a question. In other words, students' deeper understanding might not be transformed into high test scores in school standardized assessments. This argument is supported by the evidence that the performance of the experiment group who used computer simulations was lower than the control group one year after the instruction (Stern, Barnea, & Shauli, 2008). Especially in Chinese highly structured classroom environments with the pressure of college entrance examination, student academic performance is the most important factor for principals, teachers, parents and students to make academic decisions. Such value norms prompt students to treat the attainment of chemistry knowledge and science performance as the main source of self-efficacy beliefs.

In addition, some students' conclusion about the lack of change might result from their personal philosophy about the malleability or stability of chemistry self-efficacy beliefs. When responding to the Q5 in Appendix C, two students argued that the computer simulation contributed to improving perceived abilities rather than the perceived confidence of learning chemistry. They argued that the confidence was inborn and more stable than the ability (e.g., S6 and S7). Therefore, chemistry self-efficacy beliefs should be developed and shaped over longer periods. As one student commented in the interview, “it is too early to conclude” because the computer simulation in this study was integrated for only one class period. However, students’ viewpoints are quite different from researchers’ argument that the ability “may be changeable, but only after a long period of time” (Gist & Mitchell, 1992).

Positive Emotions

The second conclusion is about how the computer simulation influenced students’ perceptions of positive emotions. Pre- and post-survey data indicated that the computer simulation significantly and positively increased students’ positive emotions (t [202] = -2.04, p = .004) (Table 6), which is consistent with the results of previous research (Kiboss, Ndirangu, & Wekesa, 2004). Based on Cohen’s (1988) rules of thumb, the effect size for this analysis (d = .41) was medium. Such positive effect was further supported by 61 open responses to Q1, Q2 and Q4 in Appendix C. When using various terms to summarize their general feelings about simulation-integrated chemistry classes, 37 students described their emotions with the term “excited”, 27 students with “happy”, 25 students with “curious”, and 19 students with “enjoyable.”

Table 6.

Four Affective Variables in Lecture-Based and Simulation-Integrated Instruction

Affective Variables	Pre-survey (N = 103)		Post-survey (N = 101)		Independent t tests (*df* = 202)	
	M	*SD*	*M*	*SD*	*t*	*p*
Chemistry Self-Efficacy	3.32	.65	3.56	.77	-2.38	.018
Positive Emotions	3.56	.59	3.81	.63	-2.94	.004
Negative Emotions	2.39	.53	2.35	.61	.445	.657
Classroom Engagement	3.67	.68	3.76	.74	-.839	.403

How did external classroom environments shape students' perceptions of positive emotions? Pekrun, Goetz, Titz and Perry (2002) noted that that positive emotions are developed based on two different types of cognition: thoughts about the learning materials and appraisals of mastery and success. Specifically in simulation-integrated chemistry classrooms, the novelty of learning materials (i.e., computer simulation), defined as the perceived newness of an innovation, might have stimulated individuals' positive affective reactions because the integration of such innovative technology tool represented a significant improvement over its existing predecessor (Wells, Campbell, Valacich, & Featherman, 2010). Such argument is supported by qualitative data. Among 61 open responses, 27 students attributed their positive emotions (e.g., curiosity, excitement) to experiencing interactive technology in a chemistry class for the first time. They compared with previous learning experiences and suggested that the integration of computer simulation transformed the traditional lecture-based instruction (e.g., "using computers is better than using blackboards") and made chemistry class more enjoyable (e.g., S11 and S12 in Table 7*)*. Students' emotional states of excitement were also reflected in their sounds of "wow" and "yay" when the chemistry teacher operated simulation variables. As one teacher said in the interview, "students see new things. They are excited when new animations are presented. Such excitement can infect classmates around and increase the [classroom] discussion or extend [students'] imaginations." Someone might concern about the sustainability of positive emotions. In other words, curiosity and excitement from computer simulations may be temporary and may disappear if they were integrated in long-term. The qualitative data indicated the answer might be "no." As one student commented, "If the teacher uses this computer simulation again, she will use other functions. They are different from [the function or content knowledge] this time. If the teacher uses a different computer simulation next time, these features are also different."

Regarding the second factor, students' senses of being able to master the material is another main source of students' positive emotions (Pekrun et al, 2002). For example, one student commented in Section 1, "I am happy when I understand (the content)." Students' perceptions of successfully understanding content knowledge, which is indicated by increased chemistry self-efficacy beliefs, creates conditions for perceiving positive emotions. In Chinese highly structured classroom environments, students' positive emotions from understanding the knowledge might be more valuable than those from the simulation itself. Therefore, the advantage of improving students' positive emotions would still exist as long as computer simulations could supplement traditional lecture-based chemistry instruction and promote conceptual understanding. Just as one teacher commended in the interview:

> *"The most impressive part of using the simulation is (to show) increasing the concentration of A can increase the reaction rate. [Usually] I orally describe that the number of molecule A in per unit volume increases so the reaction rate increases naturally. But how does this process happen? Actually, I do not point it out, or it is difficult to describe clearly with oral language. If using the animation, students can see B is surrounded by A. It is difficult to avoid the collision and reaction. As the [frequency of] collision increases, the percentage of reacting also increases."*

The simulation's affordances of visualizing microscopic processes to promote intuitive understanding is particularly evident in chemistry where students often need construct different mental models for explaining and understanding scientific mechanisms. In many cases, students are uncertain or confused about whether their imagined assumptions are correct or not. The diverse representations in the computer simulation can enrich students' experiences of learning scientific concepts. As one student noted, “I was confused when I learned the content. I carefully read [textbook content] and thought what was correct. Then I followed [my way of] thinking and memorized it at that time. Today I observe the simulation and realize that it should be like this. It breaks my old thinking.” These visualized dynamic animations, which can be used to evaluate the validity of mental models, might contribute to bridging the cognitive gap between texts in lectures and images in minds. As indicated in the teacher interview:

> *“It has the function of guidance. Some chemistry knowledge like the inner crystal structure is so difficult for students who have limited [abilities of] spatial imagination or [students who] have never been exposed to such things. If they could not imagine [the situation], then much work could not continue. ...In some cases, two people are talking and describing [the same thing]. For instance, the model should be in the format of A. But the imagination is B. A and B have something in common. Our verbal description may sound the same, or cannot show the difference. In fact, they are different.”*

Table 7.

The Summary of Qualitative Data

	Open Responses (N = 61)	Student Quotes
Chemistry Self-Efficacy	“Increased” (N = 23)	S1: “It makes abstract concepts more vivid and easy to understand and grasp. This is the first time I have the thought that chemistry is so easy.” S2: “It helps. The concrete format conforms to my way of thinking and promotes understanding.” S3: “It helps to some extent. [I am] clearer about various reaction processes. These concepts are no longer vague. But it does not help much with exams. [It] might be useful when learning new content.”
		S4: “No influence at this moment. It does not help much with my knowledge because I have learned them. But it helps deepen my understanding of

		knowledge.”
	“No [big] influence” (N = 29)	S5: “No big influence. I think basic knowledge and test scores influence confidence. Such software only makes classes interesting but does not benefit much for preparing exams.” S6: “It influences my learning ability rather than confidence.” S7: “It can help [me] learn more intuitively. [It has] no relations with my confidence. The confidence is an inborn feeling.
Positive Emotions	“Excited” (N = 37) “Happy” (N = 27) “Curious” (N = 25) “Enjoyable” (N = 19)	S11: “It makes us enjoy [chemistry] classes more and facilitates the discussion.” S12: “My feelings change from nervousness to excitement. It is a challenge for me to take chemistry classes, which brings pressure and tension. The computer simulation is more like one type of game, which can help relieve my tension.” S13: “I am very anxious. it is a waste of time taking this class. I would rather do more exercises.”
Negative Emotions	“Less boring” (N =1) “Less drowsy” (N =1)	
Classroom Engagement	“More engaged” (N = 42)	S14: “I can engage more. Very effective with teacher’s explanations.”
	“Complex” (N = 6)	S15: “The computer simulation helps me concentrate for a while. But the concentration might come from the novelty [of technology], which might distract our attention to the content knowledge itself.” S16: “The curiosity helps me engage more but sometimes I only observe the screen and neglect the teaching content.” S17: “I am superficially engaged and watch it for entertainment. I have not learned anything new.”
	“Less engaged” (N = 2)	S18: “Partly, it distracts me. Perhaps we cannot devote ourselves to what we are doing when we are too excited.” S19:” I cannot engage because the classroom order decreases, and I cannot hear what teacher says.”

Negative Emotions

The third conclusion is about how the computer simulation influenced negative emotions. Despite the fact that the current study extends prior literature by taking students’ negative emotions into consideration, the mean difference of negative emotions in pre-and post- survey was minimal (*t* [202] = .445, *p* = .657) (Table 6). The effect size for this analysis (*d* = .07) was negligible. In other words, the integration of computer simulations had a negligible effect on students' negative emotions. Open response data also showed that students were more likely to use positive terms (e.g., interested, excited, happy) rather than negative ones (e.g., angry, anxious) to describe their feelings. Only four students mentioned negative emotions at all. Among them, three students said that computer simulations "relieve the tension" (e.g., S12) and made chemistry classes "less boring" and "less drowsy" while one student said that he was anxious because "it is a waste of time taking this class. I would rather do more exercises" (e.g., S13). Such phenomena is consistent with the previous finding that students reported positive emotions more often than negative emotions concerning situations of attending classes (Pekrun, Goetz, Titz, & Perry, 2002b). One possible explanation is that negative emotions such as anxiety and anger are usually outcome-directed while this study focused more on students' emotional experiences related to classroom activities. For example, the feeling of anxiety might result from the worry about the failure of improving science performance. In addition, students may be discouraged or unaccustomed to express negative emotions in Chinese classroom climates (for further discussion see Section 1).

Classroom Engagement

The fourth conclusion is about how the computer simulation influenced student engagement in chemistry classrooms. The pre- and post-survey data indicated the computer simulation did not significantly increase the level of engagement (t [202] = -.839, p = .403) (Table 6). The effect size for this analysis (d = .11) was small. Among 61 open-responses to Question 6 in Appendix C, 42 students reported that they were more engaged in simulation-integrated chemistry classes (e.g., S14 in Table 7). Six students held more complex opinions (e.g., S15, S16 and S17 in Table 7). On the one hand, the computer simulation attracted them to observe the dynamic movement of animated balls on the screen. On the other hand, the sole concentration on the graphic section might lead to the neglect of teacher guidance and explanations, which might distract students from connecting the computer simulation with the content knowledge. Two students thought that the computer simulation distracted their attention due to the over-excitement towards the computer simulation and the decreased classroom order (e.g., S18 and S19 in Table 7).

The inconsistency between the survey data and qualitative data might result from the multidimensional nature of classroom engagement (Fredricks, Blumenfeld, & Paris, 2004), which is reflected in survey items and interview quotes. The survey items evaluated students' engagement based on cognitive activities such as the process of using the computer simulation to achieve conceptual understanding. For example, two example survey items were "when I'm in chemistry class, I listen very carefully" and "when I'm in chemistry class, my mind wanders." In contrast, qualitative data provided engagement information based on external classroom behaviors. For example, students reported that they were attracted by the new learning material specifically the graphic section of the simulation interface, which presented molecular collisions in a dynamic approach. However, students explained that the full attention to the molecular movements resulted from the curiosity in using the computer simulation for the first time. If computer simulations were integrated over the long-term, the novelty effect might wear off and students might be more cognitively engaged due to the awareness of being responsible for their own learning. As one student commented, "the class time is short. These things are secondary. [I will] listen to teachers first. If teachers emphasize such issues, the problem [of distraction] can be avoided." This commentary also highlights the importance of teacher guidance when using computer simulations especially in large classes, which is consistent with previous finding

(Smetana & Bell, 2012). Such guidance might include giving hints about where to observe and asking guiding questions about how different sections are related to each other. The teacher guidance might help monitor students to transform behavioral engagement into cognitive engagement that connect the observed dynamic animations with related content knowledge.

Conclusions, Limitations and Implications

Previous literature has documented two pedagogical strategies of integrating computer simulations: an inquiry tool for developing scientific practices and a visualization tool for promoting content understanding. Even though using computer simulations as an inquiry tool can maximize advantages of technology, such pedagogical strategy is susceptible to classroom contexts such as the number of students, class time, technology equipment, and teachers' pedagogical goals. This study narrated how the two Chinese chemistry teachers integrated the computer simulations as a visualization tool and the impact on students' various affective perceptions in real classroom contexts. Therefore, it contributes to educational research in the following two ways: first, it provides one pedagogical strategy for integrating computer simulations into typical highly structured and large Chinese classrooms. Second, it shows that this specific way of integrating computer simulations can potentially deepen conceptual understanding and improve specific affective perceptions. The survey data showed that computer simulations significantly and positively increased students' chemistry self-efficacy beliefs and positive emotions. However, there were no significant differences in students' negative emotions and classroom engagement.

Based on the findings of this study, I recommend that computer simulations can be and should be integrated in large Chinese classes to support traditional chemistry instruction. The dynamic and concrete format of representing abstract scientific concepts can facilitate the cognitive process of constructing mental models and benefit students who are disadvantaged or disengaged in lecture-dominated classrooms. Even though the interview data revealed that dynamic animations might also distract students from learning science content, such concerns can be reduced or avoided if teachers can give effective and timely directions, which guide students to connect between simulation features with content knowledge. Teachers' pedagogical strategies are critical for managing the tradeoff between possible advantages and disadvantages of computer simulations. The current study also encourages further research to explore what kinds of pedagogical practices of using computer simulations are more effective for engaging students in science classes. In summary, this study is worthwhile for those who are interested in utilizing computer simulations to create emotionally pleasant classroom climates and in improving the effectiveness of integrating computer simulations in different classroom contexts.

Interpretations of the results should take the following limitations into consideration. First, this study was exploratory in nature where the computer simulation was integrated for only one chemistry class. The short period of intervention could not accurately illuminate the longitudinal effect of integrating computer simulations on students' affective perceptions. Specifically, it is unknown whether the novelty from the technology itself is meaningful or not in the long term. Second, due to the availability of identification data, I used the independent sample t tests to compare means of four affective variables between pre- and post- surveys. The same group of participants violated the assumption of independence, which might lead to the failure of detecting the difference that was significant in dependent t tests. Third, the interview data indicated that students held different goal orientations when reporting the change of self-efficacy beliefs. Due to the lack of identification information, this study could not control students' goal orientations before comparing their chemistry self-efficacy beliefs. Based on above limitations, I provide two suggestions for future research directions. First, the larger and longitudinal data should be collected to systematically examine the influence of computer simulations on students' affective perceptions and academic performance. Second, researchers can first code students' goal orientations into two categories (i.e., learning VS. performance) and then examine the significance of difference in chemistry self-efficacy beliefs between two groups.

Concluding Remarks

Current Chinese education systems pay more attention to learning outcomes rather than the learning process. Students' affective perceptions in the learning process are often assigned a low priority or even ignored in classrooms. Considering their significant roles of influencing cognitive processes, performance, physiological health (Fredricks, Blumenfeld, & Paris, 2004; Pekrun, Goetz, Titz, & Perry, 2002) and career choices (Lent, Brown, & Larkin, 1986), researchers should pay more attention to the affective dimension of learning.

In this dissertation, I investigated students' achievement emotions in a specific cultural and subject context – Chinese high school chemistry classrooms. First, I examined how different dimensions of achievement emotions related to other variables in traditional lecture-based classroom instruction. The results of Section 1 showed that both chemistry self-efficacy beliefs ($\beta = 0.42$) and positive emotions ($\beta = 0.45$) had medium effects on students' engagement at the individual level. Second, I investigated how teachers could utilize computer simulations to improve the quality of instruction and make science more attractive. The results of Section 2 showed that the computer simulation significantly increased chemistry self-efficacy beliefs and positive emotions. However, its effects on negative emotions and classroom engagement was negligible. In other word, the increased chemistry-efficacy beliefs and positive emotions did not necessarily indicate the increased classroom engagement.

Results of Section 1 and Section 2 showed that the relationships among affective perceptions might be more complicated in simulation-integrated classroom environments. Even though there were no classroom effects for pre- survey, preliminary multivariate analyses of variance (MANOVAs) of post-survey revealed that there were significant differences between the two classrooms with respect to the four affective variables, $F(4, 96) = 4.269, p = .003 < .05$;

Wilk's $\Lambda = .849$, partial $\eta^2 = .151$. Follow-up univariate ANOVAs indicated that positive emotions, negative emotions, and classroom engagement were significantly different for the two classrooms, $F\,(1, 99) = 7.183$, $p = .009 < .05$, partial $\eta^2 = .068$, $\mathrm{F}\,(1, 99) = 6.369$, $p = .013 < .05$, partial $\eta^2 = .060$, and $\mathrm{F}\,(1, 99) = 17.004$, $p < .001$, partial $\eta^2 = .147$, respectively. There were no significant differences in chemistry self-efficacy beliefs, $F\,(1, 99) = 3.382$, $p = .069 > .05$, partial $\eta^2 = .033$. These findings suggest that the computer simulation might positively influence students in the two classrooms to different extents even though pedagogical strategies were similar.

One possible explanation is that the computer simulation influenced students' affective perceptions both at the individual level and at the classroom level. On one hand, the incitement of positive emotions (e.g., curiosity) might attract the individual's attention to dynamic animations in the computer simulation. On the other hand, students' positive emotions might create an over-exciting atmosphere and decrease the classroom order. At the individual level, one student mentioned that the over-excitement decreased classroom engagement, which supports the previous argument that students' positive emotions may reduce cognitive resources available and distract attention away from academic tasks (Meinhardt & Pekrun, 2003). In other words, the excitement may lead to shallow processing of information and reduce the motivation to deep involvement. At the classroom level, where students interact and influence each other, the influence of positive emotions on engagement is more complicated. The survey data and classroom observation showed that the demonstration of dynamic animations increased positive emotions, which also influenced others' behaviors and the whole instructional or learning environments (Pekrun et al., 2002).The relatively relaxed classroom atmosphere potentially decreased classroom order. In the interview, both teachers mentioned the problem of "controlling the scene." Contextual factors such as the noise in the classroom might distract students at the back of classrooms from learning the content who struggled to hear the authority figure - teacher's hints and directions. As classroom management is one important issue in large classrooms, one tentative inference is that the computer simulation's function of increasing chemistry self-efficacy beliefs is more appealing than the effect of inciting positive emotions in large Chinese classrooms. Teacher guidance plays critical roles in transforming the behavioral engagement into cognitive engagement.

In addition, since this study did not interfere with teachers' instructional decisions, the two Chinese teachers integrated the computer simulation as a visualization tool to review content knowledge. Despite various contextual challenges embedded within Chinese education system (e.g., rigid curriculum standards and heavy curriculum tasks), it is still possible to reform the traditional lecture-based instruction and integrate computer simulations as an interactive demonstration tool to support inquiry practices. In the future, researchers can compare how different pedagogical strategies of integrating computer simulations influence students' affective perceptions in large Chinese classrooms.

Appendices

Appendix A: Achievement Emotion/Self-Efficacy/Engagement Survey

English Version

Part 1. This part pertains to the feelings you may experience when attending chemistry classes.

Please carefully read each statement and decide to what extent it is true for you.

SD – Strongly Disagree

D – Disagree

N – Neutral

A – Agree

SA – Strongly Agree

	SD	D	N	A	SA
1. I look forward to my chemistry classes.	○	○	○	○	○
2. I enjoy my chemistry classes.	○	○	○	○	○
3. The material we deal with in chemistry is so exciting that I really enjoy my classes.	○	○	○	○	○
4. I enjoy my class so much that I am strongly motivated to participate.	○	○	○	○	○
5. I am proud of my contributions to the chemistry class.	○	○	○	○	○
6. I am annoyed during my chemistry classes.	○	○	○	○	○
7. I am so angry during my chemistry class that I would like to leave.	○	○	○	○	○
8. I get angry because the material in chemistry is so difficult.	○	○	○	○	○
9. I worry if the material is much too difficult for me.	○	○	○	○	○
10. When thinking about my chemistry class, I get nervous.	○	○	○	○	○
11. When I say something in my chemistry class, I can tell that my face gets red.	○	○	○	○	○
12. My face is getting hot because I am embarrassed that I cannot answer the teacher's questions.	○	○	○	○	○
13. I am ashamed that I cannot answer my chemistry teacher's questions well.	○	○	○	○	○
14. I think I can be proud of my knowledge in chemistry.	○	○	○	○	○

Part 2. This part investigates the confidence you have in undertaking different tasks. Please carefully read each statement and decide to what extent it is true for you.

	SD	D	N	A	SA
1. I can apply a set of chemistry rules to different elements of the Periodic Table.	○	○	○	○	○
2. I can achieve a passing grade in a chemistry test.	○	○	○	○	○
3. I can tutor another student in class.	○	○	○	○	○
4. I can ensure that data obtained from an experiment is accurate.	○	○	○	○	○
5. I can propose a meaningful question that could be answered experimentally.	○	○	○	○	○
6. I can explain something that you learnt in this chemistry course to another person.	○	○	○	○	○
7. I can choose an appropriate formula to solve a chemistry problem.	○	○	○	○	○
8. I know how to convert the data obtained in a chemistry experiment into a result.	○	○	○	○	○
9. After reading an article about a chemistry experiment, I can write a summary of the main points.	○	○	○	○	○
10. I can learn and explain chemistry theory.	○	○	○	○	○
11. I can determine the appropriate units for a result determined using a formula.	○	○	○	○	○
12. I can write up the experimental procedures in a laboratory report	○	○	○	○	○
13. After watching a television documentary dealing with some aspect of chemistry, I can write a summary of its main points.	○	○	○	○	○
14. I can apply theory learnt in a lecture for a laboratory experiment.	○	○	○	○	○
15. I can write up the results section in a laboratory report.	○	○	○	○	○
16. After listening to a public lecture regarding some chemistry topic, I can explain its main ideas to another person.	○	○	○	○	○

Part 3. This part pertains to the engagement when attending chemistry classes. Please carefully read each statement and decide to what extent it is true for you.

	SD	D	N	A	SA
1. I try hard to do well in chemistry class.	○	○	○	○	○
2. In chemistry class, I work as hard as I can.	○	○	○	○	○
3. When I'm in chemistry class, I participate in class discussions.	○	○	○	○	○
4. I pay attention in chemistry class.	○	○	○	○	○
5. When I'm in chemistry class, I listen very carefully.	○	○	○	○	○
6. When I'm in chemistry class, I just act like I'm working.	○	○	○	○	○
7. I don't try very hard in chemistry class.	○	○	○	○	○
8. In chemistry class, I do just enough to get by.	○	○	○	○	○
9. When I'm in chemistry class, I think about other things.	○	○	○	○	○
10. When I'm in chemistry class, my mind wanders.	○	○	○	○	○

第一部分:

下一部份是有关你对于化学课的情绪。请仔细阅读每句话决定你是否同意这些观点。

A. 请选择你上化学课前的感觉。

		十分不同意	不同意	中立	同意	十分同意
1	我期待着上化学课。					
2	一想到化学课我就不自在。					

B. 请选择你上化学课时的感觉。

		十分不同意	不同意	中立	同意	十分同意
3	我喜欢上化学课。					
4	我觉得化学很复杂。					
5	如果不能很好地回答老师的课堂提问我会感到丢脸。					
6	我上化学课时感到烦躁。					
7	当我在化学课上发言时，我能感觉到自己脸红。					
8	化学课给我带来许多乐趣，我因此积极参与课堂活动。					
9	上化学课时，我因为恼火恨不得一走了之。					
10	因为我不能回答老师的问题，觉得难堪以至于脸上发烫。					
11	化学课上学的东西十分令人兴奋，所以我真的喜欢上化学课。					
12	我因为化学内容困难而感到恼火。					

C. 请选择你上化学课后的感觉

		十分不同意	不同意	中立	同意	十分同意

13	我为我能学到这些化学知识感到自豪。					
14	如果能回答老师的提问，我会感到自豪。					

第二部分:

下一部份是有关你对化学学科的自信程度。请仔细阅读每句话决定你是否同意这些观点。

		十分不自信	不自信	中立	自信	十分自信
1	能够运用化学规律来解释周期表的元素性质。					
2	在考试中获得高分。					
3	帮助同班的另一位学生。					
4	确保在实验操作是准确的。					
5	提出一个有意义的问题，并且可以通过实验回答。					
6	能够把化学课上学到的知识解释给另一个人听。					
7	能够选择合适的公式来解决化学问题。					
8	知道如何根据实验数据和现象来得出结论。					
9	在读完有关化学实验的文章后，能够总结出要点。					
10	学习并解释化学理论。					
11	根据公式能够推测出某个物理量的单位。					
12	能够准确描述实验过程。					
13	再看了有关化学实验的电视节目后能够总结其中的要点。					

14	能够把课上学到的理论知识应用到实验中去。					
15	能够准确描述实验结论。					
16	在听了有关化学的公共讲座后，能够把中心思想解释给另一个人听。					

第三部分：

下一部份是有关你在化学课上的集中程度。请仔细阅读每句话决定你是否同意这些观点。

		十分不同意	不同意	中立	同意	十分同意
1	我在化学课上想尽量做好。					
2	我在化学课上尽自己最大努力学习。					
3	我在课堂上积极参与讨论。					
4	在课堂上我注意力很集中。					
5	在化学课上我认真听讲。					
6	在化学课上我假装自己在学习。					
7	在化学课上我不是很努力。					
8	化学课上我只要基本学会就满足。					
9	化学课上我经常做别的事情。					
10	化学课上我容易走神。					

Appendix B: Interview Questions (English)

1. Please tell me a little bit about your general chemistry class.
2. How do you feel about your general chemistry class?
3. Please tell me a little bit about your simulation-based chemistry class.
4. How do you feel about simulation-based chemistry class?
5. What is the influence of using computer simulations in classroom? (e.g., interest in course materials, involvement in the lecture, interaction with other students, achieving course objectives, participation in classroom discussions, teachers' responses to concepts that might not have understood, engagement and involvement)
6. What do you think of using computer simulations in long term?

Appendix C: Open-Response Questions (English)

1. Please describe your feelings about simulation-based chemistry class in general.
2. Please check following words that can accurately describe your feelings in simulation-based chemistry class.

   ☐ Happy ☐Excited ☐ Nervous ☐Anxious ☐ Proud ☐Shamed ☐ Annoyed

   ☐Angry ☐ Enjoyable ☐ Other
3. Please describe the reason for above feelings.
4. What is the influence of using computer simulations on your feelings in chemistry class?
5. What is the influence of using computer simulations on confidence of learning chemistry?
6. What is the influence of using computer simulations on your engagement in chemistry class?

Glossary

Achievement Emotions: emotions directly related to academic activities and outcomes.

Engagement: the effort, attention, and persistence during the initiation and execution of learning activities.

Self-Efficacy: judgments of one's capability to organize and execute courses of action required to attain designated types of performances.

Goal Orientation: individuals' purposes or aims in terms of developing competence during activities.

Learning Goal Orientation: individuals approach a task to master materials and enhance competence or knowledge.

Performance Goal Orientation: individuals approach a task to maximize favorable evaluations of competence and minimizing negative evaluations of competence.

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