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Flow State Experiences in Second Semester General Chemistry

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FLOW STATE EXPERIENCES IN SECOND SEMESTER GENERAL CHEMISTRY

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ABSTRACT

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"Flow" is a mental state in which a person experiences an optimal performance of an activity, when they are completely immersed in it. The flow state is characterized by a feeling of confidence, and the activity seems to be effortless. A person enters a state of flow when their skills performing a task (activity) *matches* its level of difficulty. They perceive that the task is neither too easy nor too difficult. Flow state experiences have been connected to increased levels of performance in domains such as athletics and music, as well as in academic domains such as learning foreign language. However, prior to my investigations, there has been little research examining flow state experiences within the context of chemistry. Through my work, utilizing a mixed methods research design, I have been able to establish a connection between students' flow state experiences and their performance in second semester general chemistry. The pilot study included data from 157 participants, and the dissertation study included data from 150 participants. Additionally, I examined how students' approaches to learning are related to both their flow state experiences and their performance. Qualitative data from student interviews allowed us to gain deeper insight into the quantitative findings. Based on these findings, I can offer possible instructional strategies that can be implemented to facilitate students to enter this optimal state of flow.

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CHAPTER I

INTRODUCTION

Educators often wonder why some students thrive in academic environments while others struggle. Although modern educators often claim that education should be designed based on constructivist principles, behaviorism still permeates many classrooms (Bernal, 2006; Livengood, Lewallen, Leatherman, & Maxwell, 2012; Scerri, 2003). That is, instructors often expect students who receive the same instruction to achieve similar outcome levels (Gökmenoğlu, Eret, & Kiraz, 2010). Conversely, several research studies have found that even when students in a particular class receive similar instruction, their scholarly outcomes often vary widely (Crimmins & Midkiff, 2017; Daniels et al., 2008). Several factors that account for these unexpected outcomes are relatively stable characteristics, such as personality traits and general intelligence, which have been found to predict academic performance (Chamorro-Premuzic & Furnham, 2008). However, more fluid characteristics, such as attitude towards learning, can also affect how well a student performs academically. Specifically, emotional states, self-regulated learning, and motivation have also accounted for performance (Mega, Ronconi, & De Beni, 2014). Educational studies should consider affective characteristics when attempting to account for how students learn and understand concepts.

The Problem

Chemistry can be an especially difficult subject for students to learn (Calatayud, Barcenas, & Furio-Mas, 2007; Cooper, Kouyoumdjian, & Underwood, 2016; Johnstone, 1991; Pienta, Cooper, & Greenbowe, 2005). Students often have difficulties conceptualizing the information presented in general chemistry. This is likely due to its abstract and complex nature, as chemistry is often presented as three modes of representation: symbolic (equations and symbols), particulate (diagrams of atoms and molecules), and macroscopic (phenomena witnessed in a laboratory setting) (Johnstone, 1991). To fully understand general chemistry, students must understand it at all three of these levels of representation (Johnstone & Selepeng, 2001).

A simplistic assumption is that abstract knowledge can be transferred directly from the instructor into the minds of students. Conversely, constructivist principles state that students must construct their own knowledge based on their personal experiences. (Bodner, 1986). The latter statement explains some of the difficulties that students face when learning chemistry. Furthermore, their performance is confounded by their motivation and attitudes towards chemistry, which have been shown to impact performance in chemistry (Ferrell, Phillips, & Barbera, 2016). Motivation and attitudes also influence the learning approaches that students use which, in turn, have accounted for their performance (Beckley & Suits, 2012; Laird, Seifert, Pascarella, Mayhew, & Blaich, 2014; Zeegers & Martin, 2001). Thus, to optimize learning, the information presented must be meaningful and perhaps even *aesthetically pleasing* to the students in order for them to develop the intrinsic motivation necessary to conceptualize it and to begin developing their expertise (Suits, 2003).

Chemical educators have faced many challenges when designing instruction and creating optimal learning environments for students (Robinson, 2001; Ruder & Stanford, 2018). Students come from a wide variety of backgrounds, so factors such as prior knowledge, student attitude, emotions, motivation, and learning approach must be considered (Beckley & Suits, 2012; Chamorro-Premuzic & Furnham, 2008; Mega et al., 2014). While instructors are not able to control the levels of prior knowledge that their students have, they can create learning environments that foster student engagement. Kember (1991) contends that meaningful learning can be addressed with proper instructional design. Within the context of chemistry, this can be achieved through connecting topics to societal issues, using modern instrumentation in the laboratory, and having students work cooperatively towards a common goal (Galloway & Bretz, 2015; Mason, 2004). Consequently, students need to be both properly challenged and motivated in order to have an optimal learning experience.

Attempts have been made in the past to improve how chemistry is taught and learned. These attempts often focus on increasing student engagement and making the content more meaningful to students. Pedagogical techniques such as process-oriented, guided inquiry learning (POGIL) have been utilized to encourage cooperative and collaborative learning in the chemistry classroom and laboratory (Hunnicutt, Grushow, & Whitnell, 2015; Luxford, Crowder, & Bretz, 2012). This technique, based on constructivist principles, has students examining data, forming mental concepts, and developing problem-solving skills, and it has been shown to positively impact student learning and performance in chemistry (Hein, 2012). Another pedagogical technique that also aims to foster student engagement and meaningful learning is the flipped classroom method. Under this technique, the classroom roles are reversed; students learn at their own pace, while the instructor serves more as a guide rather than as direct transmitters of information (Bergmann & Sams, 2012). The flipped classroom method has been demonstrated to show improvements in student learning and success in both small and large lecture formats (Benedict & Ford, 2014; Shattuck, 2016). These techniques share a common goal: to optimize and personalize student learning so that it is engaging and meaningful.

If a person is deeply engaged and motivated while performing an activity, that person may be in a state of *flow*. *Flow* is the mental state in which a person performing an activity is fully immersed in the activity. Flow states have been described as optimal experiences for people performing tasks (Csikszentmihalyi, 1975). This mental state is proposed to occur when the difficulty of a task just meets the skill level of the person performing the task. It is categorized by a focused concentration on the present moment, a merging of action and awareness, loss of self-consciousness, sense of control over the situation, distortion of perception of time, and intrinsic rewards from the experience (Csikszentmihalyi, 1990). Previous research in this area has shown that flow experiences are positively correlated to increased positive affect and motivation (Rogatko, 2009; Vollmeyer & Rheinberg, 2006).

Purpose of this Study

Flow experiences have been shown to be particularly useful for students learning difficult content areas such as foreign language, statistics, and mathematics (Engeser & Rheinberg, 2008; Schiefele & Csikszentmihalyi, 1995). One such difficult subject is chemistry, which can be difficult to both teach and learn (Pienta et al., 2005). Although there have been many studies aiming to uncover the best practices for teaching and learning chemistry, there is a gap in the literature when it comes to examining chemistry education from the perspective of these flow experiences. Understanding the flow experiences of chemistry students could help educators improve their instructional methods by possibly employing educational strategies that may induce these flow states.

For this study, I focused specifically on the topic of acid/base chemistry within the course of second semester general chemistry for science majors. I chose this topic because it is often a difficult topic for students to understand (Calatayud et al., 2007; Cooper et al., 2016), and its central concepts appear again and again throughout chemistry and the physical sciences, where it appears in organic chemistry, biochemistry, biology, and environmental science (Brown, Henry, & Hyslop, 2018; Cartrette, & Mayo, 2011; Stoyanovich, Gandhi, & Flynn, 2015).

In this research study, I strived to answer the following research questions:

Q1 What is the relationship between flow experiences and academic performance in chemistry?

Q2 What is the relationship between flow experiences and students' learning approaches?

Q3 How do students' subjective flow experiences (or lack thereof) reflect in their academic performance in class?

The first two research questions were addressed using a multiple regression analysis as described in Chapter III. The third question was addressed using qualitative techniques designed to understand students' perceptions of their experiences in chemistry and how the independent variables from the first two research questions are related to the dependent variable in the regression model. All of these research questions were described in detail in Chapter III.

Limitations and Assumptions

This study was limited by the reliability and validity of the instruments used to gauge flow experiences, learning approach, prior knowledge, and achievement in chemistry. While I attempted to account for as many variables as possible that may impact student achievement in chemistry, I recognize that there could still be other variables that affect academic performance. Because student interviews were voluntary and only a relatively small number of students were interviewed, it was possible that information about students' subjective flow experiences (or lack thereof) could have been missed. As the researcher, I served as an instrument of data collection in this study and thus it is subject to researcher-introduced biases. I was a teaching assistant at the University of Northern Colorado where this study was conducted, so I may have had prior relationships with some of the students who were interviewed in this study.

CHAPTER II

LITERATURE REVIEW

In this chapter, I have reviewed the literature relevant to my dissertation study on the relationships among students' flow experiences, their learning approaches, and their academic performance in chemistry. Previous studies of these factors are described as well as how each one is explored or measured.

Flow

The concept of flow comes from the area of psychology known as positive psychology, which is "the scientific study of what makes life worth living" (Peterson, 2008). Flow, also described as being "in the zone", was first proposed by Mihaly Csikszentmihalyi in 1975, although the concept has existed for much longer. Ideas similar to the concept of flow have been found in Eastern religions such as Zen Buddhism, Hinduism, and Taoism (Csikszentmihalyi, 1990).

A flow experience can occur when the skills of the person performing an activity match the challenge or demand of that activity. If the person's skills are too far below the level of challenge, the person may experience anxiety or frustration; however, on the other hand, if the task is too easy, the person may experience boredom. The proposed "flow channel" exists between these two states of frustration and boredom (see Appendix A). In addition to this balance between these challenge and skill levels, the flow experience is facilitated when the student has clear goals and has received immediate feedback (Csikszentmihalyi, 2014).

The flow state can be characterized as merging action and awareness, centering of attention, losing of self-consciousness, and feeling control over the situation. Another indicator of flow is an *autotelic experience* during an activity, meaning the person doing the activity does not require external goals or rewards; rather the person is doing the activity out of enjoyment, which indicates intrinsic motivation (Csikszentmihalyi, 1975). Ryan and Deci (2000, p. 56) define intrinsic motivation as “the doing of an activity for its inherent satisfactions rather than for some separable consequences.” However, it is unclear as to whether or not autotelic experience is a fundamental component of flow, as it is possible that a person could be totally immersed in an activity for extrinsic reasons (Csikszentmihalyi, 2014).

Though it may not be a fundamental component of flow, *intrinsic motivation* does seem to be related to flow experiences. Martin and Cutler (2002) studied the flow experiences of theater actors and found significant correlations between flow experiences and the intrinsic motivation needed to accomplish the task. Vollmeyer and Rheinberg (2006) examined flow in a statistics course, where they found that students with higher levels of intrinsic motivation were more likely to experience flow and partake in self-regulated learning. Increased intrinsic motivation may be a consequence of the skills-demand balance, which is characteristic of the flow state (Landhäußer & Keller, 2012). When students were given an easy task, an appropriately challenging task, and an overly difficult task, and then asked afterwards if they wanted to try the task again, significantly more students chose to work on the appropriately challenging task again, as opposed to the overly easy and difficult tasks. This suggests that an appropriate challenge can serve as a source of intrinsic motivation (Keller, Ringelhan, & Blomann, 2011).

Measuring Flow

One of the first methods of measuring flow was the *Flow Questionnaire*, developed by Csikszentmihalyi (1975). This instrument partitions experiences into flow, anxiety, or boredom. The questionnaire starts by defining a flow experience and then asking participants if they have had a similar experience. It then asks participants about their skill level and the challenges they face when having this type of experience. This instrument was helpful during the early days of flow research, as it allowed researchers to discover situations in which people may experience flow. However, this instrument does not allow for the measurement of the intensity of flow; that is, it is unable to distinguish between activities where one may experience deep flow and those where one may experience shallow flow. It also does not assess how the perceived ratio between challenge and skill influences the flow state (Moneta, 2012).

Csikszentmihalyi and Larson (1987) developed the *Experience Sampling Method*, often abbreviated as ESM, as another way to assess flow experiences. With this method, the researchers give each participant a pager, which randomly gives an electronic signal eight times per day. Upon receiving a signal, the participant fills out an experience sampling form (ESF). The ESF is a self-report form that asks participants what they are doing at the time they were paged, their perceived skill level in that activity, their perceived level of challenge from that activity, and how they are feeling about it. This allows researchers to quantitatively assess the intensity of flow in different activities in which someone may participate throughout the day, and this assessment occurs as close to the time of the activity as possible. However, one of the strongest criticisms of the ESM is that, if a person is truly immersed in an activity and is experiencing flow, receiving a signal from a pager and taking the time to report on their experience may take them out of the flow state (Moneta, 2012).

In an attempt to develop a psychometrically sound method to assess flow experiences, researchers have taken a componential approach to the flow construct. Jackson and Marsh (1996) developed the *Flow State Scale*, which characterized the flow state by nine components: focused concentration, sense of control, merging of action and awareness, autotelic experience, loss of self-consciousness, distortion of perception of time, clear goals, unambiguous feedback, and balance between challenge and skills. Jackson, Ford, Kimiecik, and Marsh (1998) utilized this Flow State Scale to assess flow in athletic activities, finding that flow correlated positively with perceived sport ability and intrinsic motivation and negatively with anxiety. However, a weakness of the Flow State Scale was that it was designed to assess flow only in physical activities. This led to the development of the *Flow State Scale-2* (FSS-2) and the *Dispositional Flow Scale-2* (DFS-2), which assess flow in more general settings. The FSS-2 instrument was designed to measure the intensity of a flow state, while the DFS-2 measures flow as a general dispositional trait or domain specific trait (Jackson, Martin, & Eklund, 2008). The FSS-2 and DFS-2 instruments have been utilized to assess flow experiences in a variety of contexts such as software engineering and online gaming (Kuusinen, Petrie, Fagerholm, & Mikkonen, 2016; Wang, Liu, & Khoo, 2009).

Another componential instrument to measure flow is the *Flow in Education* (EduFlow) scale. This scale, developed by Heutte, Fenouillet, Martin-Krumm, Boniwell, and Csikszentmihalyi (2016b) was developed to evaluate flow in different learning environments. This scale measures four components of scale that are believed to be most relevant in educational settings: cognitive control, immersion and time transformation, loss of self-consciousness, and autotelic experience. The development of this scale was fueled by the idea that flow perception is bound by context, and thus, there are fundamental differences between educational tasks and physical or athletic activities. The former are cognitive activities that consist of more inter-related task components with much less physical demands (Heutte, Fenouillet, Kaplan, Martin-Krumm, & Bachelet, 2016a). Although the EduFlow scale is still a relatively new instrument, it has been utilized to assess flow experiences when using a brain-computer interface as well as flow experiences in a massive open online course, which is an open-access online course that allows for an unlimited number of participants (Heutte et al., 2016a; Kaplan & Haenlein, 2016). The EduFlow scale has also been employed to assess flow experiences in collaborative problem solving (Molinari & Avry, 2018).

Despite the fact that componential approaches to measuring flow have established strong evidence of psychometric validity and reliability, there are still weaknesses (Moneta, 2012). One criticism is that these componential instruments impose some level of flow on all participants, even if they may not have experienced flow at all. Also, the componential approach does not consider the balance between challenge and skills to be a precursor to the flow experience; rather it considers this factor to be a component of flow. Finally, the componential instruments do not distinguish whether an experience of heightened attention originates from the flow experience or from the feeling of pressure.

Overall, the methods of measuring flow span from the original flow questionnaire, to the experience sampling method, and to the componential surveys. However, these methods need to be continually refined and improved upon plus they need to be tested across settings and cultures. Each of these methods has potential to provide insight about the flow experience as long as proper considerations are taken (Csikszentmihalyi, 2014; Moneta, 2012).

Flow and Education

As described in the previous sections, much of the research of flow has examined flow experiences in sports and leisure activities; there have been fewer studies that aim to assess flow in an educational setting. One educational area where flow has been extensively studied is music education. Music tends to be a good domain in which flow can be studied because of its clear goals and immediate feedback (Csikszentmihalyi, 1990). Custodero (2002) echoed this assertion by focusing on the importance of the skills-challenge balance in music education. MacDonald, Byrne, and Carlton (2006) utilized the Experience Sampling Form (ESF) to measure flow experiences of first year college students during music composition. They found that students who experienced higher levels of flow composed more creativity musical pieces. Bernard (2009) conducted a qualitative study in which pre-service music educators were instructed to write autobiographical stories reflecting on times when they were teaching music, making music, and learning music. She concluded that as these future teachers develop better understand of their own flow experiences, they will be able to employ teaching techniques that encourage flow experiences in their students.

In high school classrooms, flow experiences have been connected to deeper student engagement. Shernoff, Csikszentmihalyi, Schneider, and Shernoff (2014), used the ESM to assess flow and student engagement across a variety of different high school subjects including, math, English, science, foreign language, history, computer science and art. They found that student disengagement in classroom activities may stem from a lack of challenge or meaning. The importance of the challenge-skills challenge is again noted, with the researchers finding that students who were properly challenged not only were more engaged and motivated, but they were also more likely to find enjoyment in the learning experiences. Additionally, Bressler and Bodzin (2013) used an augmented reality science game with high school students to study which students experienced flow, and they found that it increased their science interest, even after controlling for gender and prior interest.

Taber (2015) discusses how the framework of flow can be applied to properly challenge gifted students in high school chemistry. While chemistry can be an overwhelmingly challenge for some students, gifted students may need more difficult challenges in order to enter a state of flow. In this study, secondary students enrolled in a gifted program were given two different models of the structure of matter as well as a list of naturally occurring phenomena such as ice melting or starch being converted to glucose. Students were asked to determine how these two models could explain each phenomenon on the list. As opposed to just learning and regurgitating facts, these students noted that this activity gave them a chance to explore new ways of thinking, to be involved in in depth discussions, and to think independently. This study is similar to Vygotsky's *zone of proximal development*, where students need a level of challenge that matches their skill level in order to have an optimal learning experience (Liu & Matthews, 2005).

Flow and Performance

As described in the above sections, flow has been positively correlated to performance in a variety of domains such as academics, music, sports, and video games. However, it is difficult to determine whether flow leads to higher levels of performance, or if good performance makes flow experiences more probable (Landhäußer & Keller, 2012). Flow experiences are closely related to intrinsic motivation, and higher levels of intrinsic motivation are related to higher levels of student learning (Pintrich & de Groot, 1990). Ferrell et al. (2016) studied how general chemistry students were able to make connections between motivation and learning. They found a link between students' motivation levels and their performance in the course. Although the correlation between performance and motivation is well established, it is difficult to determine whether the flow experience itself leads to better performance, or if the higher levels of motivation associated with the flow experience are responsible for better performance (Landhäußer & Keller, 2012).

That being said, studies have been conducted that connect flow experiences to academic performance. Engeser and Rheinberg (2008) examined the relationship between flow experiences and final grades in a French language course and a statistics course. They found that flow had a small but significant effect on final grades when controlling for previous knowledge. Schüler (2007) found that flow experiences were a significant predictor of exam performance for undergraduate university students taking an introductory psychology course. Overall, more work still needs to be done to properly assess the relationship between flow state experiences and academic achievement.

Student Approaches to Learning

Learning approach refers to "the ways in which students go about their academic tasks, thereby affecting the nature of the learning outcome" (Biggs, 1994, p. 319). Under this model, students can take a deep, surface, or strategic/achieving approach. The approach in which an individual student employs is influenced by presage and process factors. Presage factors are factors that are independent of the learning situation, and include personal factors such as ability, personality characteristics, and prior knowledge, as well as situational factors such as subject content, teaching methods, and course structure. Process factors refer to the way students go about learning, including the students' motivations for learning, as well as the strategies they employ. Both of these factors determine how students approach learning (Biggs, 1987).

Each of these three learning approaches has a motive and strategy associated with it. The *deep approach* is characterized by an intrinsic motivation to learn and to become competent in a given subject. The strategy associated with the deep learning approach includes trying to discover meaning in the content and to relate information to prior knowledge (Biggs, 1987). Students using a deep approach tend to ask questions that demonstrate a sense of wonderment or curiosity about the subject. They tend to think ahead and predict outcomes, and they are less likely to give up on ideas that do not work. They also show increased metacognition through self-monitoring and self-assessment (Chin & Brown, 2000). In contrast to this, Biggs (1987) describes the *surface approach* as being "a balancing act between failing and working more than necessary". The surface learning strategy involves more rote memorization rather than meaningful learning. The third learning approach in the Biggs model is the *achievement approach,* which is characterized by the desire to do as well as possible in a given class, even when the student does not find the material to be particularly interesting. Students using this strategy tend to approach the material in an organized and systematic manner. The achievement learning approach seems to be related to extrinsic motivation, which is motivation due to a reward or separable outcome, rather than the activity itself (Ryan & Deci, 2000). However, Biggs (1987) notes that this achieving approach focuses on the way in which students organize how a task is performed; thus, it can be combined with either the deep or surface approach depending on the context of the situation.

Previously studies have explored the connections between learning approach, achievement, and the extent to which learning outcomes are achieved. Zeegers and Martin (2001) examined the learning approaches of chemistry students, finding that the deep learning approach was positively correlated with performance. In a subsequent study, Zeegers (2004) found that learning approach has a direct effect on learning outcomes. Specifically, learning chemistry was positively correlated with students who used a deep learning approach, while learning was negatively correlated with students who used a surface learning approach. When Chamorro-Premuzic and Furnham (2008) studied undergraduate students in the United Kingdom, they also found a positive correlation between academic performance, measured by scores on second year exams that are taken by all university students in the UK, and the deep learning approach. An additional study found that in addition to having a positive relationship with academic performance, deep learning is also related to cognitive gains and positive student attitudes (Laird et al., 2014).

If the deep learning approach is associated with academic success, then one might expect for it to be more widely used in classrooms. However, there are several confounding factors that influence which learning approach a student takes, such as the perceived course value and the level of engagement. Floyd, Harrington, and Santiago (2009) found that students who use a deep learning approach include those who are more engaged in a course, and those who perceive the course to be highly valuable. Similarly, they also found that students with negative perceptions of the course were more likely to take a surface approach. Higher levels of motivation and self-efficacy are also associated with students using a deep learning approach (Zusho, Pintrich, & Coppola, 2003). Building on this linkage, Diseth (2011) found that self-efficacy predicted the use of a deep learning approach, while avoidance motives were a predictor of the surface approach.

Kember (1991) found that students' approach learning can be influenced and manipulated with the use of proper instructional design. The type of assessment can influence perceptions of task requirements, which in turn can influence the learning approach that students use (English, Luckett, & Mladenovic, 2004). Formative assessments can be implemented to help encourage deep learning (Rushton, 2005). Even with good instructional design, a student's learning approach can still change over the course of a semester. Zeegers and Martin (2001) found that deep learning approaches decreased over time in a chemistry course. In addition, they found that students' reported motivation, confidence, and their perceived value of chemistry decreased over the course of a semester. However, this was more pronounced among low-achieving students, while high-achieving students actually showing an increase in reported self-efficacy (Zusho et al., 2003).

Measuring Learning Approach

Entwistle and Ramsden (1983) initially developed the *Approaches to Studying Inventory* (ASI) questionnaire based on three factors:

- the concepts of deep and surface learning approaches (Marton & Säljö, 1976),
- learning strategies that were based on relating ideas (holist) and using evidence (serialist) (Pask, 1976), and
- the effects on study strategies from intrinsic and extrinsic sources of motivation (Biggs, 1979).

Revised versions of the ASI instrument, including the most current *Approaches and Study Skills Inventory for Students* (ASSIST) questionnaire that classifies Pask's holist and serialist learning strategies under the broader umbrella of deep learning, as they correlated strongly with the deep learning approach characteristics of intrinsic motivation and intention to seek meaning. In addition to the section for assessing learning approach, the ASSIST questionnaire also includes sections designed to assess student conceptions of learning and student preferences for types of courses and teaching, (Entwistle, 1997).

The ASI and ASSIST questionnaires have been employed to assess the learning styles of students in a wide variety of learning environments. Entwistle and Tait (1990) utilized the ASI to assess the relationship between learning approach and learning environment, finding that learning approach is indeed influenced by the learning environment and that proper teaching can possibly cause students to employ a deep approach. The ASI instrument has also been utilized to help identify at risk students who use ineffective study strategies (Tait & Entwistle, 1996). Byrne, Flood, and Willis (2002), employed to the ASSIST questionnaire with Irish accounting students to assess the relationship between learning approach and learning outcomes. They found that the deep approach is associated with higher levels of performance, and the surface approach is associated with poor performance.

Acid-Base Chemistry

Acid-base chemistry has traditionally been both an important and difficult subject for students to understand. Hoe and Subramaniam (2016) identified several misconceptions that students have regarding the pH scale, neutralization of acids and bases, and the submicroscopic ionic properties of acids and bases. Calatayud et al. (2007) found that grade-12 high school students possessed some knowledge of macroscopic acid-base concepts, but struggled with sub-microscopic concepts. Additionally, they found that students had trouble connecting these two modes of concepts to each other. Students also often tend to confuse the acid-base models that are presented to them in general chemistry (Carr, 1984).

By the time university students get to organic chemistry, they are expected to have been introduced to three models describing acid-base chemistry: the Arrhenius model, the Bronsted-Lowry mode, and the Lewis model (Cooper et al., 2016). However, within the context of organic chemistry students faced difficulties applying concepts that they had previously learned in general chemistry. Cartrette and Mayo (2011) found that while students were able to define and give examples of Bronsted-Lowry acids and bases, they struggled to define Lewis acids and bases correctly. Additionally, students struggled to connect the concept of Lewis acids and bases to electrophiles and nucleophiles, which are central concepts in organic chemistry. Stoyanovich et al. (2015) identified several acid-base chemistry learning outcomes for students in first semester organic chemistry. These outcomes include understanding the three acid-base models, identifying the most acidic proton in an organic molecule, understanding equilibrium concepts, and properly using pKa. While many of these concepts are introduced in general chemistry, they are applied and expanded upon in organic chemistry.

Several instructional interventions have been employed to help improve student understanding of acid-base chemistry. Sisovic and Bojovic (2000) demonstrated that cooperative learning techniques can be employed to help students better understand acid-base chemistry. Demircioglu, Ayas, and Demircioglu (2005) developed a method for teaching acids and bases that was based on a conceptual conflict strategy in which students' preconceptions and possible misconceptions were determined and analyzed before any teaching plan was prepared. They found this strategy to be more successful than the traditional teaching approach for this topic, possibly due to the vast amount of misconceptions that students often harbor regarding acids and bases. Yaman and Ayas (2015) found that the use of concept maps helped students develop deeper understandings of acid-base chemistry. Guided simulations have also been shown to increase student engagement when learning about the chemistry of acids and bases (Chamberlain, Lancaster, Parson, & Perkins, 2014). In this study, I examined how flow experiences are connected to the learning of acid-base chemistry in a general chemistry course.

Summary

In this chapter I have reviewed relevant literature regarding flow experiences, the measurement of flow, the connection between academic performance and flow, and learning approaches. I have also reviewed literature pertaining to difficulties that students face when learning acid-base chemistry. With this study, I aimed to fill a gap in the literature by connecting students' potential flow experiences, as well as their learning approach, to their performance on an exam over acid-base chemistry. The next chapter will outline the methods that I employed for this study.

CHAPTER III

METHODOLOGY

Mixed Methods Design

This study followed an explanatory sequential mixed methods design under the paradigm of pragmatism. Under the pragmatism paradigm, the practices that work best to understand a particular problem are employed (Tashakkori & Teddlie, 2003). Due to the subjective nature of flow experiences, I contend that both quantitative data and qualitative findings are necessary in order to best understand the relationship between flow and performance in chemistry. For this study, following the explanatory sequential mixed methods design, quantitative data was collected and analyzed first, and then qualitative findings were collected in an attempt to explain the quantitative results. In the design for this study, a higher priority was placed on the quantitative piece (Creswell & Plano Clark, 2011).

Theoretical Framework

This study was conducted under the theoretical framework of flow theory. Under this theory, the flow experience is considered an optimal human experience, not just in academic settings, but in all aspects of life. The flow experience is characterized by a deep concentration on the present moment, a change in perception of time, increased intrinsic motivation, and a feeling of overall well-being (Csikszentmihalyi, 1990). However, in order to achieve this mental state, the skills of the person performing the task must match the difficulty of the task. In other words, skills and task difficulty must be in balance such that the task is neither too easy nor too difficult. It is for this reason that flow experiences can occur in a wide variety of settings such as athletics, music performance, theater, and business. For the purposes of this study, I examined experiences in academic educational environments through the lens of flow theory.

I also contend that the concept of flow experiences, especially in education, are closely related to Sternberg's triarchic theory of intelligence (1985). Under this theory, human intelligence is divided among three types of intellectual abilities: analytic, creative, and practical. Analytic abilities refer to those needed to evaluate, explain, compare, and contrast. Creative abilities refer to those involved in creating, designing, discovering, or inventing. Finally, practical abilities are those needed to apply problem solving processes to concrete and everyday problems (Howard, McGee, Shin, & Shia, 2001).

Sternberg, Torff and Grigorenko (1998) found that instruction designed to accommodate and teach to these three types of intelligence led to higher levels of learning and achievement. This is similar to Taber's (2015) findings that a flow-oriented classroom could lead to deeper and more meaningful learning. To achieve the proper skills-challenge balance necessary to enter a flow state, one must first develop the skills to properly address the problem, whether they be analytical, creative, or practical. As flow states are often associated with increased creativity (Csikszentmihalyi, 1990), instruction designed to foster flow states could also serve as a way to teach to the creative aspect of triarchic intelligence. While the aim of this study was not to examine instructional design, I feel that the findings of this study could possibly be used to influence future instructional design. In this regard, I feel that the intersection between the triarchic theory of intelligence and flow experiences must be cited and considered within the framework of this study.

Participants and Setting

The sample of this study consisted of students enrolled in second semester general chemistry courses during the Spring 2019 semester. These students were chosen because they have had, to some extent, similar previous experience. For example, all of them had to pass first semester general chemistry with a grade of "C" or better, or an equivalent course at another institution. In addition, the second semester course contains more complex types of problems as compared to the first semester course, and thus the former produces a wider variety of challenge levels for students.

This study took place at a mid-sized university in the Rocky Mountain region of the United States. Convenience sampling was utilized. An a priori power analysis was conducted using G*Power 3.1 (Faul, Erdfelder, Lang, & Buchner, 2007). For a multiple linear regression analysis with seven total predictors with a medium effect size f_2=0.15, α=0.05, and power=0.80, the minimum sample size needed was calculated to be 103 participants (Faul, Erdfelder, Buchner, & Lang, 2009). A total of 150 students participated in this study, however only 109 completed all of the surveys necessary to have their data included in the multiple linear regression model. Approval to conduct this study was received from the university's Institutional Review Board. All participants were 18 years old or older and gave consent to take part in this study.

Quantitative Methods for Question One and Question Two

Instrumentation

EduFlow scale. The Flow in Education (EduFlow) scale was employed to assess the flow experiences of the participants. This scale was chosen because it was designed to measure flow in educational settings (Heutte et al., 2016b). The EduFlow scale is a 12-item survey designed to measure four components of flow: cognitive control, immersion and time transformation, loss of self-consciousness, and autotelic experience. Each of these four components has three items associated with it. Items are each rated on a 7-point Likert-type scale ranging from 1 (no flow experiences) to 7 (deep flow experience). For each component, means were calculated, with the scores ranging from 1 to 7, thus the total possible flow scores range from 4 to 28.

The language of this EduFlow scale was originally developed in French, and the authors (Heutte et al., 2016b) provided an English translation of the instructions and items, and this translation was used in this study. I made some slight changes to some items on the questionnaire in an attempt to make it more relevant to the setting and improve internal consistency. Specifically, the item from the loss of self-consciousness subscale,

- “I did not care what others would think of me” was changed to “I did not notice the others around me”.

These changes was made because I felt the original was too similar to the item “I did not fear the judgment of others”. For the cognitive control subscale, the item,

- “I feel that what I do is under my control” was changed to “I felt that my success was under my control”

This modification was made so that the item would be more relevant to the exam setting. For the autotelic experience subscale, the item

- "When I talk about this activity, I feel a strong emotion and want to share it" was changed to "When I talk about this exam, I feel a strong positive emotion and want to share it".

Finally, for the immersion and time transformation subscale, the item

- "I did not notice the time passing" was changed to "I found myself losing track of time".

These changes were made based off on pilot study data and interviews with students who took the survey.

The version of the survey that I distributed to students can be found in Appendix B. In order to be consistent with the purpose of this study, which explores students' flow experiences during an in-class exam, I changed the prompt before the items from

- "During a learning activity…" to "Answer each of the following in regard to how you felt during this exam".

I added several lines on the survey so students can report their name and academic major.

Previous internal consistency studies on scores from the EduFlow scale, with a sample of students working on master's degrees in French (Heutte et al., 2016a), yielded Cronbach's alpha values of .75 for cognitive control, .86 for immersion and time transformation, .91 for loss of self-consciousness, and .85 for autotelic experience. Internal consistency tests were conducted for the data collected in this study, yielding Cronbach's alpha values of .81 for cognitive control, .73 for immersion, .72 for loss of self-consciousness, and .83 for autotelic experience. For the immersion subscale, the item “I did not notice the time passing” was removed due to its detrimental contribution to internal consistency. This item may have been detrimental to internal consistency because it did not have fit well within the context of the exam, as the exam was a 1-hour timed exam with time updates being written on the board at the front of the room by the instructor

Heutte et al. (2016b) conducted both principal component exploratory factor analysis with Oblimin rotation, as well as confirmatory factor analysis to provide validity evidence for the EduFlow Scale, finding that items loaded on factors in which they were expected. For this dissertation study, I used principal competent exploratory factory analysis with an Oblimin rotation in order to assess the internal structure of this instrument. The findings from this analysis showed that some of the items in the EduFlow loaded onto multiple factors, such as items from the autotelic experience subscale strongly correlating with items from the cognitive control subscale. This was not entirely surprising, as the components of flow are all related to one another and would all be experienced if a person was in a deep flow state. Additionally, some of the components of flow, such as immersion, are overlap with experiences of hyper-focus (Csikszentmihalyi, 2014). Because of these results from the exploratory factor analysis, I chose to sum all of the subscale scores from the EduFlow scale for a total EduFlow score, rather than examining the contribution of each component individually.

Toledo Chemistry Placement Exam (TCPE). At the beginning of each semester, the instructor for this second semester general chemistry course always administers the Toledo Chemistry Placement Exam (TCPE) to all students. In this study, it served to assess both students’ background knowledge in chemistry as well as the mathematics necessary to solve chemistry problems. The exam contains 60 multiple-choice questions; there are 15 math questions that cover math skills up to college algebra, and there are 45 chemistry questions. An example of a math question is "Evaluate the following expression: $7.0 \times 10^4 + 6.0 \times 10^3$". One of the chemistry questions is "What volume of 12.0 M HCl solution is needed to provide 0.6 mol of HCl". The American Chemical Society Division of Chemical Education (2009) collects national data on the TCPE for undergraduate chemistry students, reporting a KR-21 reliability of 0.77.

Approaches and Study Skills Inventory for Students (ASSIST). The ASSIST questionnaire was given to students in this study during the first week of the semester. It assesses the extent to which students utilize three learning approaches: the deep approach, the surface apathetic approach, and the strategic approach. Each approach contains four subscales. Deep approach contains subscales of seeking meaning, relating ideas, use of evidence, and interest in ideas. Surface apathetic approach was condensed to surface approach, and it contains subscales of lack of understanding, lack of purpose, syllabus-boundness, and fear of failure. The strategic approach contains subscales of organized studying, time management, monitoring effectiveness, and achievement motivation. The instrument contains 52 items, and students respond to items on a scale of 1-5, with 5 being a high, strongly agree response. Each subscale contains four items, with scores from the items being summed to form the subscale score. Subscales scores under each of the three main learning approaches were summed to create scores for each learning approach (Entwistle, 1997).

Evidence for validity of the ASSIST questionnaire has previously been established. Entwistle (1997) analyzed the instrument upon its development, sampling

817 first-year university students from six British universities, finding that the factor structure fit with the proposed theorized factor structure. Reliability tests were also conducted, with Cronbach's alpha values of .84 for deep approach, .80 for strategic approach, and .87 for surface approach being reported. Byrne, Flood, and Willis (2004) also studied the psychometric properties of the ASSIST instrument, sampling 298 full-time students at a private university on the east coast of the United States, and reporting Cronbach's alpha values of 0.82 for deep approach, 0.87 for strategic approach, and 0.80 for surface approach. Internal consistency tests were conducted based on the data collected for this study, yielding Cronbach's alpha values of .82 for the deep approach subscale, .85 for the surface approach subscale, and .85 for the strategic approach subscale.

Assessment and Learning in Knowledge Spaces (ALEKS). The Assessment and Learning in Knowledge Spaces (ALEKS) homework system was a required as part of the grade for all students who take this course. This system gives diagnostic feedback to students as they progress through the topics relevant to the syllabus in this course. It also uses periodic assessments to determine what students know within a specific domain of general chemistry skills and concepts. Students can move on to more advanced topics once they have achieved mastery in one domain (Eichler & Peeples, 2013). For this study, each student's score from ALEKS was examined to assess their level of preparation.

Achievement performance on the acids-bases exam. Student performance on the instructor-written hour examination over acid and base chemistry served as the dependent variable for this study. This exam was the third one given during the semester.

It consisted of 12 multiple-choice questions (6 points each) and six short-answer questions (30 points), which total 100 points. Topics for this exam included those such as pH, acid and base dissociation constants, and acid and base strengths. A copy of this exam can be found in Appendix D. I chose this exam because the topic of acid-base chemistry contains a wide variety of questions and problems that produce a relatively wide range of challenges for the students.

Data Collection Procedure

The ASSIST questionnaire was given to the student participants during the first week of the semester in this second-semester general chemistry course. At the beginning of the semester, TCPE pretest scores, which gauge students' prior knowledge, was administered and collected by the instructor. The EduFlow survey was administered to students during the acid-base examination (as described above). Participants completed the survey immediately after finishing the exam The ALEKS online homework program was part of the regular instruction in the course, and all students were required to participate in it. The exam used to gauge achievement performance (see above) was given after the chapter (topics) on acid-base chemistry were covered in lecture. The course instructor provided me with the exam scores, TCPE pretest scores, and ALEKS online homework scores for the participants in this study.

Data Analysis

Multiple linear regression was used as the statistical method to answer Research Questions 1 and 2. In this regression model, scores on the acids-base exam were used to measure performance in chemistry, which served as the outcome variable (i.e., the dependent variable). The predictor variables included the EduFlow subscales of cognitive control, immersion and time transformation, loss of self-consciousness, and autotelic experience, as well as the ASSIST subscales on deep, surface, and strategic learning approach. Additional predictors include scores from the TCPE pretest, and scores from ALEKS online homework. Overall, this model was designed to use a total of nine predictors. The significance and contribution to the model by each predictor variable will allow me to examine the relationship between the flow subscale scores (EduFlow) and exam performance (research Q1). In addition, correlations between flow variables and learning approach variables allowed me to examine the relationships between them (Q2). The assumptions for multiple linear regression were checked, including linear relationships between dependent and independent variables, normal distribution of regression residuals, no multi-collinearity, and homoscedasticity. The analysis was be conducted using SPSS Version 24 statistical package.

Qualitative Methodology for Question Three

Phenomenology

The qualitative portion of this study followed the qualitative methodological framework of phenomenology (Q3). Merriam (2009) defines phenomenology as the "study of people's conscious experience of their life-world" (p. 25). The aim of phenomenological research is to depict the essence of participants when they experience a certain phenomenon. For this study, the phenomenon of interest was flow state experiences. My goal for using this qualitative research was to gain an understanding of the subjective flow state experiences that students may experience when they take the acid-base chemistry exam.

Participants

Purposeful sampling (Merriam, 2009) was employed to select 10 volunteers from the larger quantitative sample of participants. They were chosen based on their scores on the acid-base exam, EduFlow scale scores, ASSIST scores, and academic major, in an attempt to achieve maximum variation by choosing a diverse variety of students. Pseudonyms were employed to protect the identity of the volunteers.

Data Collection Procedure

A semi-structured interview was conducted with each volunteer after they have taken the acid-base exam. The interviews lasted approximately 30 minutes each. Volunteers were asked about their experiences while they were preparing for the exam, and their experiences taking the exam. They were also asked about their responses on the EduFlow survey. In addition, they were be asked to explain their thought processes for solving certain exam problems using a think aloud protocol (Jääskeläinen, 2010). Finally, towards the end of the interviews, the concept of flow was explained to each volunteer. Specifically, they were asked to describe whether they faced anxiety and frustration, flow, or boredom during this exam. A list of interview questions can be found in Appendix C.

Qualitative Data Analysis

The data was coded and stored separate from the personal information of the volunteers. Recorded interviews were transcribed and coded. Original recordings were stored on a password protected flash drive that was stored in a locked drawer in a locked research office.

The data was analyzed qualitatively, using *thematic analysis* (Merriam, 2009). Major themes were identified, allowing us to compare and contrast experiences of the participants of this study. Conclusions were drawn regarding how the themes identified from the data are related to the possible flow state experiences of each student.

Summary

In this chapter, I outlined the methods that I employed to answer my research questions. The research questions were answered using a mixed methods approach. A quantitative design was used to examine the relationships between flow, learning approach, and academic performance in chemistry (Q1 & Q2). Semi-structured interviews were employed to further investigate students' perceptions and subjective experiences (Q3).

CHAPTER IV

FLOW STATE EXPERIENCES IN GENERAL CHEMISTRY

Contributions of Authors and Co-Authors

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Contributions: Helped conceive study topic, helped develop and implement study design, collected and analyze data, wrote first draft of manuscript

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Contributions: Helped conceive and implement study design, helped collect data, provided feedback on data analyses and early drafts of manuscripts.

Introduction

Flow is the mental state in which a person performing an activity is fully immersed in the activity. It is categorized by a focused concentration on the present moment, a merging of action and awareness, loss of self-consciousness, sense of control over the situation, distortion of perception of time, and intrinsic rewards from the experience (Csikszentmihalyi, 1990). Previous research in this area has shown that flow experiences are positively correlated to increased positive affect and motivation (Rogatko, 2009; Vollmeyer & Rheinberg, 2006).

Flow experiences have been shown to be particularly useful for students learning difficult content areas such as foreign language, statistics, and mathematics (Engeser & Rheinberg, 2008; Schiefele & Csikszentmihalyi, 1995). One such difficult subject is chemistry, which can be difficult to both teach and learn (Pienta et al., 2005). Though there have been many studies aiming to uncover the best practices for teaching and learning chemistry, there is a gap in the literature when it comes to examining chemistry education from the perspective of these flow experiences. Understanding the flow experiences of chemistry students could help educators improve their teaching by possibly employing educational strategies that may induce these flow states.

What is Flow?

The concept of flow comes from the area of psychology known as positive psychology, which is "A science of positive subjective experience, positive individual traits, and positive institutions promises to improve quality of life and prevent the pathologies that arise when life is barren and meaningless," (Seligman & Csikszentmihalyi, 2014, p. 279). The flow state, also described as being "in the zone," is considered to be an optimal human experience. This experience can be characterized by a merging of action and awareness, immersion in the activity, loss of self-consciousness, and a feeling of control over the situation. Another indicator of flow is a positive feeling of overall well-being when doing the activity (Csikszentmihalyi, 1975). This flow experience can occur when a person performing an activity is being perfectly challenged in conjunction with their skill level. If the person's skills are too far below the level of challenge, the person may experience anxiety or frustration, but, on the other hand, if the task is too easy, the person may experience boredom. (Csikszentmihalyi, 1990).

Flow and Education

Though much of the research about flow state experience has examined flow experiences in sports and leisure activities, there have been studies that aim to assess flow in an educational setting. One educational domain where flow has been extensively studied is music education. Custodero (2002) noted the importance of the skills-challenge balance in music education. MacDonald et al. (2006) assessed flow experiences of first year college students during music composition, finding that students who experienced higher levels of flow composed more creativity musical pieces. Bernard (2009) found that as music teachers better understand their own flow experiences, they can employ teaching techniques to encourage flow experiences in their students.

In high school classrooms, flow experiences have been connected to deeper student engagement. Shernoff et al. (2014), found that student disengagement in classroom activities may stem from a lack of challenge or meaning. The importance of the challenge-skills challenge is critical; the researchers found that students who were properly challenged were more engaged, more motivated, and more likely to find enjoyment in the learning experiences.

Flow and Performance

Though flow has been positively correlated to performance in a variety of domains such as academics, music, and athletics, it is unclear whether flow leads to higher levels of performance, or if good performance makes flow experiences more likely (Landhäußer & Keller, 2012). Flow experiences are closely related to intrinsic motivation, and higher levels of intrinsic motivation have been shown to be connected to higher levels of student learning (Pintrich & de Groot, 1990). Ferrell et al. (2016) were able to apply the connections between motivation and learning to general chemistry students, finding a link between students' motivation levels and their performance in a general chemistry course.

That being said, there have been studies conducted that connect flow experiences to academic performance. Engeser and Rheinberg (2008) examined the relationship between flow experiences and final grades in a French language course and a statistics course, finding that flow had a small but significant effect on final grades when previous knowledge was controlled for. Schüler (2007) examined students in an introductory psychology course and found flow to be a significant predictor of exam performance in undergraduate university students.

Rationale and Purpose of the Study

There is still much work to be done to understand the connection between flow experiences and academic performance. Flow may be more difficult to assess and characterize in some academic settings because they often lack the immediate feedback that is received in sporting or musical settings (Moneta, 2012). A relationship between academic performance in chemistry and flow has yet to be established, necessitating further investigation. Establishing a connection between flow experiences and performance in chemistry could give chemistry instructors justification to employ strategies designed encourage students to enter this optimal state of flow, with the hopes of facilitating deeper learning and higher levels of motivation. The purpose of this study was to both establish this connection and assess the effectiveness of using the EduFlow scale to measure flow experiences in a chemistry setting.

Methods

Mixed Methods Design

This study follows an explanatory sequential mixed methods design under the paradigm of pragmatism, where practices that work best to understand a particular problem are employed (Tashakkori & Teddlie, 2003). Flow state experiences can be subjective; therefore, we contend that both quantitative and qualitative methods are necessary to best understand the relationship between flow and performance in chemistry. This study follows an explanatory sequential mixed methods design where quantitative data was collected and analyzed first, and then qualitative data was collected to help explain the quantitative findings. (Creswell & Plano Clark, 2011).

Quantitative Methods

Participants. The target population of this study was student's enrolled in second semester general chemistry courses. We chose to examine general chemistry II students because they have, to some extent, similar previous experience, as all of these students had to pass general chemistry I or an equivalent class as a prerequisite to general chemistry II. Additionally, general chemistry II contains more complex types of problems than general chemistry I, which produces a more diverse variety of challenge levels for students.

This study took place at a mid-sized university in the Rocky Mountain region of the United States. Convenience sampling was utilized. The sample consisted of 157 general chemistry II students from two different sections, both taught by the same instructor. An a priori power analysis was conducted using G*Power 3.1. For a hierarchical multiple linear regression analysis with four tested predictors and 8 total predictors with a medium effect size f_2=0.15, α=0.05, and power=0.95, the necessary sample size was calculated to be 129 (Faul et al., 2009). Out of 196 total students in these two classes, 157 took part in this study, giving a response rate of 80.1%. The general chemistry II course was lecture-based, with four 1-hour meetings per week. All participants are 18 or older and have given consent to take part in this study.

Demographic information was collected for the participants. The sample consists of 31 students who are chemistry majors (19.7%), and 125 who reported a major other than chemistry (79.6%), with one participant not reporting a major. Students from a variety of majors, including biology and pre-health majors are required to take general chemistry II, so the small proportion of chemistry majors in the sample was not uncharacteristic of a typical general chemistry II course. This sample consisted of 45 male students (28.7%) and 110 female students (70.1%), with two participants not reporting their gender. While the distribution of this sample was female by a wide majority, the university at which this study was conducted has an undergraduate student population that was 35% male and 65% female. The chemistry program at this university was accredited by the American Chemical Society, so the curriculum was similar to other universities nationwide with the same accreditation.

Instrumentation

EduFlow scale. The Flow in Education (EduFlow) scale was employed to assess the flow experiences of the participants (Heutte et al., 2016b). The EduFlow scale is a 12-item survey designed to measure flow within educational contexts. The questionnaire measures four components of flow: cognitive control, immersion and time transformation, loss of self-consciousness, and autotelic experience. Each of these four components has three items associated with it. Items are each rated on a 7-point Likert-type scale ranging from 1 (no flow experiences) to 7 (deep flow experience). For each component, means were taken, with the scores ranging from 1 to 7, with the total possible flow score ranging from 4 to 28.

Though this scale was originally developed in French, the authors (Heutte et al., 2016b) provided an English translation of the instructions and items; we utilized the English version for this study. The version of the survey that I distributed to students can be found in the Appendix section of this paper. Because for this study I aimed to study flow experiences during an in-class exam, I changed the prompt before the items from "During a learning activity…" to "During this exam…". In addition, we included a line on the survey for students to report their major; this was done to examine whether a student's major (chemistry or non-chemistry) serves as a moderator variable when assessing the relationship between flow and performance in chemistry. Previous internal consistency studies on scores from the EduFlow scale, with a sample of students working on master's degrees in French, yielded Cronbach's alpha values of .75 for cognitive control, .86 for immersion and time transformation, .91 for loss of self-consciousness, and .85 for autotelic experience (Heutte et al., 2016a). Internal consistency examinations of scores from the EduFlow scale for this study yielded Cronbach's alpha values of .68 for cognitive control, .60 for immersion and time transformation, .84 for loss of self-consciousness, and .64 for autotelic experience. For the cognitive control subscale, the item "I feel what I do is under my control" was removed, yielding a Cronbach's alpha of .72. For the immersion and time transformation subscale, the item "I don't notice the time passing" was removed, yielding a Cronbach's alpha of .76. Finally, for the autotelic experience subscale, the item "When I talk about this activity, I feel a strong emotion and want to share it" was removed to yield a Cronbach's alpha of .72. The version of this instrument that participants in this study completed can be found in Appendix A of this paper.

Heutte et al. (2016b) conducted both principal component exploratory factor analysis with Oblimin rotation, as well as confirmatory factor analysis to provide validity evidence for the EduFlow Scale, finding that items loaded on factors in which they were expected. For this study, principal competent exploratory factory analysis with Oblimin rotation and a salient loading cutoff at .4 was conducted to assess the internal structure of this instrument. For the initial exploratory factor analysis with eigenvalues greater than 1, the results of the analysis showed three factors. Because this scale was designed to have four factors, we conducted a second exploratory factor analysis, this time forcing four factors. After this, each item loaded as expected, as summarized in Table 4.1.

Table 4.1

Exploratory Factor Analysis Pattern Matrix

	Component			
	Loss of Self-Consciousness	Autotelic Experience	Immersion/Time Transformation	Cognitive Control
I was not worrying about what the others think about me	.925			
I did not care what others could think of me	.900			
I don't feel the judgement of others	.768			
I have the feeling of living a moment of excitement		.938		
This activity makes me happy		.733		
I am totally absorbed in what I'm doing			-.866	
I am deeply concentrated in what I am doing			-.850	
I feel I am able to meet the high demands of the situation				-.811
I know what I have to do at every step of the task				-.754

Demographic characteristics. Demographic questions were included with the EduFlow scale. Participants were asked to provide their gender as well as their major.

Toledo Chemistry Placement Exam (TCPE). The instructor of the general chemistry II course from which the sample was being drawn for this study administers the Toledo Chemistry Placement Exam (TCPE) to all students at the beginning of each semester. This exam was designed to assess prior knowledge in chemistry and mathematics. The exam contains 60 multiple choice questions; there are 20 math questions that cover math skills up to college algebra, and there are 40 chemistry questions. An example of a math question is “Evaluate the following expression: 7.0 x 10^4 + 6.0 x 10^3”, and an example chemistry question is “What volume of 12.0 M HCl solution is needed to provide 0.6 mol of HCl”. The American Chemical Society Division of Chemical Education (2009) collects national data on the TCPE for undergraduate chemistry students, reporting a KR-21 reliability of .77.

Assessment and Learning in Knowledge Spaces (ALEKS). The Assessment and Learning in Knowledge Spaces (ALEKS) system was a required as part of the grade for all students in the class. This system used periodic assessments to determine what students know within a specific domain of general chemistry skills and concepts. Once students achieved mastery in one domain, they could move on to more advanced topics (Eichler & Peeples, 2013). For this study, each student’s score from ALEKS was examined to assess their level of preparation. At the time of this study, students had completed 12 topics within the system, giving a possible range of scores of 0.0 to 12.0.

Performance on acids-bases exam. Scores from the third exam of the semester served as the dependent variable for this study. The topic of the exam was acid/base chemistry, and it was a 100-point exam which consisted of 12 multiple choice questions and five short answer questions. There were also two bonus questions worth a total of five points, giving a possible range of scores from 0 to 105. Questions from this exam included “Calculate the acid dissociation constant of 1.0 M acetic acid,” and “Rank the following acids from strongest to weakest”. This exam was chosen because the topic of acid base chemistry contains a wide variety of questions and problems that produce a range of challenges for the students.

Data Collection Procedure

The EduFlow survey was administered to students during one of their examination times. Participants completed the survey immediately after finishing the exam. TCPE scores were collected by the instructor at the beginning of the semester. The online homework/study software that students are required to use for this general chemistry II course collects data on how much time each student spends working practice problems. The course instructor will provide me with the exams scores, TCPE scores, and online homework times for the participants in this study.

Data Analysis

Hierarchical multiple regression analysis was utilized to examine the relationship between flow experiences, operationally defined as the scores from the EduFlow survey, and performance in chemistry, operationally defined as exam score. Tests were conducted to ensure that the assumptions of a hierarchical multiple regression were met. These assumptions include a linear relationship between independent and dependent variables, a normal distribution of residuals, no multicollinearity in the data, and homoscedasticity.

The initial model contained three extraneous variables: prior chemistry knowledge, operationally defined as the chemistry sub-score from the TCPE, prior math knowledge, operationally defined as the math sub-score the TCPE, and preparation level, operationally defined as each student's score from the ALEKS online homework. Students' major (chemistry or non-chemistry major) was also included in the initial model as a moderator variable, giving the initial model four predictor variables total. The final model incorporates the four subscale scores from the EduFlow scale. The analysis was done using SPSS version 24. Significance was tested at α=.05.

Qualitative Methodology

Phenomenology. The qualitative portion of this study followed the qualitative methodological framework of phenomenology, which is defined as the "study of people's conscious experience of their life-world" (Merriam, 2009, p. 25). For this study, the phenomenon of interest was flow state experiences. Our goal with this qualitative research was to gain an understanding of the subjective flow state experiences that students may have had during their chemistry exam.

Participants. Purposeful sampling was employed to select 10 participants from the quantitative sample. Participants were chosen based off of their Exam 3 scores, EduFlow scale scores, major, and gender in an attempt to achieve maximum variation (Merriam, 2009). Pseudonyms were employed to protect the identity of the participants. The characteristics of each participant, as well as their exam scores and EduFlow subscale scores are summarized in Table 4.2.

Table 4.2

Interview Participant Characteristics

Participant	Gender	Major	Exam Score	Cognitive Control	Immersion/Time Transformation	Loss of Self-Consciousness	Autotelic experience
Amy	F	Chemistry	79	6.5	7	7	7
Bart	M	Biology – Pre Med	75	4	5.5	7	1
Charlotte	F	Chemistry	69.5	5	6	7	7
Dan	M	Sports & Exercise Science	78	4	3.5	7	3
Jane	F	Biology – Pre Med	81	5.5	7	7	1.5
Karen	F	Chemistry	100	6.5	7	7	6
Mabel	F	Biology – Pre Med	72	4	6.5	6	1.5
Rose	F	Biology	69	5	5	5.7	5
Tessie	F	Biology – Pre Health	81	5	5.5	7	3.5
Susan	F	Chemistry	105	5.5	6	6.7	2.5

Data collection procedure. A 15-minute semi-structured interview was conducted with each participant. All interviews took place within a two-week period following Exam 3. Participants were asked about their experiences preparing for the exam and their experiences taking the exam; they were also asked about their responses on the EduFlow survey. Additionally, towards the end of the interviews, the concept of flow was explained to each participant, and they were asked to describe whether they faced anxiety and frustration, flow, or boredom during the exam. A list of possible interview questions can be found in Appendix C.

Qualitative data analysis. The data was coded and stored separate from the personal information of the participants. All recorded interviews were transcribed and coded by the first author. Original recordings were stored on a password protected flash drive that was stored in a locked drawer in a looked research office.

The data was analyzed qualitatively, using thematic analysis (Merriam, 2009). Major themes were identified, which allowed us to compare and contrast experiences of the participants of this study. Conclusions were drawn regarding how the themes identified from the data are related to the possible flow state experiences of each student.

Results and Discussion

Quantitative Results

Descriptive statistics were calculated for each subscale of the EduFlow scale, as well as TCPE math and chemistry scores, scores from ALEKS, and Exam 3 scores. These results are summarized in Table 4.3.

Table 4.3

Descriptive Statistics of Variables in Regression Models

	Mean	Std. Dev.	Skewness	Kurtosis	Range
Cognitive Control	4.38	1.28	-.451	-.008	6.00
Immersion/Time Transformation	5.62	1.22	-1.145	1.350	6.00
Loss of Self-Consciousness	5.86	1.33	-1.320	1.519	6.00
Autotelic Experience	3.66	1.71	.076	-1.004	6.00
TPCE Math	15.95	2.29	-1.213	2.408	6.00
TPCE Chem	23.79	4.68	-.030	-.495	24.0
ALEKS score	9.94	2.66	-1.565	1.839	12.0
Exam 3 score	73.27	17.94	-.551	-.357	78.0

From the EduFlow scale, the “Immersion/Time Transformation” and “Loss of Self-Consciousness” subscales exhibit the most skewness, skewing towards higher responses. A possible reason that the "Immersion/Time Transformation" subscale skewed towards the higher responses could be that focused attention can not only be associated with flow, but also when a person is facing a threat; the general anxiety and stress associated with taking an exam may be the cause of this deep immersion (Moneta, 2012). For the "Loss of Self-Consciousness" subscale, a possible reason for the high skewness could be a social desirability bias, as items from this subscale include "I did not care what others think of me" and "I was not worrying what others think of me". Another possible reason for the skewness in this subscale could be due to the nature of the exam itself; because it was an individual and solitary activity, participants may not experience self-consciousness regardless of their level of flow experience.

To assess the relationship between flow and exam scores, a hierarchical linear multiple was conducted to measure the contribution of the EduFlow scores to the model. A comparison of the two models from this analysis is shown below in Table 4.4.

Table 4.4

Hierarchical Multiple Linear Regression: Model Comparison

Model	R	R_2	R_2 Change	F Change	df1	df2	Sig. F Change
1	.573	.328	.328	17.485	4	143	.000
2	.647	.418	.090	5.354	4	139	.000

Model 1 does not include the subscale scores from the EduFlow scale, taking into account only the TCPE math and chemistry scores, ALEKS scores, and major, while Model 2 does include them. When the EduFlow subscale scores are included, we see R_2 increase by .090; these variables account for an additional 9.0% of the variance in the scores from Exam 3. This change in R^2 from Model 1 to Model 2 is statistically significant (F=5.364, p<.001). The effect size, Cohen's f^2, for this change was calculated according to guidelines provided by Selya, Rose, Dierker, Hedeker, and Mermelstein (2012) to be f^2=.155, which is a medium effect size. The contribution of each individual variable to each model is summarized below in Table 4.5.

Table 4.5

Variables in Hierarchical Multiple Linear Regression

Model	Variable	B	Std. Error	t	Sig.
1	(Constant)	-5.375	11.587	-.464	.643
	ALEKS_grade**	2.773	.469	5.908	.000
	TPCE Math**	1.644	.608	2.705	.008
	TPCE Chem*	.738	.297	2.484	.014
	Major (Chem or other)	4.033	3.094	1.303	.194
2	(Constant)	-19.766	13.384	-1.477	.142
	ALEKS_grade**	2.412	.467	5.164	.000
	TPCE Math*	1.244	.592	2.101	.037
	TPCE Chem**	.948	.286	3.313	.001
	Major (Chem or other)	5.039	3.066	1.643	.103
	Cognitive Control**	3.968	1.204	3.295	.001
	Immersion/Time Transformation	1.127	1.104	1.021	.309
	Loss of self-consciousness	-1.201	1.021	-1.176	.241
	Autotelic Experience	.243	.817	.298	.766

*p<.05, **p<.01

Not surprisingly, the scores from both the math and chemistry portions of the TCPE as well as the scores from the ALEKS online homework were significant predictors in both models, indicating that student who had more prior knowledge coming into the class and students who had higher levels of preparedness throughout the semester were more likely to score high on the exam. When examining Model 2, the only component of flow that was found to be a statistically significant predictor in this model was Cognitive Control, which was the measure designed to assess the extent to which student feel they are able to meet the demands of the situation (Heutte et al., 2016b). This ability to meet the demands of the situation was consistent with balance of challenge and skills that is necessary for one to enter a flow state (Csikszentmihalyi, 1975).

Interestingly, the “Loss of Self-Consciousness” subscale contributes negatively to the model, but again this may be due to the high level of skewness in this subscale. The “Immersion/Time Transformation” and “Autotelic Experience” subscale are not statistically significant in the model but may hold some practical significance. As discussed earlier, deep levels of immersion can be associated with both flow states and anxiety, and future work may be necessary to differentiate the reason for the immersion. The results from the “Autotelic Experience” subscale were interesting, as scores from this subscale were the lowest of the four subscales, had the highest amount of variance, and had the least contribution to the regression model. This may suggest that positive experiences in chemistry, and the intrinsic motivation that comes with it, are not related to performance in chemistry. This contradicts past literature which does demonstrate a connection between intrinsic motivation and academic performance (Ferrell, et al., 2016; Pintrich & de Groot, 1990). This contradiction could also mean that there may be an issue with how the EduFlow scale measures autotelic experiences in an exam setting. These subscales and contradictions were further investigated in the qualitative portion of this study.

Qualitative Results

Challenge-skills balance. The proper balance between the skills of a person performing a task and the difficulty of the task may be the most fundamental requirement for a person to experience flow (Csikszentmihalyi, 1975). Because of this, we asked students what strategies they used to prepare for the exam in hopes of gaining a better understanding of how students hone their chemistry skills. The most common responses included doing practice exam given out by the instructor and the ALEKS online homework. Some students noted that they watched online videos for extra help, and others read the textbook.

When we asked students about how difficult they perceived the exam to be, we again received a wide variety of answers. Some of the students found the exam to be especially difficult, while some commented that they found it to be easier than other exams they have taken in that same class. Both Amy and Dan noted that this was their best exam of the semester. Amy explained it was due to her interest in the topic, while Dan discussed that he started studying with other students in the class, which he found to be helpful.

Immersion and time transformation. With the exam only lasting 1 hour, time was certainly a concern for some students. Rose mentioned that the time always worries her when taking chemistry exams. Charlotte mentioned having similar experiences, explaining:

> I'm always worried about the time. Fifty minutes is very hard to get through a whole test, but I used to like, from high school, an hour and thirty minutes for a

> test. But even then I was nervous, but all the time I'm looking at the clock, I get nervous, I look around a lot.

Other students described different ways in which they judge the amount of time that has passed. Dan mentioned that he becomes aware of time passing when other students get up to turn in their tests. Tessie discussed that she had a rough idea of how long it would take her to do each problem, explaining:

> I think I have a pretty decent sense of how long it takes me to do big problems. So usually I'll have a sense of, "Ok like the multiple choice might take me like 20-30 minutes, and then the rest will take me 20-30 minutes." So I feel like I'm not like constantly looking at the time, but I have a good sense of you know, once I do a multiple choice that was about a like a minute.

Bart discussed that his perception of time was related to how prepared he was for the exam. He mentioned that if he knows what he is doing as he is working through problems, then he loses track of time, but if he is struggling, then he is more aware of the time. This suggests that for him, immersion and time transformation may be due to flow experiences, where his skill level matches the task difficulty, rather than anxiety induced focus.

The students interviewed that performed especially well on the exam did indicate that they lost track of time during the exam, suggesting that they were likely having a flow state experience. Susan mentioned that she not only lost track of time as she performed calculations, but also that she did not notice anything else around her. Karen echoed this, explaining:

> Yeah that's pretty common for me like in any class when I'm taking exams. Or even just doing homework, like online homework, I'll just be doing it and all of a sudden it's like two hours have passed. Yeah, just always seems to go so fast and that's kind of how I always know that I was really like "into it" I guess. Because like, I don't even notice the time passing.

Loss of self-consciousness. In attempt to explain why scores from the "Loss of Self-Consciousness" dimension of the EduFlow scale skewed towards higher responses, we asked students to explain some of their responses to items within this subscale. Going into the interviews, we speculated that this skewness could possibly be related to the fact that an exam was a solitary activity. We also wondered if the responses were skewed due to a social desirability bias, as it may be socially desirable to not care what others think. The results from the interviews indicated that both of these hypotheses had some validity. Mabel noted that since other students in the class are not aware of what answers she gives on the exam, she did not feel self-conscious. Amy provided a similar response:

> To begin with, I don't think there's anyone that doesn't completely care about what other think of them. But especially when you're taking a test, you know that everyone is doing the exact same thing as you pretty much. And you can also know that the score you are about to get is going to rely solely on you, and you don't really have to take into account what other people are doing.

Dan mentioned that he did not care what others thought of him because of his personality, stating that he generally did not care how what others thought of him in school or in life. Jane, a nontraditional student, explained that she did not feel self-conscious due to her age. She explained:

> I think it's an age thing (laughs). You know, you get to a point where it really doesn't matter what somebody else thinks. I am never going to see these people again, and I'm going to do what I do. And sometimes I will look like an idiot, and it doesn't matter (laughs).

While some of the high responses to the "Loss of self-consciousness" items may be due to flow state experiences, it appears that there are also other reasons for these responses. However, it is unclear what items should be changed, as the items from this subscale demonstrated the highest internal consistency out of all of the subscales. Perhaps an item such as "I did not notice the others around me," could replace the item "I did not care what others could think of me," in order to diminish some of the social desirability bias.

Autotelic experience. Participants gave a wide variety of responses when asked to explain their responses to items from the autotelic experience subscale of the EduFlow Scale. Amy commented that she found the topic of acids and bases to be especially interesting. Shen noted that even when she made mistakes, she still enjoyed trying. Karen indicated a 7 on each of the three autotelic experience items. When asked if she enjoys taking chemistry exams, she explained:

> Yeah it makes me really happy when I work through a whole problem and get an answer and I look at the multiple-choice options and I can tell, like this is the answer I got, so I know that I got it right. And I just like to talk about it, even after, like with my friends and other classmates in chemistry and just talk about the test and go over it, how everybody did.

Charlotte commented that the difficulty of the exam took away from having a positive experience while taking it. Still, she noted that she enjoyed chemistry and would not rather be doing anything else. Though she did not mention the difficulty of the exam, Tessie also mentioned that she did not feel an overwhelming excitement or joy taking the exam. However, she did note that she tried to keep a positive mindset as much as possible during the exam.

The EduFlow scale item “When I talk about this activity, I feel a strong emotion and want to share it,” was removed from the quantitative analysis in order to improve internal consistency. Through the qualitative portion of this study, we attempted to gain a better understanding of what emotions students were feeling and why responses to this item showed low consistency. Rose, who was retaking the class, explained that she felt a feeling of relief was the exam was over, saying that she was less stressed until the next exam came up. Bart indicated that he felt a feeling of hope when he finished the exam; he felt that the exam was not as difficult as he expected and hopeful that he would receive a grade that would satisfy him. Mabel noted that she felt upset after the exam and said that when other classmates asked her how she did on the exam, she responded negatively. Due to this range of explanations it seems as though the way this item is worded does not fully contribute to the measurement of the autotelic experience component of flow. A more effective wording might be, “When I talk about this experience, I feel a strong *positive* emotion and want to share it.”

Limitations

Reliability and validity analyses could not be conducted for the TPCE scores, ALEKS online homework scores, and Exam 3 scores due to a lack of data. Only the scores for each student for each of these assessments was provided; item-by-item data was not provided.

There may be some limitations of using the EduFlow scale to assess flow experiences while taking an exam. The items meant to assess loss of self-consciousness may need to be adjusted to measure that subscale of flow within this setting. For the other three subscales in the EduFlow scale, Cognitive Control, Immersion/Time Transformation, and Autotelic Experience, one item had to be deleted from each of subscale in order to improve internal consistency to yield a Cronbach's alpha greater than .70. While the qualitative portion of this study did provide us with some ideas as to how the wording on some items of the English version of the EduFlow scale could be improved, further investigation may be necessary to examine the effectiveness of these improvements.

Conclusions

Despite some of the flaws previously discussed regarding the use of the EduFlow scale in this setting, these flaws could be remedied with adjustments to some of the items with hopes of improving the reliability and variance within each of the subscales. The significance of the Cognitive Control subscale in the regression model demonstrates its connection to performance in chemistry.

Results from the qualitative portion of this study suggest that students may go in and out of flow experiences over the course of an exam. A student may find a certain problem to be too difficult, resulting in anxiety or frustration, but that same student may encounter a different problem that is properly challenging in relation to his or her skill level, resulting in a flow experience. Study strategies that students utilize may also be related to their flow experiences; further investigation may be needed to assess which study strategies lead to deeper flow experiences. It is possible and even likely that students may have flow experiences while studying, which could lead to increased motivation, deeper learning, and better performance on exams.

The results from this study indicate that flow experiences of students during an exam are indeed related to their performance on the exam. Highlighting the importance of the skill-challenge balance, these results provide evidence for the utility of the flow experiences in chemistry. Based on these findings, we contend that chemical educators should consider the possibility of flow experiences when designing curriculum and learning activities.

CHAPTER V

FLOW STATE EXPERIENCES AND PERFORMANCE IN GENERAL CHEMISTRY

Contributions of Authors and Co-Authors

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Contributions: Helped conceive study topic, helped develop and implement study design, collected and analyze data, wrote first draft of manuscript

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Contributions: Helped conceive and implement study design, helped collect data, provided feedback on data analyses and early drafts of manuscripts, edited and formatted final draft of manuscript

Introduction

Students learn chemistry best when the content is meaningful to them (Bretz, 2008; Bretz, Fay, Bruck, & Towns, 2013; Ebenezer, 1992). When students experience a lack of meaning then tend disengage in classroom (Shernoff et al., 2014; van Tilburg & Igou, 2012). Conversely, when they can connect the content to societal issues and use modern instruments can chemistry can become meaningful to them (Galloway & Bretz, 2015). Also, it is possible that students can find meaning by overcoming their difficulties associated with learning chemistry and thus can succeed in chemistry classes. In other words, meaning may come from conquering challenges.

Acid-base chemistry is a general chemistry topic that many students struggle to understand (Calatayud et al., 2007; Cooper et al., 2016). This can be a problem, as the concepts taught in the general chemistry acid-base unit appear throughout other chemistry and physical science courses (Brown et al., 2018; Cartrette, & Mayo, 2011; Stoyanovich et al., 2015; Winberg & Hedman, 2008). Students especially struggle with the submicroscopic acid-base concepts (Calatayud et al., 2007; Hoe & Subramaniam, 2016). Instructional interventions such as cooperative learning, concept maps, and guided simulations have been employed to help students gain a deeper understanding of the important acid-base concepts (Chamberlain et al., 2014; Sisovic & Bojovic, 2000; Winberg & Hedman, 2008; Yaman & Ayas, 2015). However, there is still much work to be done to improve the way in which students are taught acid-base chemistry at the general chemistry level.

Chemistry instructors face many challenges when designing instructional strategies and creating optimal learning environments for students (Robinson, 2001;

Ruder & Stanford, 2018). This is partly due to the fact that students can come from a wide variety of backgrounds, so many factors such as prior knowledge, attitudes, emotions, motivation, and learning approach must be considered (Beckley, 2013; Chamorro-Premuzic & Furnham, 2008; Mega et al., 2014). However, meaningful learning can be fostered with proper instructional design (Kember, 1991). Previously, pedagogical techniques such as process-oriented, guided inquiry learning (POGIL) have been utilized to encourage student engagement and meaningful learning in the chemistry classroom and laboratory (Hunnicutt, et al., 2015; Luxford et al., 2012). The flipped classroom method has this same aim and has been demonstrated to show improvements in student learning and achievement (Benedict & Ford, 2014; Shattuck, 2016).

A person who is deeply engaged in an activity may be in a state of *flow*. The flow state is characterized by focus on the present moment, merging of action and awareness, loss of self-consciousness, distortion of the perception of time, and intrinsic enjoyment or excitement from the experience (Csikszentmihalyi, 1990). The flow concept is also closely related to Vygotsky's *zone of proximal development*, where a student is challenged just beyond the limit of their skills and knowledge (Liu & Matthews, 2005). This flow state is proposed to occur when there is a balance between the skills of the person performing a given task and the difficulty of the task. If the task difficulty exceeds the person's skill level, then they may experience anxiety or frustration (King, Ritchie, Sandhu, Henderson, & Boland, 2017). On the other hand, when their skills are beyond the demands of the task, the person may experience boredom (van Tilburg & Igou, 2012). The flow experience is facilitated when the person has clear goals and can receive immediate unambiguous feedback (Csikszentmihalyi, 2014).

Flow state experiences have been shown to be connected to other positive outcomes. Flow experiences have been positively correlated to increased positive affect and intrinsic motivation (Rogatko, 2009; Vollmeyer & Rheinberg, 2006). Increase in intrinsic motivation may be a direct result of the skills-challenge balance; overcoming an appropriately challenging task can be motivating for students (Keller et al., 2011; Landhäußer & Keller, 2012). Increased levels of motivation have been connected to higher levels of performance in chemistry (Ferrell et al., 2016). Additionally, students who are properly challenged and experience flow may not just gain increased engagement and motivation but may also find more enjoyment in their learning experiences and develop a deeper interest in the topic (Bressler & Bodzin, 2013; Shernoff et al., 2014).

Flow states have also been directly connected to performance in a variety of academic domains. Music students who experience higher levels of flow compose more creative musical pieces (MacDonald et al., 2006). Flow experiences have been shown to be a significant predictor of exam performance in psychology courses (Schüler, 2007) and informatics (Giasiranis & Sofos, 2017). Finally, flow was connected to final grades in both French and statistics courses, even when controlling for prior student knowledge (Engeser & Rheinberg, 2008).

Learning approach refers to the approaches that students take towards their academic tasks (Biggs, 2001; Biggs, Kember, & Leung, 2001). Students can take a deep, surface, or strategic/achievement approach to their learning, with each approach having a motivation and tactic associated with it. Students who employ the deep approach have an intrinsic motivation to learn and become competent in a given subject, and they try to discover meaning within the content and relate it to their prior knowledge (Biggs, 1987). The deep learning approach has been associated with higher levels of metacognition (Chin & Brown, 2000), student engagement (Floyd et al., 2009), self-efficacy (Cheung, 2015; Graham, Bohn-Gettler, & Raigoza, 2019; Zusho et al., 2003), and academic performance, specifically in chemistry (Zeegers & Martin, 2001). In contrast, students who used the surface approach use rote memorization as their primary academic strategy (Biggs, 1987). The surface approach is also characterized by a fear of failure, as avoidance motives have been found to be a predictor of the implementation of this approach by students (Diseth, 2011). Students with negative perceptions towards a course are more likely to employ the surface approach (Floyd et al., 2009). The third learning approach is the strategic approach. In this approach, the student strives to learn the material in an organized and systematic manner. Students using this approach have a desire to succeed in a given class, even if the student does not have a great intrinsic interest in the content (Biggs, 1987). The strategic learning approach is connected to extrinsic motivation, which is motivation due to a reward or separable outcome (Ryan & Deci, 2000). Because students using this learning approach focus on the way they organize how an academic task is performed, the strategic approach can be combined with either the deep or surface approach, depending on the student's interest and situation (Biggs, 1987; Biggs, 2001). Within the context of chemistry, learning approach has been connected to the varying achievement levels of students, with A/B students utilizing the deep approach, D/F students utilizing the surface approach, and C students not fully utilizing deep approach techniques, but also not fully relying on the rote memorization associated with the surface approach (Bunce, Baird, & Jones, 2017).

Research Questions

While much work has been done to examine the connections between flow state experiences and academic performance in various subjects, there is a gap in the literature when it comes specifically to the connection between flow and performance in chemistry. Additionally, there is also a gap in the literature when it comes to establishing a relationship between flow experiences and learning approach. With this study, we aimed to answer the following research questions:

Q1 What is the relationship between flow experiences and academic performance in chemistry?

Q2 What is the relationship between flow experiences and students' learning approaches?

Q3 How do students' subjective flow experiences (or lack thereof) reflect in their academic performance in class?

Theoretical Framework

This study was conducted under the framework of flow theory, where a state of flow is considered to be an optimal human experience (Csikszentmihalyi, 1975). For a state such as this to occur, the person performing the task must have the skills necessary to just match the difficulty of the task being performed so that the task is neither too easy nor too difficult. A person in a state of flow may experience deep concentration, changes in the perception of time, increased intrinsic motivation, and a feeling of overall well-being (Csikszentmihalyi, 1990).

One way to measure the flow state experience is through the componential approach, in which the characteristics of the flow experience are measured separately.

The *Flow in Education* (EduFlow) scale was designed to measure flow states experiences in educational settings using the componential approach, measuring four components that are believed to be most relevant to educational settings: cognitive control, immersion, loss of self-consciousness, and autotelic experience (Heutte et al., 2016b).

Methodology

Due to the subjective nature of flow state experiences, we chose to use a *mixed methods design* for this study. Quantitative methods were employed to answer Research Questions 1 and 2, while qualitative methods will help us answer the third research question. This study followed an explanatory mixed methods design where the quantitative data was collected and analyzed first, and then qualitative data was collected and analyzed in an attempt to explain the quantitative results (Creswell & Plano Clark, 2011).

Participants and Setting

This study took place at a mid-sized university in the Rocky Mountain region of the United States. Before any data was collected, we received permission to conduct this study from the university's Institutional Review Board (IRB). The target population for this study was students (N = 150) enrolled in two sections of second-semester general chemistry course during the spring semester. For the quantitative portion of this study, convenience sampling was used, and the same instructor taught both sections. All participants were the age of 18 or older and they gave their informed consent prior to participating in this study.

For the qualitative portion of this study, purposeful sampling (Merriam, 2009) was employed to select 10 participants from the quantitative sample. These volunteers were chosen based off their Exam 3 scores, ASSIST scores, and EduFlow scores in order to achieve maximum variation. Pseudonyms were used to protect the identities of the volunteers. Table 1 summarizes the scores and characteristics of each interview participant. Once each interview was transcribed, a copy of the transcript was member-checked with the participant.

Table 5.1

Characteristics and Scores of Interview Participants

Name	Major	TPCE Score	ALEKS Score	Exam Score	EduFlow Score	Primary Learning Approach
	Maximum Score	60	12	100	28	
Class	Average Score *	40.9	9.37	70.7	18.19	
Heather	Exercise Science	49	9.1	94	23.0	Deep-Strategic
Sofia	Biology, Pre-Med	35	11.3	93	17.0	Strategic
Betty	Biology	41	11.9	87	19.83	Deep-Strategic
Lauren	Biology, Pre-Health	45	11.9	86.5	16.17	Strategic
Mark	Biology, Pre-Med	41	11.9	85.5	21.33	Strategic
Greg	Biology	46	10.9	82	26.33	Deep
Pete	Chemistry, Pre-Health	37	10.7	72.5	18.33	Surface-Strategic
Megan	Biology, Pre-Med	37	8.6	62.5	14.5	Strategic
Trudy	Biology	33	11.7	53	19	Surface-Strategic
Jon	Chemistry/ Secondary Ed.	42	6.0	34	16.17	Deep
	* N (Students)	N = 149	N = 148	N = 145	N = 143	

Data Collection Procedures

The instructor for this course administered the Toledo Chemistry Placement Exam (TCPE) during the first week of the semester to all students enrolled in the course. The ASSIST questionnaire was distributed to students at the end of a class period during the first week of the semester, and they were given time in class to complete the survey. The EduFlow questionnaire was distributed to participants with Exam 3 with instructions to complete the survey after finishing the exam. The instructor of the course provided the Exam 3 scores, ALEKS scores, and TCPE scores for participants.

Following Exam 3, recorded interviews were scheduled with 10 participants. All interviews took place within two weeks following the exam. The interviews were semi-structured and lasted approximately 30 minutes. Participants were asked about their experience preparing for the exam, as well as their experiences taking the exam. Additionally, participants were asked to explain their thought processes on a few exam questions of varying difficulty. Finally, near the end of the interview, the concept of flow was explained to each interviewee, and they were asked to describe whether they faced anxiety and frustration, boredom, or flow during the exam (King, et al., 2017; van Tilburg & Igou, 2012).

Instrumentation

Acids-bases examination. The exam over acids and bases was the third exam of the semester in this general chemistry course and was a 1-hour, timed exam. The scores from this exam served as our measure of student performance, our dependent variable in this study. Exam 3, which consisted of 12-multiple choice questions (6 points each) and five short-answer questions (30 points), was written by the instructor of the course, and totaled 100 points. Topics for this exam included pH, acid and base dissociation constants, and relative acid and base strengths. We chose this exam and topic because acid-base chemistry is an important general chemistry topic that contains a wide-variety of questions and problems at varying levels of difficulty.

Approaches and Study Skills Inventory for Students (ASSIST). The ASSIST questionnaire is designed to assess the extent to which students utilize the deep, surface, and strategic learning approaches. This instrument contained 52 items, with each item representing one of the three learning approaches. Responses to these items were given through a 1-5 Likert scale rating, with 5 being "strongly agree" (Entwistle, 1997; Entwistle & McCune, 2013). Subscale scores from each of the three learning approaches were summed to create scores for each learning approach. Internal consistency tests were conducted, yielding Cronbach's alpha values of .82 for the deep approach subscale, .85 for the surface approach subscale, and .85 for the strategic approach subscale. A principal components exploratory factor analysis with Oblimin rotation and a salient loading cutoff at 0.3 was also conducted, with items on factors as expected.

Flow in Education (EduFlow) scale. The EduFlow scale was employed to assess the flow experiences of students while they were taking Exam 3. We chose this scale to assess flow because it was designed for educational settings (Heutte et al., 2016b). We used a slightly modified version of the EduFlow scale in this study, modifying some items in order to make it more relevant to the exam setting. A full version of the questionnaire we employed can be found in the Supplemental Materials of the article.

The EduFlow scale contains subscales which are designed to measure four components of flow state experiences: cognitive control, immersion, loss of self-consciousness, and autotelic experience. The EduFlow survey contains 12 items, with each of the 4 components being represented by three items. Items are rated on a Likert scale from 1 to 7, with 1 representing no flow experience, and 7 representing deep flow experiences. For each of the four components, means were calculated, giving a range of scores for each subscale of 1-7. The scores from each component were summed together, giving a range of 4-28 for total EduFlow scores. Internal consistency tests were conducted for each of the subscales, yielding Cronbach's alpha values of .81 for cognitive control, .73 for immersion, .72 for loss of self-consciousness, and .83 for autotelic experience. For the immersion subscale, the item "I did not notice the time passing" was removed due to its detrimental contribution to internal consistency; this item also does not fit with the context of the exam, as the exam was a 1-hour timed exam with time updates being written on the board at the front of the room by the instructor.

Toledo Chemistry Placement Exam (TPCE). The Toledo Chemistry Placement Exam was used to assess the prior math and chemistry knowledge that students had at the beginning of the course. At the beginning of the semester, the instructor for this second-semester general chemistry course administered the TPCE to all students. The exam consists of 60 multiple-choice questions: 15 math questions that cover math skills up to college algebra and 45 chemistry questions (Hovey & Krohn, 1963; McFate & Olmsted, 1999).

Assessment and Learning in Knowledge Spaces (ALEKS). Scores from the Assessment and Learning in Knowledge Spaces (ALEKS) online homework system were used to assess the preparation level of each participant. Doing ALEKS was a requirement for all students in this general chemistry course, as their ALEKS score was part of their course grade. This system used periodic assessments and diagnostic feedback to help students learn various general chemistry topics over the course of the semester. The ALEKS program was synced with what students are learning in lecture, serving as an extra resource for practice and learning. Once students had achieved mastery in one domain, they could move on to more advanced topics (Eichler & Peeples, 2013). Student ALEKS scores were provided by the instructor of the course. The scores ranged from 0 to 12, with 0 indicating that the student had not completed any of the required ALEKS topics, and 12 indicating that students had completed all of the required ALEKS topics.

Data Analysis Procedures

Quantitative procedures. Research Questions 1 and 2 were addressed using a hierarchal multiple linear regression analysis. Analyses were conducted in order to verify that the assumptions of multiple linear regression, including linear relationships between dependent and independent variables, normal distribution of regression residuals, no multi-collinearity, and homoscedasticity, were met. Scores from the exam over acids and bases served as the outcome (dependent) variable. The predictor variables in the first model were scores from TPCE, scores from ALEKS online homework, and scores from the deep, surface, and strategic subscales of the ASSIST questionnaire. The second model included all of the variables in the first model, in addition to EduFlow scale scores. We chose to employ this two-model approach in order to see how much additional variability in exam score was accounted for by possible flow state experiences. Additionally, through this analysis, we were able to examine how variables such as learning approach and flow correlated to one another. The analysis was conducted using SPSS Version 24 statistical package.

Qualitative procedures. The qualitative portion of this study followed the methodological framework of phenomenology. We chose this framework because phenomenological research aims to depict the essence of experiencing a certain phenomenon (Merriam, 2009). For this study, the phenomenon of interest was flow state experiences. In this studied, we tried to understand the essence of student's flow state experiences (or lack thereof) while they were taking the exam over acids and bases. Thematic analysis was employed to assess the qualitative interview data used to address Research Question 3. Students were asked about their preparation strategies for the exam and also about the components of flow from the EduFlow questionnaire. Towards the end of the interviews, they were introduced to the diagram in Figure 1 and were asked to place themselves on that diagram based on how they were feeling at different points during the exam. Recorded interviews were transcribed and coded, with major themes being identified (Merriam, 2009).

Results and Discussion

Quantitative Results

A principal component exploratory factor analysis with Oblimin rotation (Harman, 1976) was conducted to examine the internal structure of the EduFlow instrument. In this analysis, we found that some of the items loaded on to multiple factors. For example, items from the autotelic experience subscale correlated strongly with items from the cognitive control subscale. This was not entirely surprising, as all of these components of flow are related to one another and would all be experienced if a person is in a deep flow state (Csikszentmihalyi, 2014). Because of this we chose to sum all of the subscale scores from the EduFlow scale for a total EduFlow score, rather than examining the contribution of each component individually.

Descriptive statistics for data collected from the quantitative instruments of this study are summarized in Table 5.2. From the descriptive statistics, we see that skewness and kurtosis values were between the acceptable values of 1.0 to -1.0 for all instruments, with the exception of the skewness of the ALEKS online homework scores. It is likely that the ALEKS scores skewed towards higher values because it was required homework that counted towards students' overall grades in the class.

Table 5.2

Descriptive Statistics

Instrument	N	Mean	Std. Deviation	Skewness	Kurtosis
ASSIST Deep	139	58.6	7.65	-.035	-.545
ASSIST Strategic	140	74.6	10.09	-.321	.738
ASSIST Surface	140	48.1	9.93	.111	-.411
TCPE Math	149	12.8	1.62	-.805	.477
TCPE Chem	149	28.1	5.22	-.132	-.325
ALEKS	148	9.37	3.05	-1.15	.269
EduFlow Total	123	18.2	4.35	-.461	.070
Exam Score	145	70.7	22.73	-.593	-.308

Table 5.3 shows the comparison of the two multiple linear regression models that predict exam scores. In the Model 1, there are no EduFlow scores; in the Model 2, EduFlow scores were included along with Model 1. The R_2 changed of .080 was statistically significant at the *p* < .001 level, which establishes a noteworthy relationship between flow experiences and achievement in chemistry. That is, an additional 8.0% of the variance in exams scores was explained when taking flow state experiences into account.

Table 5.3.

Comparison of Regression Models (Model Summaries)

Model	R	R_2	Adjusted R_2	R_2 Change	F Change	df1	df2	Sig. F Change
1	.660	.435	.402	.435	13.11	6	102	.000
2	.718	.516	.482	.080	16.71	1	101	.000

A full summary of each variable's contribution to the prediction of exam score can be seen in Table 5.4. By examining the regression model coefficients, we can see which variables the strongest predictors of exam score are. Based on this model, ALEKS scores, which are used as a measure of how well each student was prepared, served as the strongest predictor of chemistry achievement with a standardized beta of 0.348, which was significant at $p < 0.001$. This was not surprising, as students who are more prepared tend to perform better on exams (Kitsantas, 2002). Chemistry pretest scores were also significant predictors at $p < 0.05$. This was also not surprising, as prior knowledge has been demonstrated to be a predictor of achievement (Beckley, 2013). Scores from the strategic approach subscale of the ASSIST questionnaire were also found to be significant predictors at $p < 0.05$, while deep and surface subscale scores were not significant. This was an interesting finding, as the deep approach has previously been found to be a significant positive predictor of student achievement and the surface approach a significant negative predictor (Zeegers, 2004). However, previous studies did not take the strategic approach into consideration, so further investigation may be needed to fully understand the impact of the strategic approach on student achievement.

Table 5.4.

Regression Model Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients		
		Beta	Std. Error	Beta	t	Sig.
1	(Constant)	-36.622	31.430		-1.165	.247
	ALEKS	3.314	.636	.436	5.210	.000
	TPCE Math	.922	1.278	.062	.721	.473
	TPCE Chem	1.451	.398	.345	3.647	.000
	Deep	-.365	.254	-.128	-1.433	.155
	Strategic	.598	.214	.252	2.798	.006
	Surface	-.010	.227	-.004	-.043	.966
2	(Constant)	-41.974	29.286		-1.433	.155
	ALEKS	2.643	.614	.348	4.302	.000
	TPCE Math	1.109	1.191	.074	.931	.354
	TPCE Chem	.977	.388	.232	2.519	.013
	ASSIST Deep	-.461	.238	-.162	-1.938	.055
	ASSIST Strategic	.509	.200	.215	2.543	.012
	ASSIST Surface	.066	.212	.028	.313	.755
	EduFlow Total	1.723	.421	.334	4.088	.000

Finally, after ALEKS scores, EduFlow scores served as the second strongest predictor of exam scores, with a standardized beta of .334, which was significant at $p<.001$. This finding helps to establish the relationship between flow state experiences and chemistry achievement. However, the magnitude of this relationship was slightly surprising, as previous studies of the relationship between flow and academic performance in other subjects have only shown small but significant connections (Engeser & Rheinberg, 2008). It is possible that the magnitude of the relationship between flow and performance may vary from subject to subject, so further investigation may be needed.

To gain an understanding about the relationships between flow and each of the three learning approaches, we examined their correlations with each other. The correlations between all variables included in the final regression model were summarized in the Supporting Information (Table 5.5).

Qualitative Results

Data collected from student interviews can help us to better explain some of our findings from the qualitative portion of this study. We focused on the themes that emerged from student preparation strategies, and the components of flow from the EduFlow questionnaire. The theme of students experiencing time transformation was the only component of flow that did not emerge from our interviews. This was possibly because the exam was a timed test, so students were not able to totally disregard the time it took for them to complete the exam.

When we coded the information from the interviews and the following themes emerged from the data:

- *Preparation for the Exam*: The Practice Exam had a similar format to the actual exam.
- *Feeling of Excitement*: This feeling is associated with having a flow experience.
- *Concentration/Focus*: Being able to focus on the content of the exam is associated with flow
- *Skills-Challenge Balance*: Interviewees were asked if they felt ‘flow, anxiety, or boredom during the exam.

Preparation for the exam. When we asked students how they prepared for the exam, we received a variety of answers, but every student we interviewed noted that they studied the practice exam given out by the instructor. About a week before the exam, the instructor posted a ‘practice exam’ online that had a similar format to the actual exam. Student utilization of this practice exam as a preparation tool could help to explain the connections between performance on the exam and the strategic approach, as studying the practice exam seemed to be a common strategy among the students.

Some of the students may have taken a surface approach when utilizing the practice exam as a study tool. Trudy and Megan both noted that they ended up relying too much on memorizing the practice exam. Trudy, categorized as a surface-strategic approach (Table 5.1), explained:

> Yeah, I think I panicked, and I tried to put the study guide too much to the exam, like thinking it was acidic when it was basic.

When we asked Megan, strategic approach, about her thought process on specific problem from the exam, she noted:

> I kind of remembered how to do it because I looked at the practice exam right before the test, and so I just kind of tried to remember all the steps on the thing... it was different than the practice exam, and that’s a lot of what I studied.

The over reliance on memorizing the practice exam reflected poorly in both of their exam scores. Taking this surface approach to studying may have prevented them from further developing their skills (Mazzarone & Grove, 2013) and therefore may have prevented them from having flow state experiences when working the more challenging problems.

Feeling of excitement. Several of the interview participants expressed that they had felt a sense of excitement while taking the exam. Throughout the interview process, we tried to probe as to whether this excitement was associated with a possible flow state experience, as increased excitement and sense of well-being are characteristics of the flow experience (Csikszentmihalyi, 1975). Mark, strategic approach, noted that he felt excitement when he saw a problem on the exam that he knew how to do:

> On question 12A, I was actually kind of excited when I saw it, because I was like, 'I know exactly how to do this'.

Lauren, strategic approach, echoed this, explaining that she felt excitement when she knew how to approach a problem, but also noted that she still did not enjoy the subject of chemistry:

> I mean I was a little excited that like, 'Oh I know these formulas, I know what I have to use!' But I was also like, damn it, chemistry.

Lauren's statements highlight the importance of the skill-challenge balance; though she may not have been intrinsically interested in chemistry, she was able to have a positive experience through attaining competency in the subject.

Betty, deep-strategic approach, compared the excitement of the challenge of the exams to her past experiences in sports, comparing her desire to succeed in chemistry to her desire to win at a sport:

> Well it's kind of like both, because I have a love/hate relationship with exams. I used to play a lot of sports, so like with sports, like winning, you know? I like to win and I like to succeed, so for exams, it's kind of like, oh ok finally I get to succeed in something kind of. Or fail I guess too,

that sucks. But I get to try to win, so that's where it's kind of exciting. Especially if I feel like I'm doing well.

Sofia, strategic approach, explained that she had changed her studying habits after performing poorly on the first two exams of the semester. She also expressed feeling excitement from being challenged by the exam. She discussed how working with a study group helped her to feel more confident, and while she was still nervous about the exam, she felt that the support from her study group gave her the confidence to rise up to the challenge.

Concentration/focus. An increase in concentration and focus was another aspect of the flow experience that we wanted to learn more about through these student interviews. Both Greg and Heather expressed that they were deeply focused during the exam. Greg, deep approach, even noted that chemistry was fun for him, thus it was easy to get absorbed. Heather, deep-strategic approach, explained that she had the attitude of 'you either know it or you don't', so she just tried to give her full focus and attention to completing the exam and not worrying too much about it. Mark and Sofia both felt that they were able to focus deeply on the exam because they felt well-prepared and confident. Sofia, strategic approach, noted that she was able to stay focused enough to go back and double-check each of her answers when she finished her exam. Lauren, strategic approach, also expressed becoming totally absorbed in the exam, explaining that she did not look up or take a short break while taking the exam, something that she said she usually does.

Not all students interviewed experienced the concentration and focus, which is indicative of the flow state experience. Megan, strategic approach, described being distracted by "little things", such as a person standing up, a person tapping a pencil, or a person dropping something. She noted that struggling to focus was common for her. Jon, deep approach, expressed that he was in and out of concentration during the exam:

> I was definitely focused on the test itself. As far as concentration goes, I think my mind maybe was jumping around to what I knew and what I didn't know.

He explained that whenever he came across a problem that he did not know how to do, he would find himself thinking about it, even when working on other parts of the exam. He also discussed noticing the other people around him, noting that he was worried about how his roommate, who was also in the class, was doing because he said they are competitive about their grades. Pete, surface-strategic approach, echoed Jon's sentiment about going in and out of concentration during the exam, citing stress as his reason for losing focus.

Skills-challenge balance. Towards the end of each interview, we introduced the concept of flow and the skills-challenge balance to the students and asked them if they felt they experienced flow, anxiety, or boredom during the exam (Eren & Coskun, 2016; van Tilburg & Igou, 2012; Wang & Hsu, 2014; Wilde, 2012). Greg, deep approach, noted that he felt like he immediately knew how to do most of the problems on the exam but made a few careless mistakes. He explained that he had taken advanced chemistry in high school, so he had already seen much of the material that was being taught. Greg expressed that he did experience boredom while learning the material in class but felt like he was more in flow during the exam due to the challenge and pressure that comes with an exam. No other student interviewed expressed feeling boredom. That is, most students stated they experienced either flow or anxiety/frustration. Sofia, Heather, and Lauren all noted that they felt they were in the flow range for the entirety of the exam. Mark, strategic approach, expressed that he was in flow for the majority of the exam. He noted:

> I wasn't really anxious when I got the test in my hand. I was like 'Ok, like I know how do this'. You know, I might have even gone kind of into like boredom because, I'm like 'Ok, I know how to do this. Like this is easy stuff'...And I don't think I got really anxious or frustrated, I just knew I had a challenge in front of me, and I had to do it.

He explained that he was slightly nervous because of the impact of the exam on his grade, but felt confident enough in his abilities that even if he saw a problem he was not totally sure how to do, he knew he would not lose enough points to be seriously hurt by it.

Betty, deep-strategic approach, noted that she was between flow and frustration (anxiety) throughout the whole exam. She said that the anxiety was due to her poor performance on the previous exam; she explained that she was feeling anxious because she did not also want to perform poorly on this exam, even though she felt well prepared. This could possibly suggest that flow state experiences could be influenced by outside sources other than the skills-challenge balance. Betty noted that studying helps her feel better about exams, reinforcing the importance of the skills-challenge balance.

Trudy, surface-strategic, explained that she was in flow for the easier questions that she knew how to do but experienced some frustration (anxiety) when she came to problems that she was not sure how to solve. She explained:

> I don't know why the acid and base unit was so hard for me to understand, like compared to the other ones... I was a little worried... I'm always nervous and just want to get it over with.

Other students expressed feeling anxiety and frustration throughout the majority of the exam. Megan, strategic approach, explained that she felt stressed both while studying and taking the exam. Jon, deep approach, noted that he felt frustration because he thought that the content of the exam was very difficult, above his skill level. He explained:

> I didn't know every step, and there were some things I didn't know at all... I think exams, just in general, are stressors...the difficulty was fairly high for me as far as my skill level went. I felt like I kind of dipped in and out of that flow area with some of the stuff I at least thought I knew and versus some of the stuff I didn't know.

These findings indicated that students with lower skill levels can experience flow when working easier problems. On the other hand, they faced anxiety or frustration (King et al., 2017) when they encountered a more difficult problem, which they struggled to do correctly.

Limitations

This study was limited by the reliability and validity of the instruments used to gauge flow experiences, learning approach, prior knowledge, and achievement in chemistry. Sample size and difficulties separating individual components of the flow experience prevented us from analyzing each component of flow as an individual variable. Because student interviews were voluntary and only a relatively small number of students were interviewed, it was possible that information about students' subjective flow experiences (or lack thereof) could have been missed.

Implications for Future Research

While we have established a relationship between flow state experiences and academic performance in general chemistry through this study, more work needs to be done to fully understand this relationship, as well gain a further understanding of the role that learning approach plays. While we have found that flow is positively correlated to the deep and strategic learning approaches, we know nothing of the causality between them. Findings from the qualitative data seemed to indicate that employing a proper study strategy helps to raise student skills and lead to flow experiences. However, is the deep approach a precursor to the flow experience, or does intrinsic motivation result from the flow experience? It may also be interesting to examine whether this relationship between flow and academic performance varies with different populations of students or different chemistry courses, such as upper level chemistry courses where students are likely to be more intrinsically motivated in chemistry.

It may also be helpful to examine flow within different educational contexts that could be more conducive to flow experiences. Many of the students interviewed noted that they felt inherent stress in just taking any examination. Also, with exams, there is not instant, unambiguous feedback, which can be important for the flow experience (Csikszentmihalyi, 2014). Several of the students interviewed expressed that they felt that they had experienced flow during their laboratory periods, noting that they felt the time went by faster when they were in the lab. They attributed the feeling of flow to the hands-on nature of the laboratory. Flow states have previously been studied in other hands-on activities such as video games, athletics, and music, so the chemistry laboratory may be the next logical place for us to further examine these flow experiences.

Implications for Instruction

The results of this study highlight the importance of the skills-challenge balance within the context of general chemistry. These results suggest that for optimal performance the problems presented should be neither too easy nor too difficult for students. Instructors should begin with presenting easier problems to students, and then slowly ramp up the difficulty so that the problems become more challenging and complex as student skill increases. While this sounds like an ideal solution, it may still prove to be a challenge as students come from a variety of different backgrounds and therefore have a variety of different skill levels that can grow at different rates (Beckley, 2013; Chamorro-Premuzic & Furnham, 2008; Mega et al., 2014). Flow-oriented classrooms could possibly lead to deeper and more meaningful student learning of chemistry topics (Taber, 2015).

A plausible solution on how to 'ramp up' student skills might be to use a diagnostic software for chemistry learning, where students can work through at their own pace (Eichler & Peeples, 2013). The software can present problems of slowly increasing difficulty to students. This could help keep students maintain a flow state throughout the entire learning process. The results of this study suggest that less skilled students can experience flow while working easier problems that are appropriate for their skill level. While the ALEKS online homework system does this progression to varying levels of success (Eichler & Peeples, 2013), it could be improved by making it more diagnostic. This in turn could relieve some of the frustrations that students have with it (personal observations). For example, if a student gets the wrong answer on a long, multistep problem, the software could then break the long problem up into its individual steps to determine precisely where the student made a mistake. This could help students to determine where they need to develop their skills and help them to enter the optimal state of flow where the level of the challenge is appropriate for their skill level.

Supporting Information

Table 5.5

Correlation of Variables in Regression Model

Exam3 Score	ALEKS	TPCE PreMath	TPCE PreChem	ASSIST Deep	ASSIST Strategic	ASSIST Surface	EduFlow Total
Exam 3 Score	.506**	.203*	.307**	.024**	.391**	-.255**	.540**
ALEKS	-	-.032	-.104	-.133**	.359**	-.072	.264**
PreMath	-	-	.484	.194	.048	-.325	.173*
PreChem	-	-	-	.319	.062	-.486	.377**
ASSIST Deep	-	-	-	-	.342	-.419	.245**
ASSIST Strategic	-	-	-	-	-	-.340	.293**
ASSIST Surface	-	-	-	-	-	-	-.346**

*p<.05, **p<.01

CHAPTER VI

CONCLUSIONS, FUTURE WORK, AND IMPLICATIONS

In this chapter, I have summarized some final conclusions based on the results of both the pilot study and dissertation study. I related these findings to existing literature to demonstrate how this work contributed to the fields of chemical education and educational psychology. I have also discussed possible future research that can be done to further understand the intersection between flow state experiences and chemical education. Finally, I have discussed possible ways in which the findings from my studies can be applied to the instruction of chemistry.

Conclusions

The findings from my two studies indicated that there is indeed a connection between the flow state experience and student performance in chemistry. In each case, there was a statistically significant contribution from the measured flow state variable to the regression model; the R_2 change when flow variables were included in the in each case was very similar (+0.090 in the pilot study and +0.081 in the dissertation study). These findings are consistent with studies that have connected the flow state experience to increased performance in other academic course such as music composition (MacDonald et al., 2006), statistics (Vollmeyer & Rheinberg, 2006), and introductory psychology (Schüler, 2007).

While I expected to find a connection between flow and academic performance in chemistry based on previous studies connecting flow to performance in many other domains, I did not expect to find the strong connection between flow state experiences and the strategic learning approach. The flow state experience has been previously associated with intrinsic motivation (Keller et al., 2011; Vollmeyer & Rheinberg, 2006). The association between flow and intrinsic motivation makes sense, as someone experiencing a state of flow is likely to find meaning and enjoyment in the experience (Csikszentmihalyi, 1990). However, the strategic learning approach is often associated with extrinsic motivation. This observed connection between the strategic learning approach and flow could be related to the exam setting in which these studies were conducted. During my interviews, many of the students discussed preparing for the exam in some sort of organized and strategic manner such as working through the practice exam and completing the ALEKS online homework. It is possible that students who prepared for the exam in this strategic manner were able to grow their chemistry skills enough to meet the challenges of the exam. Depending on their levels of prior knowledge, students may have been able to achieve a state of flow on specific problems where their skills matched the challenge of that problem, even if the student did not experience flow throughout the entire exam.

Based on these findings, I hypothesized that a flow state experience can be a catalyst that transforms extrinsic motivation into intrinsic motivation. It is possible that students who utilize strategic study habits can increase their skills to point where they have a flow state experience, and once they have this experience, they find meaning in overcoming the challenge. It is possible that the meaning and positive feeling associated with the flow state experience can lead to the student becoming intrinsically interested in the subject, even if they did not feel this way initially.

Future Research

There is a still much work to be done to study flow state experiences within the domain of chemistry and chemistry education. The research in this study focused solely on student exam performance within the lecture setting. However, laboratory is crucial component to students learning chemistry. Many of the students that I interviewed for these studies said things that would possibly indicate that they experienced flow while working in the laboratory; they noted that they felt totally immersed in the lab work and that time seemed to go by quickly when they were in lab. The lab setting may be more conducive to flow state experiences due to it being a more “hands-on” type experience, as well as the instantaneous feedback that students receive while working in lab; instantaneous, unambiguous feedback has been described as one of the preconditions necessary for one to have a flow state experience (Csikszentmihalyi, 1990). I would be interested to further investigate student experiences within the chemistry laboratory setting to examine to what extent they are similar and differ from the chemistry lecture setting.

Additionally, I would also like to examine student flow state experiences within other chemistry courses, as these studies were focused on second semester general chemistry only. I believe that organic chemistry would be an interesting chemistry course to examine, as problems presented in organic chemistry such as drawing reaction mechanisms, determining structures from NMR spectra, and synthesis planning all require critical thinking skills and creative thinking. The challenge level can vary greatly as well; synthesis problems can be simple, one step problems, or they can be complex multistep pathways. The relationship between flow, performance, and gamification would be especially interesting to study as Farmer and Schuman (2016) developed a dominoes-like card game to help teach students organic chemistry reactions. I would be interested to investigate whether the implementation of this card game within an organic chemistry course would lead to higher levels of student flow experiences and student performance.

I would also be interested in examining flow state experiences in upper division chemistry courses such as biochemistry or physical chemistry. Students taking these upper division courses may have a stronger interest in chemistry since they are likely chemistry majors or majoring in something closely related; these students may be more intrinsically motivated towards chemistry. Flow experiences have been connected to higher levels of intrinsic motivation (Vollmeyer & Rheinberg, 2006), so I would be interested to assess the motivation of these students and examine how it is related to their performance in chemistry and their possible flow state experiences.

Other possible future work could be aimed at assessing and improving online homework systems. Students that I interviewed had mixed feelings regarding the ALEKS online homework system that was required as part of the course; some felt that it would a helpful tool for studying and learning, while others found it frustrating. While the system attempts to keep students in flow by slowly ramping up the difficulty of problems it presents (Eichler & Peeples, 2013), many of students frustrated with ALEKS noted that it was not diagnostic enough; when they got a problem wrong, ALEKS presented them with the whole solution at once, which students found to be overwhelming, especially for complex, multistep problems. While the feedback provided by ALEKS was instantaneous, it may be overwhelming for some students. It may be better for the system to break complex problems down into their individual steps so that students can learn exactly where they went wrong. I would be interested to conduct a study that focused specifically on online homework systems to gain a deeper understanding of student perceptions towards them and to possibly suggest some evidence-based improvements that could be made to them.

Finally, I previously hypothesized that the flow state experiences could be the catalyst that transforms extrinsic motivation into intrinsic motivation. The results of my work indicate that the strategic learning approach, which is associated with extrinsic motivation, is strongly connected to both flow state experiences and performance in chemistry. Proper skills-challenge balance has been previously linked to intrinsic motivation (Keller et al., 2011), so it is possible that a student could reach this proper balance through developing their skills, even if there are extrinsically motivated to do so. I would like to explore some causation studies in the future to test this hypothesis. This study would likely need to be a long-term longitudinal study that assesses student motivation, performance, and flow state experiences over a period of time, possibly over one to two years.

Implications for Teaching

With the results of this work indicating that there is a positive correlation between flow state experiences and performance in chemistry, I contend that courses should be taught in a way that could facilitate student flow state experiences. There are several strategies that could be implemented to do this. One strategy would be to slowly increase the difficulty and complexity of the material presented so that students are always being properly challenged in regard to their skill level. However, this can be especially challenging to achieve in the classroom, as student come in with different amounts of prior knowledge and learn at different rates. I think this is where online homework systems can be helpful, as they allow each student can work through the material at their own pace; the more skilled students can work through the material more quickly, while the less skilled students can take the time to build their skills up so that they can be successful.

Gamification is another way to help facilitate flow state experiences (Bressler & Bodzin, 2013). Instructors could find relevant, chemistry-related games for their students to play which would allow the students to both actively learn and have fun at the same time. Several games can be found in the literature, such as a card game designed to help teach chemical formulas (Morris, 2011), a card game designed to teach general chemistry terminology (Capps, 2008), and the previously mentioned dominoes-like card game for teaching organic chemistry reactions (Farmer & Schuman, 2016).

Finally, I believe that it is important for instructors to know where their students fall on the skill-challenge balance spectrum. Ideally, we want our students to be in the optimal state of flow, so strategies can be utilized to escape either frustration or boredom. To escape frustration/anxiety, students need to develop new skills (Csikszentmihalyi, 2014). Providing additional resources and offering extra to students lacking the necessary skills could help them develop their skills. On the other hand, students who are bored need to seek new challenges (Csikszentmihalyi, 2014). In the context of chemistry, a highly skilled student may need to be directed to a challenge such as becoming involved in a research project so that the student can achieve flow instead of boredom.

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APPENDIX A

FLOW DIAGRAM

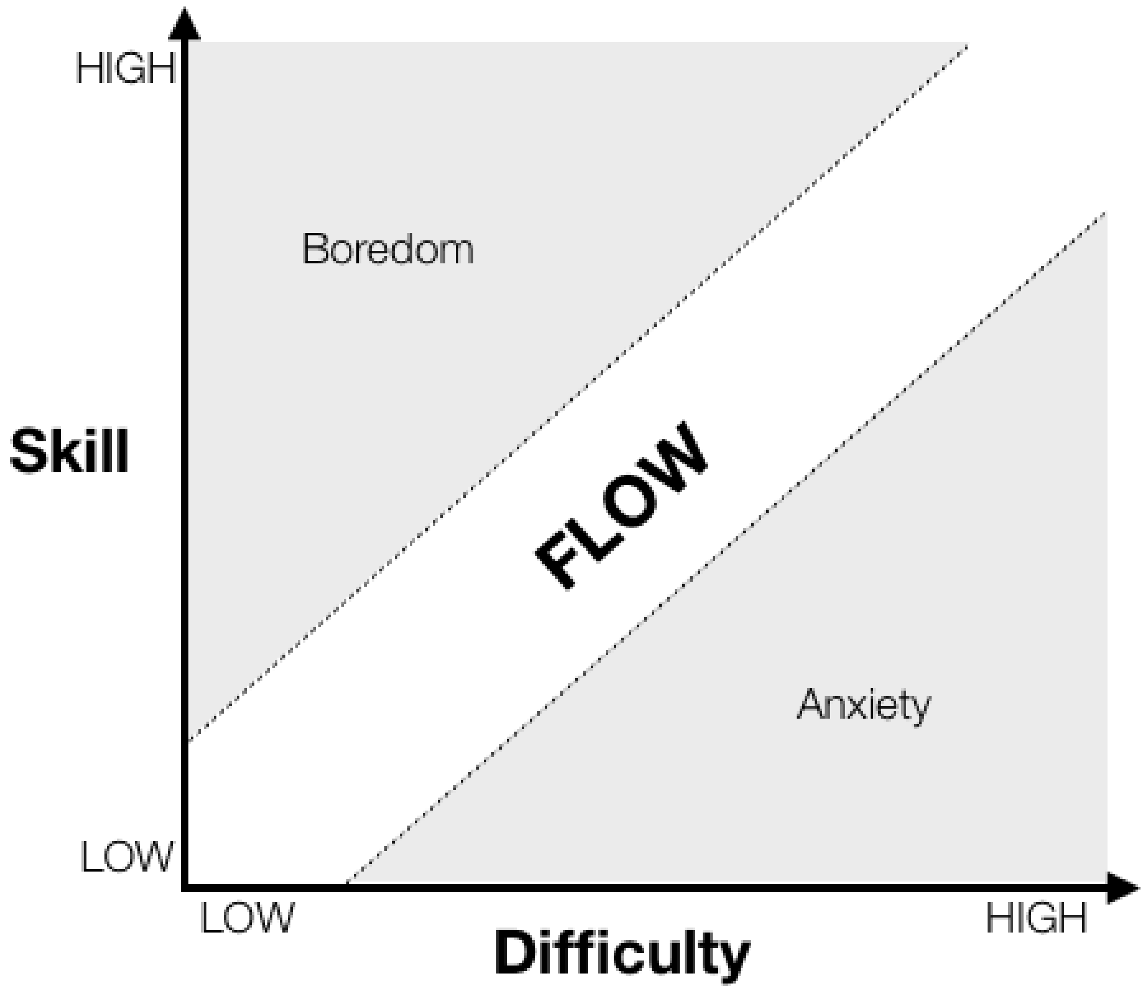


Diagram Proposed by Csikszentmihalyi (1975) highlighting when flow can occur

APPENDIX B

FLOW IN EDUCATION (EDUFLOW) QUESTIONNAIRE

Name__________________

By completing this survey, you are consenting to take part in this study. If you do not wish to participate, please return a blank survey. This has no impact whatsoever on you grade in this course. Contact Kyle Kemats (kyle.kemats@unco.edu) if you have questions or concerns.

Read each sentence carefully and circle the number which best corresponds to your answer:

1=strongly disagree 4= moderately agree 7= totally agree

Answer each of the following in regard to how you felt during the exam.

01	I felt I was able to meet the high demands of the situation.	1 2 3 4 5 6 7
02	I was totally absorbed in what I was doing.	1 2 3 4 5 6 7
03	I did not notice the others around me.	1 2 3 4 5 6 7
04	I had the feeling of living a moment of excitement.	1 2 3 4 5 6 7
05	I felt that my success was under my control.	1 2 3 4 5 6 7
06	I found myself losing track of time.	1 2 3 4 5 6 7
07	I did not fear the judgement of others.	1 2 3 4 5 6 7
08	This activity (exam) makes me happy.	1 2 3 4 5 6 7
09	I knew what I had to do at every step of the task.	1 2 3 4 5 6 7
10	I was deeply concentrated on what I was doing.	1 2 3 4 5 6 7
11	I was not worried about what the others think about me.	1 2 3 4 5 6 7
12	When I talk about this exam, I feel a strong positive emotion and I want to share it.	1 2 3 4 5 6 7

APPENDIX C

POSSIBLE INTERVIEW QUESTIONS (RESEARCH QUESTION THREE)

1) How’s it going in chemistry?

2) How did you feel about the last exam (acid-base exam)?

3) How did you prepare for this exam?

4) <<I will go through some exam questions (easy, medium, hard) with student volunteers to explore their thought processes when taking the exam. I expect to see a range of responses from frustrated to “flow” to boredom.>>

5) <<I will go through the EduFlow survey, asking them about interesting responses.>>

6) <<I will introduce Flow concept & diagram (Appendix A)>>

7) Have you ever experienced this <frustration/flow/boredom> in chemistry (class or lab)?

8) Have you ever experienced *flow* in other settings?

9) Is there anything else you’d like to add?

APPENDIX D

EXAM OVER ACIDS AND BASES

Exam_3
Spring 2019

Instructions: There are 12 multiple-choice questions (6 pts each) on this exam. Answer these on your Scantron answer sheet. Question 12 also includes an essay box (30 pts). Answer Questions 1 to 12 on the exam sheet provided. Good luck and may the *Chemical Force* be with you!!

1. What is the pH in a 1.0 x 10^{-5} M LiOH solution?
   a) 9.0   b) 12.7   c) 5.0   d) 1.0 x 10^{-5}

2. Hydrobromic acid, HBr (aq), and hydrofluoric acid, HF (aq), are both aqueous acids. Which one is a weak acid? Why?
   a. HF (aq) is a weak acid due to its short, strong bond when H-F is compared to H-Br
   b. HBr (aq) is a weak acid due to its short, strong bond when H-Br is compared to H-F
   c. HF (aq) is a weak acid due to its long, strong bond when H-F is compared to H-Br
   d. HBr (aq) is a weak acid due to its long, strong bond when H-Br is compared to H-F

3. Which of the following chemical species does not exist in an aqueous solution of H_2SO_4?

   a) H_3O^+ (aq)   b) H^+ + H_2O (aq) c) HSO_4^- (aq)   (d) SO_4^{2-}(aq)
   e) All of these exist in an aqueous solution of H_2SO_4

4. Arrange the acids $HBrO_3$, HBrO, $HBrO_2$, and $HBrO_4$ in order of increasing acid strength
   Weakest   *Strongest*
   a) $HBrO_4$ < $HBrO_3$ < $HBrO_2$ < HBrO
   b) $HBrO_2$ < HBrO < $HBrO_3$ < $HBrO_4$
   c) $HBrO_4$ < $HBrO_2$ < $HBrO_3$ < HBrO
   d) HBrO < $HBrO_2$ < $HBrO_3$ < $HBrO_4$

5. What is the expected value for the ionization constant, K_c, for this reaction? What is the acid for the reverse reaction?

   $N(CH_3)_3$ (aq) + HOH (l) $\leftrightarrow$ $NH(CH_3)_3^+$ (aq) + OH^- (aq)

   (a) $K_c > 1$; $NH(CH_3)_3^+$ (aq)
   (b) $K_c < 1$; $NH(CH_3)_3^+$ (aq)
   (c) $K_c = 1$; H_2O (l)
   (d) $K_c > 1$; OH^- (aq)
   (e) $K_c < 1$; OH^- (aq)

6. Diet cola drinks have a pH of about 3.0, while milk has a pH of about 7.0. How many times greater is the hydronium concentration in these colas than it is in milk?
   a) 4.0 times higher in colas than in milk

b) 10,000 times higher in milk than in colas
c) 100,000 times higher in colas than in milk
d) 10,000 times higher in colas than in milk
e) 4.0 times higher in milk than in colas

7. Predict whether the following reaction will have an equilibrium constant, K_c, that is… greater than/less than/equal to one, and explain "why"?
H_2SO_3 (aq) + ClO_3^- (aq). ←→ $HClO_3$ (aq) + HSO_3^-(aq)

a) greater than 1 because a strong acid is produced
b) less than 1 because a strong acid is produced
c) greater than 1 because a strong acid is consumed
d) less than 1 because a strong acid is consumed
e) equal to 1 because an acid is an acid and a base is a base

8. What is the **pH** of a 0.20 M triethylamine, $N(C_2H_5)_3$ (aq), solution ($K_b = 4.0 * 10^{-4}$)?
(a) pH = 10.7 (b) pH = $1.4 * 10^{-2}$
(c) pH = 12.0 (d) pH = 2.0
(e) pH = 7.2

9. An unknown chemical species is soluble in water. Its aqueous solution turns red litmus to blue and it produces a bright glow on the blub in the conductivity apparatus. Which of the following is the unknown species?
a) HCl b) $Ba(OH)_2$ c) $Pb(OH)_2$ d) HF
e) NH_3

10. What is the $\mathbf{K_a}$ of a 9.6 mL solution of 0.64 M hypobromous acid (HBrO) at pH = 4.4?

(a) $4.0 * 10^{-5}$ (b) 0.194 (c) $4.4 * 10^{4}$ (d) $2.5 * 10^{-4}$
(e) $2.5 * 10^{-9}$

11**.** What happens to pH and % ionization when the hypobromous acid solution in # 10 is diluted with 90.4 mL of water?
a) pH is higher and % ionization increases
b) pH is higher and % ionization decreases
c) pH is lower and % ionization increases
d) pH is lower and % ionization decreases

12. CALCULATIONS INVOLVING POLYPROTIC ACIDS
12A. Malic acid, $\mathbf{H_2M}$, is an organic diprotic acid, which used to treat fibromyalgia and acne. What is the **pH** of a 0.0100 M solution of malic acid, $H_2C_4H_6O_5$ ($\mathbf{H_2M}$)?
Given the following:
$K_{a1} = 4.0 \times 10^{-4}$ and $K_{a2} = 7.8 \times 10^{-6}$

(a) 0.00063 (b) 1.5 (c) 3.9 (a) 2.7 (d) 2.2

12B to 12F: See essay boxes
Exam 3 Essay Boxes

Name ______________________________

Questions 12: You must show your work to receive partial or full credit. Also, you must show your work for 12D on the **attached Graph**.

12. CALCULATIONS INVOLVING POLYPROTIC ACIDS

12A. (6 pts) Show your work for **H_2M**: **pH** = ________

pH of a 0.010 M **H_2M**?

12B. (6 pts) For the solution in 12A: [**HM^-**]eq = _______________; [**M^{2-}**]eq = _________________

What is the conjugate acid for **M^{2-}**? _____________

Show your work.

12C. (6 points) What is the **pH** when 0.45 M NaHM is added to the solution in **12A**? _____________ Show your work.

12D. (6 pts) On the attached graph, identify **pK_{a1}** and **pK_{a2}** plus label each of the three curves. Show the buffered **pH range** where malic acid, **H_2M**, acts as a good buffer.

Write the products of each of the following buffered chemical reaction(s):

HM^- (aq) + H^+ (aq) ←→ ________ + _________

HM^- (aq) + OH^- (aq) ←→ ________ + _________

12E. (6 pts) Rank these aqueous species from highest to lowest chemical potential energy:

H_3O^+, H_2M, H_2O, HM^-, M^{2-}

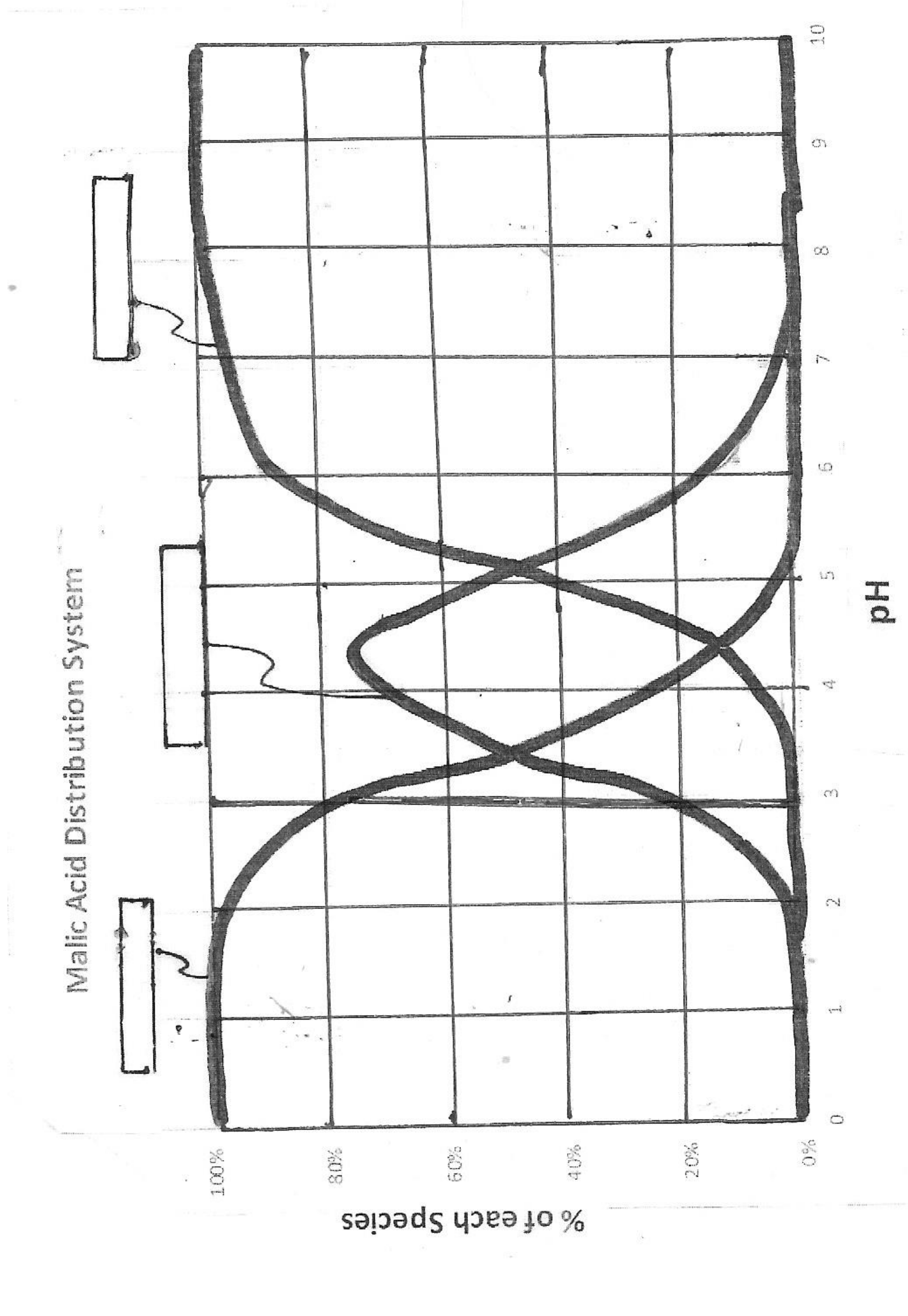
12F. (1 BONUS point) Draw the titration curve for this diprotic acid, **H_2M**. It can be a rough sketch but label the important points. You must draw this curve on the back of this page to get credit.

pH = 11

pH = 7

pH = 3

13. (4-Bonus-points) What is the main buffer in human blood? ___________________________ What is the chemical species that serves as this buffer? ______________________ What happens to this pH if the patient puts a paper bag over their head for about 5 minutes? _____________ What if the pH of blood in a living patient suddenly increases or decreases by 0.50 pH units? ______________________



Malic Acid Distribution System
% of each Species
100%
80%
60%
40%
20%
0%
0
1
2
3
4
5
6
7
8
9
10
pH

APPENDIX E

ASSIST QUESTIONNAIRE

Name________________________

Major________________________

Please work through the comments, giving your **immediate** response. In deciding your answers, think in terms of **this course (Chemistry).** It is also very important that you answer **all** the questions: check that you have.

1=strongly disagree (SD), 2=disagree (D), 4=agree (A), 5=strongly agree (SA)
*Try not to use **3** = unsure, unless you really have to, or if it does not apply to you or this course.*

1. I manage to find conditions for studying which allow me to do my work easily.
   1 2 3 4 5

2. When working on an assignment, I'm keeping in mind how to best impress the teacher.
   1 2 3 4 5

3. Often I find myself wondering whether the work I am doing here is really worthwhile.
   1 2 3 4 5

4. I usually set out to understand for myself the meaning of what we have to learn.
   1 2 3 4 5

5. I organize my study time carefully to make the best use of it.
   1 2 3 4 5

6. I find I have to concentrate on just memorizing a good deal of what I have to learn.
   1 2 3 4 5

7. I go over the work I've done carefully to check my reasoning and that it makes sense.
   1 2 3 4 5

8. Often I feel I'm drowning in the sheer amount of material we're having to deal with.
   1 2 3 4 5

9. I look at the evidence carefully and try to reach my own conclusion about what I'm studying.
   1 2 3 4 5

10. It's Important for me to feel that I'm doing as well as I really can on the courses here.
    1 2 3 4 5

11. I try to relate ideas I come across to those in other topics or other courses whenever possible.
    1 2 3 4 5

12. I tend to read very little beyond what is actually required to pass.
1 2 3 4 5

13. I regularly find myself thinking about ideas from lecture when I'm doing other things.
1 2 3 4 5

14. I think I'm quite systematic and organized when it comes to studying for exams.
1 2 3 4 5

15. I carefully look at comments on course work to see how to get better scores next time.
1 2 3 4 5

16. I don't find much of the work here interesting or relevant.
1 2 3 4 5

17. When I read an article or book, I try to find out for myself exactly what the author means.
1 2 3 4 5

18. I'm pretty good at getting down to work whenever I need to.
1 2 3 4 5

19. Much of what I'm studying makes little sense; it's like unrelated bits and pieces.
1 2 3 4 5

20. I think about what I want to get out of this course to keep my studying well focused.
1 2 3 4 5

21. When I'm working on a new topic, I try to see in my own mind how all the ideas fit together.
1 2 3 4 5

22. I often worry about whether I'll ever be able to cope with the work properly.
1 2 3 4 5

23. Often I find myself questioning things I hear in lectures or read in books.
1 2 3 4 5

24. I feel that I'm doing well, and this helps me put more effort into the work.
1 2 3 4 5

25. I concentrate on learning just those bits of information I have to know to pass.
1 2 3 4 5

26. I find that studying academic topics can be quite exciting at times.
1 2 3 4 5

27. I'm good at following up some of the reading suggested by lecturers or tutors.
1 2 3 4 5

28. I keep in mind who is going to grade an assignment and what they're likely looking for.
1 2 3 4 5

29. When I look back, I sometimes wonder why I ever decided to come here.
1 2 3 4 5

30. When I am reading, I stop from time to time to reflect on what I am trying to learn from it.
1 2 3 4 5

31. I work steadily through the semester, rather than leave it all until the last minute.
1 2 3 4 5

32. I'm not really sure what's important in lectures, so I try to write down all I can.
1 2 3 4 5

33. Ideas in course books or articles often set me on long chains of thought of my own.
1 2 3 4 5

34. Before starting work on an assignment or exam question, I think first how best to tackle it.
1 2 3 4 5

35. I often seem to panic if I get behind with my work.
1 2 3 4 5

36. When I read, I examine the details carefully to see how thy fit in with what's being said.
1 2 3 4 5

37. I put a lot of effort into studying because I'm determined to do well.
1 2 3 4 5

38. I gear my studying closely to just what seems to be required for assignments and exams.
1 2 3 4 5

39. Some of the ideas I come across in this course I find really gripping and interesting.
1 2 3 4 5

40. I usually plan out my week's work in advance, either on paper or in my head.
1 2 3 4 5

41. I keep an eye open for what instructors seem to think is important and concentrate on that
1 2 3 4 5

42. I'm not really interested in this course, but I have to take it for other reasons.
1 2 3 4 5

43. Before tackling a problem or assignment, I first try to work out what lies behind it.
1 2 3 4 5

44. I generally make good use of my time during the day.
1 2 3 4 5

45. I often have trouble in making sense of the things I have to remember.
1 2 3 4 5

46. I like to play around with ideas of my own even if they don't get me very far.
    1 2 3 4 5

47. When I finish a piece of work, I check it through to see if it really meets the requirements.
    1 2 3 4 5

48. Often I lie awake worrying about work I think I won't be able to do.
    1 2 3 4 5

49. It's important for me to be able to follow the argument, or to see the reason behind things.
    1 2 3 4 5

50. I don't find it at all difficult to motivate myself.
    1 2 3 4 5

51. I like to be told precisely what to do in essays or other assignments.
    1 2 3 4 5

52. I sometimes get "hooked" on academic topics and feel I would like to keep on studying them.
    1 2 3 4 5

APPENDIX F

INSTITUTIONAL REVIEW BOARD
APPROVAL LETTER

UNIVERSITY OF NORTHERN COLORADO

Institutional Review Board

DATE: December 11, 2018

TO: Kyle Kemats

FROM: University of Northern Colorado (UNCO) IRB

PROJECT TITLE: [1114051-5] Flow Experiences of Chemistry Students

SUBMISSION TYPE: Amendment/Modification

ACTION: APPROVAL/VERIFICATION OF EXEMPT STATUS

DECISION DATE: December 11, 2018

EXPIRATION DATE: August 22, 2021

Thank you for your submission of Amendment/Modification materials for this project. The University of Northern Colorado (UNCO) IRB approves this project and verifies its status as EXEMPT according to federal IRB regulations.

Kyle,

I hope you are doing well!

Please be sure to change Sherry's name to Nicole Morse since Sherry is now retired.

Best,

Maria

We will retain a copy of this correspondence within our records for a duration of 4 years.

If you have any questions, please contact Nicole Morse at 970-351-1910 or nicole.morse@unco.edu. Please include your project title and reference number in all correspondence with this committee.

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within University of Northern Colorado (UNCO) IRB's records.