# ASSESSING STUDENT BEHAVIORS AND MOTIVATION FOR ACTIVELY LEARNING BIOLOGY

By

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"*Now to him who is able to do immeasurably more than all we ask or imagine, according to his power that is at work within us, to him be glory in the church and in Christ Jesus throughout all generations, for ever and ever! Amen."* - Ephesians 3:20-21

This dissertation is dedicated to every person who was once told that they would never be able to realize their dreams. I am living proof that with God's help you can accomplish what others deem impossible. Never give up on your dreams.

To my dad, you are my inspiration and the one who has always encouraged me to follow my passion and supported my love of biology and teaching. I will never be able to say thank you enough for all you have done for me. I can only promise that I will pay it forward to my future students and my children. I love you very much.

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Abstract:

Vision and Change states that one of the major changes in the way we design biology courses should be a switch in approach from teacher-centered learning to student-centered learning and identifies active learning as a recommended methods. Studies show performance benefits for students taking courses that use active learning. What is unknown is why active learning is such an effective instructional tool and the limits of this instructional method's ability to influence performance. This dissertation builds a case in three steps for why active learning is an effective instructional tool.  In step one, I assessed the influence of different types of active learning (clickers, group activities, and whole class discussions) on student engagement behavior in one semester of two different introductory biology courses and found that active learning positively influenced student engagement behavior significantly more than lecture. For step two, I examined over four semester whether student engagement behavior was a predictor of performance and found participation (engagement behavior) in the online (video watching) and in-class course activities (clicker participation) that I measure were significant predictors of performance. In the third, I assessed whether certain active learning satisfied the psychological needs that lead to students' intrinsic motivation to participate in those activities when compared over two semesters and across two different institutions of higher learning. Findings from this last step show us that student's perceptions of autonomy, competency, and relatedness in doing various types of active learning are significantly higher than lecture and consistent across two institutions of higher learning. Lastly, I tie everything together, discuss implications of the research, and address future directions for research on biology student motivation and behavior.

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# CHAPTER I

## INTRODUCTION AND RATIONALE

Research shows that active learning positively affects student performance in STEM courses (see meta-analysis by S. Freeman et al., 2014). Dolan (2015) compared what we know about active learning to construction work – we know in general what tools should work, what we do not know is how best to apply these tools to help students learn biology. For example, if one needs to connect two pieces of wood using wood screws, it is not enough to know that one needs a screwdriver. One must also know what type of screwdriver is required and how much torque is required to fasten the two pieces of wood together without causing damage. The "tools" that work are the different types of active learning instruction such as clicking (use of personal response systems), Think-Pair-Share, and drawing biological processes. The specific jobs or situations to which Dolan (2015) referred are learning issues biology instructors are addressing and classes in which we introduce active learning. In this chapter, I present the rationale for the following three studies of the relationships between: 1) active learning instruction and students' behavioral engagement, 2) behavioral engagement and test performance, and 3) type of instruction and students' perceptions of how well their psychological needs that promote intrinsic motivation are met. These studies are presented in the subsequent chapters. In brief, the rationale for these studies are as follows. For study one, the premise is that an instructional technique designed to make students active participants in the learning process (Bonwell & Eison, 1991) should elicit more action (behavioral engagement) than passive learning instruction. For study two, the premise is that if an instructional technique designed to make students active participants in the learning process (Bonwell & Eison, 1991) is shown to improve student test performance, perhaps the performance benefit students receive stems from their active participation (behavioral engagement). For study three, the premise is that student participate during an activity designed to promote active learning because of their internal motivation to participate. If that is the case, students should perceive active learning activities as possessing characteristics which fulfill their psychological needs for self-determination, which increases the chances they will be intrinsically motivated (Deci & Ryan, 1985b).

*Active learning*

Many researchers have provided evidence for replacing passive learning (lecturing) with active learning, as first described by Bonwell and Eison (1991), the goal of which is to make students active participants in the learning process. Many types of instruction are classified as active learning (e.g., clickers, Think-Pair-Share, Think-A-Louds, Problem-Based Learning, and Case-Based learning). Bonwell and Eison (1991) defined active learning in terms of student action, “They must read, write, discuss, or be engaged in solving problems. Most important, to be actively involved, students must engage in such higher-order thinking tasks as analysis, synthesis, and evaluation. Within this context, it is proposed that strategies promoting active learning be defined as instructional activities that involve students in doing things and thinking about what they are doing.” However, as measuring higher-order thinking is difficult, I will, for the purposes of this research, focus on what students are doing with the assumption that students who are participating in these tasks are using higher-order thinking skills during participation.  Conversely, passive learning is defined in terms of student inaction, “Passive learning takes place when students take on the role of "receptacles of knowledge"; that is, they do not directly participate in the learning process.” (Ryan and Martens 1989, p. 20). In this work, I chose to measure student levels of "doing things" as represented by students' behavioral engagement and limit my data collection to that portion of Bonwell and Eison's (1991) definition.

Over the years, a few researchers have hypothesized rationales to explain why active learning works (Butler & Dee, 2003: Haak, HilleRisLambers, Pitre, & Freeman, 2011). A rationale explaining how active learning works is students engage with the same information repeatedly and from different sources. We know from the information processing model of learning that the more frequently one encounters the same information the greater likelihood one remembers it (Schunk, 2012; Thorndike, 1913). For example, a student learns about photosynthesis outside class through either reading or watching a video (encounter 1), comes to class and hears more about it through an example explained by the teacher (encounter 2), and then again on a group worksheet that gets returned at the end of the class period (encounter 3). Another rationale commonly used to explain why active learning works is that active learning forces students to recall previously learned information (Prince, 2004). Recalling information from long-term memory into working memory helps build and strengthen connections to that piece of information (Snowman, 1986). Because the brain is constantly pruning unused synapses, recalling information is necessary to maintain memories (Paolicelli et al., 2011). An example of an instructional tool used in stimulating recall is the use of classroom response device (clickers) and question sets. Clickers and question sets force students to recall what they have learned to answer a question in a limited amount of time. From the constructivist theory of learning, we know that connecting pieces of knowledge, or putting them in context, facilitates recall (Bruner, 1960; Phillips, 1995; Steffe & Gale, 1995). Students have the opportunity to experience this improved recall benefit through a variety of types of active learning such as group learning (Slavin, 1990), Think-Pair-Share (Lyman, 1981), and argumentation (Driver, Newton, & Osborne, 2000). In the studies described here, I investigated student behavioral responses to active learning instruction assuming behavioral engagement was a proxy for cognitive engagement and students who actively participated during active learning instruction received the cognitive benefits while participating.

*Motivation to learn*

Motivation has been defined as "the process of instigating and sustaining goal-directed behavior" and is a continuum from amotivation to intrinsic motivation (Schunk, Meece, & Pintrich, 2014). I chose the motivational construct of intrinsic or internal motivation for this study. One is intrinsically motivated when one engages in a task for the simple pleasure of being engaged in the task itself (Deci, 1975). Intrinsic motivation is positively correlated with self-efficacy (McAuley, Wraith, & Duncan, 1991). Intrinsic motivation is also positively correlated with high academic achievement while low academic achievement was correlated with high levels of pressure and tension (Malik & Parveen, 2015). The self-determination theory of motivation proposes that people have three separate basic psychological needs: competency (a sense of understanding), autonomy (a sense of choice), and relatedness (a sense of connection) and when these needs are met, individuals are more likely to be intrinsically motivated (Deci, 1975; Deci & Ryan, 1985). Students' motivation moves from amotivation to internal motivation as the three needs are met (Schunk et al., 2014).

Research on self-determination theory has shown that when the three psychological needs are met, students are more motivated to engage with subjects such as organic chemistry (Black & Deci, 2000), physical education (Standage, Duda, & Ntoumanis, 2005), and introductory psychology (Deci, Eghrari, Patrick, & Leone, 1994). High levels of autonomy support are predictive of career choices in the medical professions (Williams, Saizow, Ross, & Deci, 1997) and support self-regulated behavior (Deci et al., 1994). Schumm and Bogner (2016) showed that women have higher levels of intrinsic motivation, which compensate for low self-efficacy beliefs, therefore women's and men's psychological needs are equally met in science courses. Programs that increase intrinsic motivation may help young women become successful in science. It has been theorized that the flipped learning method of instruction, where students watch video lectures outside of class and participate in active learning instruction in class, meets these needs because it allows for more time to be spent on active learning instruction (Abeysekera & Dawson, 2014), but empirical evidence is lacking. Whether different types of active learning can meet the three needs still requires further investigation.

*Engagement*

There are three basic types of engagement: behavioral, cognitive, and emotional (Finn, Pannozzo, & Voekl, 1995: Fredricks et al., 2004; Skinner & Belmont, 1993). In this work, I focused solely on behavioral engagement, a well-accepted metric of instructional effectiveness (Finn, Pannozzo, & Voekl, 1995), that I could assess without reliance on student self-reports and thus was the most reliable form of engagement to assess. Researchers disagree on the exact definition of behavioral engagement in class. Definitions rage from broad, any type of academic or extracurricular involvement that promotes academic success (Fredricks et al., 2004); to specific, prolonged physical involvement in a learning task (Skinner & Belmont, 1993). Behavioral engagement has also been defined as the absence of inattentive or disaffective (bored, anxious, or angry) behavior (Finn, Pannozzo, & Voekl, 1995; Skinner & Belmont, 1993). Robinson and Hullinger (2008) describe course engagement as the time and energy a student expends during course activities further supporting Skinner and Belmont (1993)'s conception of behavioral engagement. For the purposes of this work, I define behavioral engagement as both prolonged physical involvement in a learning activity (Skinner & Belmont, 1993) and the absence of inattentive behavior (Finn, Pannozzo, & Voekl, 1995).

Students' engagement levels have interested instructors and researchers for some time (Fredricks et al., 2004). Fredricks et al. (2004) divided engagement outcomes into two categories: increase in positive outcomes, such as academic achievement, and reduction of negative outcomes, such as attrition rate reduction. Course engagement affects college student performance and persistence positively (Kuh, Cruce, Shoup, Kinzie, & Gonyea, 2008). Hampden-Thompson and Bennett (2013) found a significant correlation between student cognitive and emotional engagement and motivation to study and enjoyment of science. Kuh, Kinzie, Cruce, Shoup, & Gonyea, (2007) demonstrated that behavioral engagement in academic activities has been shown to offset lack of college preparedness for those with low academic ability.

The evidence supporting the use of behavioral engagement as a measure of course satisfaction and effectiveness is substantial (Finn, Pannozzo, & Voekl, 1995: Fredricks et al., 2004; Skinner & Belmont, 1993). Research has shown that students who are behaviorally engaged in class receive significantly more support from their instructors then students who are bored, disinterested, or angry (Skinner & Belmont, 1993). In addition, research has also shown that behavioral engagement can help mitigate school adjustment and increase school choice satisfaction (Birch & Ladd, 1997). Conversely, behavioral disengagement (inattentiveness) has been shown to correlate with feelings of depression and poor academic performance (Finn, Pannozzo, & Voekl, 1995). Linnebrink and Pintrich (2003) described how self-efficacy could be a catalyst for behavioral engagement.

*Assessing learning and motivation*

One hypothesis for how active learning works is that those who participate in active learning instruction are more likely to be intrinsically motivated as a result of their participation in learning. I define active learning participation as a type of behavioral engagement that occurs during an instructional method designed to elicit student behavioral responses. For example, to participate during the clicker portion of class is to physically depress the button on one’s clicker or select the corresponding answer choice on the phone app. Abeysekera and Dawson (2014) reasoned active learning could satisfy students’ motivational needs for autonomy, competency, and relatedness as discussed in self-determination theory (Deci & Ryan, 1985). To establish a path from instruction to motivation, I took a three-step approach (Fig. I.1).


Figure I.1. Three-step approach to linking instruction to motivation by answering three questions. First question: How does instruction effect behavioral engagement? Second question: Does behavioral engagement effect performance? Third question: What effect does behavioral engagement have on motivation?

These steps link the impact of method of instruction on behavioral engagement (step one) to the impact of behavioral engagement on academic performance (step two) to intrinsic motivation's role as the driver for students' behavioral engagement (step three).

Step one assesses differences in behavioral engagement elicited between active and passive learning as well as differences in engagement patterns between different types of active learning instruction. Step two assesses the impact participation has on academic performance. Participation in instructional activities, such as using clickers, is an example of behavioral engagement (Fredricks et al., 2004). Behavioral engagement studies on learning tend to focus on different participation metrics. In flipped and blended learning, students gain content knowledge outside of the class through media like videos and textbooks (Bergmann & Sams, 2009; Bristol, 2014). In courses where on-line videos are provided through an institutional learning management system (LMS), researchers can take advantage of recording students interactions with the LMS, which is the most accurate, measureable representation of behavioral engagement with online course content (Chen, Lambert, & Guidry, 2010; Coates, 2007; Dixson, 2010; Rubin, Fernandes, Avgerinou, & Moore, 2010). Forcing students to gain content knowledge outside class frees class time for active learning. Active learning instruction should enhance traditional types of instruction (lecture) (Bonwell & Eison, 1991; Prince, 2004).

Students who gain knowledge from video lectures (videos of previously recorded lectures put online for students to view) and strengthen their knowledge through practice with active learning should experience an academic performance benefit over those who do not. Therefore, I examined how well participation in lecture (video watching) and active learning (clicker participation) predicted student academic performance (exam scores).

In Step three, I examined whether increased intrinsic motivation might be associated with active learning and be the rationale for students' participation in active learning. Abeysekera and Dawson (2014) hypothesized active learning's effectiveness stems from its ability to support student psychological needs, specifically those associated with intrinsic motivation including autonomy, competency, and relatedness. Traditionally intrinsic motivation is measured via student self-report surveys (McAuley, Duncan, & Tammen, 1989; McAuley et al., 1991). I used the Intrinsic Motivation Inventory (IMI) (McAuley, Duncan, & Tammen, 1989; McAuley, Wraith, & Duncan, 1991) to compare the extent to which different types of active learning instruction met students psychological needs when compared to non-active learning instruction and to examine how measures of need fulfillment correlated with measures test performance, belonging to the scientific community, and interest in science, factors associated with motivation to persistence in the major (Bye, D., Pushkar, D., & Conway, M., 2007; Chemers, Zurbriggen, Syed, Goza, & Bearman, 2011; T. M. Freeman, Anderman, & Jensen, 2007).

The conclusions chapter is an attempt to integrate the results of the three steps and present a resulting hypothesis for the observed impact of active learning on student success as measured by performance in courses. In doing so, I cautiously connect students' active learning to an increased likelihood of those students being intrinsically motivated, thus providing one answer to the question left by S. Freeman et al. (2014)'s work as to why active learning is effective at increasing performance and for whom is it effective. Additionally, I describe how my research can be viewed as a starting point for future research laying out several possible next steps that should be taken to better understand these motivational outcomes of active learning.

# CHAPTER II

## STEP 1: ASSESSING THE EFFECT OF ACTIVE LEARNING ON STUDENT BEHAVIORAL ENGAGMENT

### ABSTRACT

The ultimate goal of instruction is to help students learn. One of the biggest hindrances to learning in class is distraction. The less distracted students are, the more likely they are to learn. One of the simplest ways to assess students' learning attempts during course instruction is to observe the behaviors in which they engage during class. Recently, there has been an increase in interest in collecting, qualifying, and quantifying behavioral data, specifically in science, technology, engineering, and math (STEM) courses. The goal of this study was to quantify and assess differences in student behavioral engagement as a representation of instructional effectiveness. To do this, I compared a flipped class to a traditional lecture class. To meet my research needs, I developed the Protocol for Research Observing Student Engagement (PROSE). Using PROSE, I recorded students' behaviors, which I then classified as on-task and off-task. I found a significant difference in engagement patterns over time between active learning instruction and lecture and among active learning instructional techniques. I propose hypotheses to account for the differences over time in off-task behavior and suggestions for further research on PROSE and student behavioral engagement.

## INTRODUCTION

Increasing student engagement has been a focus in educational reform for some time (Brewer & Smith, 2011; NRC, 2000, 2003, 2009). Engagement is comprised of both behavioral and affective components. An important and readily observable aspect of behavioral engagement is attention focus. Attention focus is the external point on which student attention is concentrated (Lohse & Sherwood, 2011). Attention focus can be influenced by difficulty of task and amount of information disseminated, also known as cognitive load (Sweller, 1991). As a student becomes more engaged in a topic, the more attention he or she focuses on learning the topic and the less likely he or she is to be distracted (Marks, 2000). The effect of improved engagement in the classroom is higher performance, greater satisfaction, better self-regulation, and increased motivation (Carini, Kuh, & Klein, 2006; Schunk, Meece, & Pintrich, 2014; Skinner & Belmont, 1993).

Increasing student focus, also known as attention, in the classroom is an important aspect of keeping students engaged in the classroom (Blatchford, Bassett, Brown, & Webster, 2009; James & Hardardottir, 2002). Students generally lose focus in class somewhere between 10 and 18 minutes during any one particular activity (Johnstone & Percival, 1976), with 15 minutes being the time at which the most students lose focus during a traditional lecture (Burns, 1985; Stuart & Rutherford, 1978). Recently, those findings have been challenged as being more nuanced than originally thought (Wilson & Korn, 2007). Research has shown techniques effective at improving attention span such as doodling (Andrade, 2010; Singh & Kashyap, 2015) and intermittent quizzing (Risko, Buchanan, Medimorec, & Kingstone, 2013). Researchers posit that limiting instructional activities to this duration will help increase student focus in the classroom no matter the instructional activity (Bland, Saunders, & Frisch, 2007; McLeod, Fisher, & Hoover, 2003).

Instructional activities can generally be categorized as passive (activities requiring students to simply absorb information) or active (activities requiring behavioral engagement and higher-order thinking) (Bonwell & Eison, 1991). Passive learning occurs when the professor disseminates knowledge to his or her students in a recitative format, whereas active learning requires a physical contribution from the student during the instruction. An example of active learning is group discussion where students discuss a question with each other and collectively produce an answer (Abeysekera & Dawson, 2014; S. Freeman et al., 2014). S. Freeman et al. (2014) conducted at meta-analysis of studies on active learning and discovered that students performed significantly better in classes with active learning than in classes without. However, that analysis did not provide insight into any differences among the effectiveness of techniques nor how the techniques had their effects, which are areas in which research is lacking (Dolan, 2015). Dolan (2015) suggested studies should look for distinguishable differences in characteristics between students who are and are not positively affected by the techniques, how the students are responding to these techniques, and what factors are driving these student responses.

Researchers have posited different hypotheses for the observed increase in students' grades in active learning classes. These hypotheses are differentiated by where the locus of control lies for active learning behavioral engagement, i.e. whether the locus is internal or is it external. Examples of loci under internal control are changes based on students' internal emotional or cognitive states as represented through a change in students' attitudes or motivation (Ryan & Deci, 2000). Those who hypothesize that the locus of control is external explain increases in students' performances through observable changes in instructor behavior, such as additional repetition of information or presenting course material in multiple formats (Smith, Jones, Gilbert, & Wieman, 2013). Evidence for these explanations has solely been derived from student self-report measures, which are inherently problematic for their potential for inaccuracy in students' self-representations (Hindelang, Hirschi, & Weis, 1979).

One way to examine the impact of active learning instruction is through quantifying students' behavioral responses to different types of instruction, known as student behavioral engagement (Fredricks, Blumenfeld, & Paris, 2004). Students who are more engaged in learning should be more focused on appropriate classroom activities and less focused on inappropriate ones like social media or texting. Rather than assessing student classroom behavior through student self-reports, I chose direct observation. Both instructor behavior and student focus have been studied as measures of instructional effectiveness (Dolan, 2015; Hora, Oleson, & Ferrare, 2013; Lane & Harris, 2015; Sawada et al., 2002; Smith et al., 2013); however, the observational techniques used in those studies were not suitable for assessing student behavioral engagement in a large classroom in a systematic fashion. Therefore, I developed a protocol to measure student behavioral engagement systematically by observing students. This assessment method allowed comparisons of students' behaviors during one passive and four active instructional activities.

*Behavioral assessments*

Existing behavioral assessments include the Reformed Teaching Observation Protocol (RTOP Sawada et al., 2002), Teaching Dimension Observation Protocol (TDOP Hora et al., 2013), Classroom Observation Protocol for Undergraduate Students (COPUS Smith et al., 2013), and Behavioral Engagement Related to Instruction (BERI Lane & Harris, 2015). RTOP and TDOP measures are considered difficult to understand, require extensive training time to execute, and report on items that may not have an effect on student attention (Smith et al., 2013). The COPUS and BERI were developed to assess student and professor actions quickly during large lecture classes. COPUS, a modified TDOP assessment, was designed to categorize the instructor's actions and capture generalized behavior of the whole class at each time point (Smith et al., 2013). This method provides an accurate assessment of the instructor's actions, but logs student behaviors only as off-task or on-task. I considered recording specific behaviors essential to better understanding how different modes of instruction influence specific behaviors. Therefore, a more systematic approach was warranted to capture a more descriptive dataset.

BERI is specifically designed to collect quantitative data on student classroom behavioral engagement. To accomplish this goal, researchers sit in random locations and observe a group of 10 students (as they determined that to be the limit one could observe simultaneously) for a whole class period collecting behavioral engagement data every 2 minutes. A researcher records the amount of on and off task behaviors onto a copy of the professor's notes for that day's instructional session so that the instructor can see how engaged students were during specific tasks at specific time points. On and off-task percentages are recorded as well as unique behaviors not previously categorized as on-task or off-task (Lane & Harris, 2015). While this may be sufficient evidence for an instructor to see if a class was engaging or not on a particular day, it does not indicate which off-task behaviors were most common, where in the classroom disengagement is occurring, or if these disengagement patterns are consistent across the classroom. Lane and Harris (2015) suggest student behavior follows a general pattern across the classroom and therefore observations of only ten students at a time were adequate. While this provides data suited to generalizing classroom behavior for the instructor's benefit, it does not provide data suited for this research. For example, neither COPUS nor BERI report data on student use of electronic devices. Collecting such data could give instructors useful insights that can be used to decide on actions that would encourage appropriate behavior.

Additionally, the focus of COPUS, BERI, and TDOP is to measure instructor behavior to indicate the extent to which the instructor practices reformed teaching in the classroom, not to provide data on the effects of these teaching practices on students' performance of specific behaviors in the class. This distinction is important if the data are to be used to test the effects instructional practices have on behavioral engagement frequency.

*Research questions:*

1) Does active learning instruction elicit more behavioral engagement and maintain that engagement at a higher level than lecture?

2) Do different types of active learning instruction differ in their abilities to elicit and maintain engagement behavior?

## MATERIALS AND METHODS

### *Classroom Environment & Subjects*

I conducted this study, with IRB approval (AS-14-56), at a large, land grant, research intensive, south-central university during the spring 2015 semester. I observed students enrolled in two sections of a mixed-majors, general-education, introductory biology course. In one section (Section A), with an enrollment of 135 students, the instructor used a flipped format (Bergmann & Sams, 2009), in which students watched recorded lectures online outside class, and active learning instruction. In the other section (Section B) with an enrollment of 102 students, the instructor lectured. Class attendance averaged 80 and 62 students for each section respectively. All students in this course took common exams written collectively by the faculty members teaching the course. Common exams ensured that all instructors were responsible for teaching, and all students for learning, the same material.

In this study, I observed student behaviors during one passive (lecture) and four active instructional activities: Verso®, group activity, discussion, and clickers. Verso® is a free crossplatform app that allows students to anonymously post, “like,” and respond to relevant questions or comments about course material from their instructor or peers. Group activities required a small subset of the class, usually between three to four individuals, to work together to complete tasks such as fill-in-the-black worksheet or diagramming a biological process. Discussion was the component of class where the conclusions and questions that resulted from the group activities were presented to the whole class for open discussion. Clickers, also known as classroom response devices, are hand-held devices that allow students to answer instructor questions. After students finished answering the question, the professor displayed the distribution of student answers, allowing students and professor to see which answer choices most students considered correct. Which answers were correct were not revealed. This allowed the professor to see if students in attendance understood the material and provided students an opportunity to discuss the validity of their answers among themselves. During a class period, these instructional activities always occurred in the following order in the flipped class: Verso®, small group activity, whole class discussion, and clickers. Each of these instructional activities lasted between 10 and 15 minutes.

*Defining Behaviors & Developing the Protocol for Research Observing Student Engagement (PROSE).*

I looked at the student response to active learning as measured by student behavioral engagement. I took six steps to develop and validate PROSE.

Step 1: During the first class period of the semester, two observers positioned themselves around the classroom and took extensive notes on what students did. The observations were conducted separately to ensure that one observer did not bias the other observer. Observers noted and described as many unique behaviors as possible. After the first session, observers compared notes to develop preliminary behavioral descriptions.

Step two:  The observers developed a preliminary list of observed behaviors and definitions of those behaviors. During the second class period, observers worked together to test preliminary definitions and check for needed changes.

Step three: Observers refined primary behavioral descriptions and created a final operationalized list of student behaviors (Table II.1).

Step four, I created a paper form for data collection (Appendix I.1). Data recorded included observation date, name of observer, quadrat observed, time of observation, number of students in quadrat, number of students attending class that day (marked in five-minute increments), and whether an instructor was in the quadrat during the observation. Additionally, there were spaces to record the number of related, unrelated, and undecided behaviors listed in Table II.1 every five minutes and a column to total the behaviors for that class period. There were also two lines for notes about students leaving the quadrat or to record behaviors not listed on the sheet.

Step five: Criteria were developed to categorize each occurrence of a behavior as either on-task or off-task (Table II.1). I defined on-task behavior as behavior appropriate for the particular course component. For example, students could access Verso questions on any mobile device; therefore, if students used their mobile devices to access the Verso questions during the Verso course component, the student's behavior would be marked as on-task. Conversely, students using their mobile device to check email during any course component would be marked as off-task.

Table II. 1. Operational definitions of student behavior in the flipped BIOL 1114 classroom.

| Behavior | Operational Definition |
|---|---|
| Listening | Student is looking at or reacting (such as nodding his or her head) to whomever is speaking or otherwise communicating. |
| Computer | The student's eyes are directed at an active screen or the student is typing. |
| Phone | The student's eyes are directed at an active screen or the student is typing. |
| Taking Notes | Instructor is presenting and student is writing while periodically glancing up to the instructor or screen. |
| Talking to Other Students | Student is talking to a peer. |
| Interacting with Instructor | Student is conversing (i.e. asking a question) with the professor or a teaching assistant. Instructor can be at head of class or within or adjacent to student's quadrat. |
| Other | A behavior that cannot be placed into the above categories. Examples included, but were not limited to, writing on or reading a worksheet, reading a textbook, doodling, and clicking. |
| **Category** | **Operational Definition** |
| On-Task | Behavior does not distract student's focus from the current classroom activity. |
| Off-Task | Behavior distracts student's focus from the current classroom activity. |

Step six: To establish interobserver reliability, the two observers conducted eight class observations in tandem. They recorded observations simultaneously from the same quadrat for an entire fifty-minute class period then compared categorizations and discussed discrepancies after each class period. To assess interobserver reliability, I followed Hallgren's (2012) recommended use of Cohen's kappa for calculating agreement. Calculation of Cohen's kappa using IBM SPSS® 23 to, produced a high interobserver reliability value of 0.857 (Landis & Koch, 1977; Watkins & Pacheco, 2000). To establish validity for our recording procedure, I examined and compared the data collected 24 times in the flipped intro biology course and 8 times in a traditional biology course and found them consistent across both environments, i.e., the same behaviors were observed in both classes, rarely was a behavior observed that was not already listed on the collection form, and there were few instances when a behavior could not be classified as either on-or off-task (see results for details). This met the desired, published standard

(Cluster 3, Standard 1.11) for content-oriented evidence (American Educational Research Association., American Psychological Association., National Council on Measurement in Education., & Joint Committee on Standards for Educational and Psychological Testing (U.S.), 2014).

*Data collection*

**Data Sources**. The classroom was divided into eight quadrats for observation. I determined quadrat size by assessing how far a student could sit from an observation point and still be observed accurately. I used a random number generator to determine which quadrats to observe. Quadrats ranged in number of occupants from seven to twenty-two students. I used scan sampling (Lane & Harris, 2015), an observation method where the behavior of a group of individuals is instantaneously surveyed (Martin, Bateson, & Bateson, 1993). Student behaviors were scored every five minutes during a typical fifty-minute class period on a scoring sheet. I also recorded the course component at time of observation. Data collection occurred during 24 flipped class periods and 8 traditional class periods.

**Analysis**. Since observations were non-continuous data, I used a log-linear chi-square analysis to determine significant differences for the main effects of time interval (5,10, and 15 minute) and task type (on/off) and for any interactions in student on- and off-task behavior during the different instructional activities. Bishop, Fienberg, and Holland (1974) showed a logarithmic transformation followed by chi-square analysis allows interpretation of results in a fashion to similar to that of ANOVA.  This model still evaluates expected versus observed frequency in the data tables (Bishop, Fienberg, & Holland, 2007). When chi-square values indicated a significant difference, I used standardized residuals values above the 2.0 or below the -2.0 threshold as the criteria to determine for which instructional activities were the differences significant (Agresti & Kateri, 2011; Rice, 1989).

RESULTS

Figure II.1 displays the mean percentage of students exhibiting off-task behavior at each sample time-point for each instructional technique. A chi-square analysis with IBM SPSS® version 23 software for the main effects of time and activity on both on- and off- task behavior indicated statistically significant effects for both factors, $\chi 2(df = 2, n = 2521) = 15.63$, $p<.001$ and $\chi 2(df = 4, n = 2521) = 88.09$, $p<.001$ respectively. A log-linear contingency analysis using VassarStat's online tool found a significant interaction of time and activity $G2(df = 8, n = 2521) = 211.86$, $p<.001$. Thus, the percentage of students involved in off-task behaviors vary over time and between behaviors but the pattern is complex (Fig. II.1 and Table II.2).

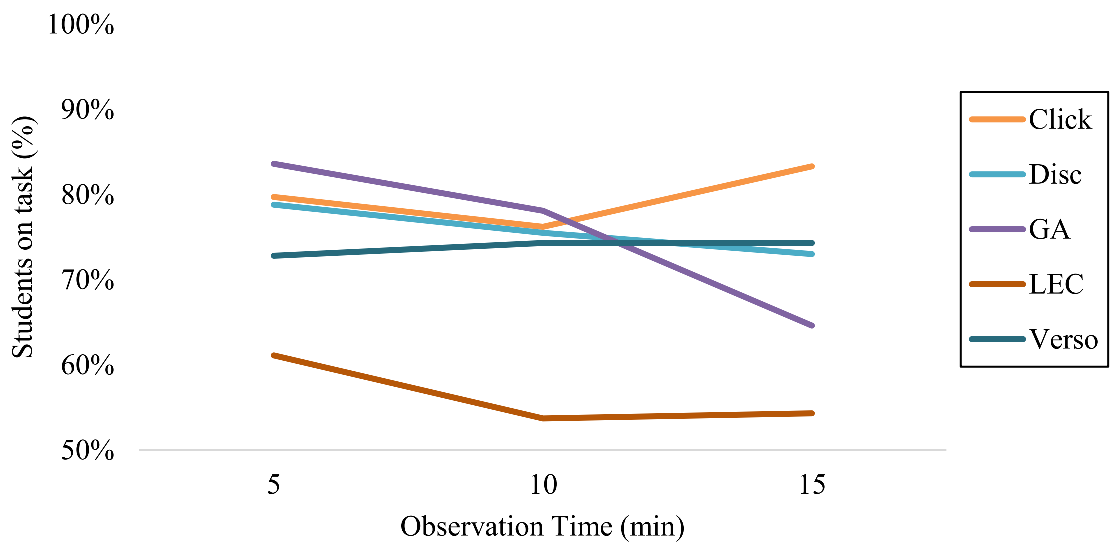


Figure II.1. On-task behavior over time during the five different in-class instructional activities: Clickers (Click), Discussion (Disc), Group Activity (GA), Lecture (LEC), and Verso. Students exhibited significantly more on-task behavior during all types of active learning (Click, Disc, GA, and Verso) than during the passive component (LEC).

Table II.2. Percentage of students exhibiting on-task behavior at the 5, 10, and 15-minute observation time points during each of the five different in-class instructional activities.

| Instructional Activity | **5 minute time point** | **10 minute time point** | **15 minute time point** |
|---|---|---|---|
| **Clickers** | 79.7% | 76.2% | 83.3% |
| **Discussion** | 78.8% | 75.5% | 73.0% |
| **Group Activity** | 83.6% | 78.1% | 64.6% |
| **Lecture** | 61.1% | 53.7% | 54.3% |
| **Verso** | 72.8% | 74.3% | 74.3% |

Three distinct trends appear to be in the data. The first trend is that student on-task behavior decreased over time during discussion, group activity, and lecture. The second trend is an increase in on-task behavior over time during Verso and clicker activities. Both activities are comprised of multiple shorter units composed of presentation and discussion of a question for about five minutes. Thus, students engaged with each new question. The third trend is the consistently lower percentage of students exhibiting on-task behavior during lecture.

Table II.3 presents the complete list of behaviors and the percentage of time each was observed as an on- or off-task behavior during each of the instructional activities. Fig. II.2 presents a comparison of the most common on-task (listening) and off-task (phone) behaviors for each of the different types of active learning. Listening included listening to the instructor or a classmate; the individual toward whom the listening was focused was not recorded, only whether the listening was an on- or off-task behavior at that moment. Group activity had the lowest percentage of listening students, but included the second highest percentage of talking to other students as a specific on-task behavior, such as (11.5%). The most commonly observed off-task behavior during the four active learning instructional methods was cell phone use (13%-17%).

Table II. 3. Percentages of on-task and off-task behaviors observed during each of the active learning instructional activities. * = Behavior that accounted for largest portion of students' on-task behavioral engagement. $ = Behavior that accounted for largest portion of students' off-task behavioral engagement.

| Behavior | Task Relatedness | Verso | Group Activity | Discussion | Clickers |
|---|---|---|---|---|---|
| **Computer** | On-Task | 0.19% | 0.74% | 0.79% | 0.00% |
| | Off-Task | 4.28% | 0.99% | 4.96% | 1.03% |
| | Undecided | 0.00% | 0.00% | 0.00% | 0.00% |
| **Listening** | On-Task | 64.20% * | 34.48% * | 60.12% * | 58.10% * |
| | Off-Task | 0.78% | 2.22% | 0.79% | 2.06% |
| | Undecided | 0.00% | 0.25% | 0.00% | 0.00% |
| **Phone** | On-Task | 0.19% | 1.11% | 0.79% | 0.26% |
| | Off-Task | 17.32% $ | 14.53% $ | 14.29% $ | 13.11% $ |
| | Undecided | 0.00% | 0.00% | 0.00% | 0.00% |
| **Taking Notes** | On-Task | 2.92% | 1.11% | 7.34% | 1.80% |
| | Off-Task | 0.19% | 1.11% | 0.20% | 0.00% |
| | Undecided | 0.00% | 0.00% | 0.00% | 0.00% |
| **Talking to Other Students** | On-Task | 3.31% | 11.45% | 0.20% | 0.77% |
| | Off-Task | 1.17% | 2.71% | 0.99% | 2.31% |
| | Undecided | 0.00% | 2.34% | 0.00% | 0.00% |
| **Interacting with Instructor** | On-Task | 0.78% | 4.06% | 0.40% | 0.00% |
| | Off-Task | 0.00% | 0.00% | 0.00% | 0.00% |
| | Undecided | 0.00% | 0.00% | 0.00% | 0.00% |
| **Other** | On-Task | 2.33% | 19.46% | 7.34% | 17.74% |
| | Off-Task | 2.33% | 3.45% | 1.79% | 2.83% |
| | Undecided | 0.00% | 0.00% | 0.00% | 0.00% |

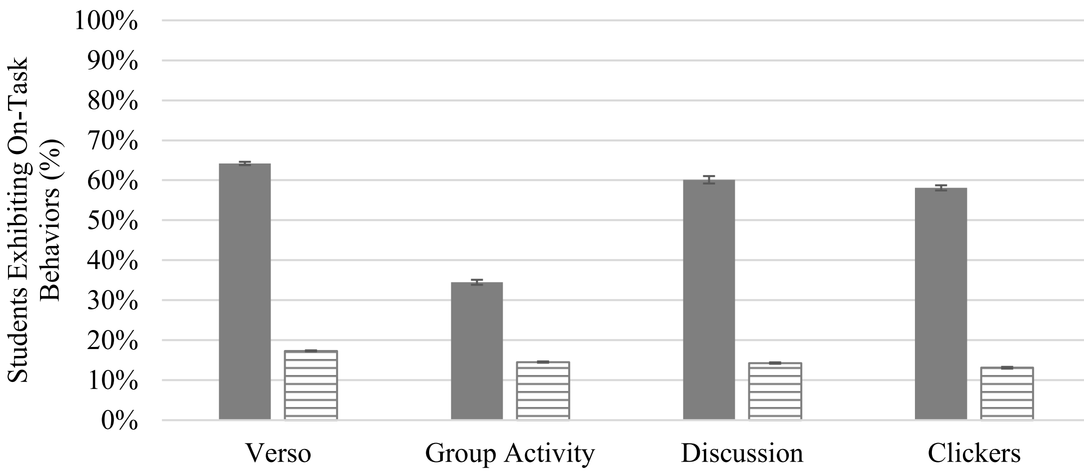


Figure II.2. Percentages of students performing the most common on-task (listening; represented by the solid grey bars) and off-task (cell phone; represented by the grey striped bars) behaviors for each of the four types of active learning instructional activities used in class. Error bars represent the standard error of the means.

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DISCUSSION

This study was designed to characterize and quantify student behavioral engagement during different types of instruction as a representation of instructional effectiveness. My questions included whether active learning instruction had the ability to elicit and maintain high levels of behavioral engagement as well as whether different types of active learning instruction elicit and maintain student behavioral engagement differently. Results indicate active learning instruction can elicit and maintain high levels of behavioral engagement; but different not all types of active learning instruction elicit and maintain students' behavioral engagement similarly. Lam et al. (2012) demonstrated that behavioral engagement was highly correlated with curiosity. Researchers have acknowledged that curiosity and interest constructs overlap (Tobias, 1994) and that people are more likely to remember that which is interesting (Bower, 1992). Interest also correlates with enjoyment (Ainley & Ainley, 2011). If a large percentage of students in a classroom are behaviorally engaged at any one point in time, then either the material or the method of material presentation is interesting. Therefore, the material covered is more likely to be remembered, unless the method of presentation is too distracting from the message being conveyed, which will result in students remembering how the material was presented without actually remembering the material itself. The feelings of enjoyment resulting from interest should encourage class attendance as long as the interest is sustained. This rationale explains the recent interest in student behavioral engagement in the classroom (Lane & Harris, 2015; Sawada et al., 2002; Smith et al., 2013). During the Verso® component of the class, the instructor addressed questions students submitted and voted for as most important to discuss. That a portion of the class was inattentive because they were uninterested in the question or perceived they knew the answer could explain the moderate level of behavioral engagement during Verso®.

Lecture was consistently least able to hold student attention. The four types of active learning observed were all more effective at focusing student attention on the material than lecture (Table II.1). This is not surprising as lecture is a passive method of learning that requires little participation from the student (S. Freeman et al., 2014). As lecture time increases, researchers have reported that "mind wandering," what we call off-task behavior, increases and content retention decreases (Risko, Anderson, Sarwal, Engelhardt, & Kingstone, 2012). These studies shed light on why some lecture courses work better than others do. If one breaks up his or her lecture with an activity, attention increases, which may lead to students remembering that which has been discussed, especially if that activity helped reinforce what was learned through retrieval practice (Karpicke & Roediger, 2008).

The discussion portion of class was used to discuss the results of the group activity. Again, most students are initially interested in discovering the solution to the activity. This behavioral pattern of initial high engagement is consistent with my observations that all types of active learning initially elicit high levels of behavioral engagement. However, as the discussion progresses students lose focus in a similar manor as they do during lecture. Possibly, students are only discussing a single topic for the entire fifteen-minute period and have no stimulus to re-focus their attention. Another explanation would be that the active learning task is too difficult for the students to complete. Vygotsky, in his zone of proximal development theory, stated that learners are able to complete, with help from others, difficult tasks that lie just outside of the ability of the individual (Vygotsky, 1980). Conversely, Vygotsky said if a task lies too far outside of one's ability, then that person will not be able to complete the task and will therefore be disengaged.

The steps followed during a clicker session are described in Table II.4. The level of complexity of the question dictated how much of the 30 seconds response period students would dedicate to answering the question. The more complex the question, the more time it took them to choose an answer. Students were also observed writing down questions that they perceived to be, as one student described them, "difficult like an exam question." Completing all the steps in Table II.4 for a single question took between five and ten minutes, after which the instructor posed a new question if the time allotted for that activity allowed. Perhaps there is a re-stimulation effect resulting in a period of re-engagement every time the instructor posed a new question. It would seem probable that there would be a large drop off in student behavioral engagement after the initial question period (30 seconds), but behavioral engagement would quickly resume once students were directed to compare answers and reasoning.

Table II. 4. Description of the process of asking a clicker question in an introductory biology course.

| Step | Definition and Description |
|---|---|
| **Question Presentation** | The point at which the instructor reveals PowerPoint slide with the question and then starts 30-second timer. During this time, the instructor answers only clarification questions. |
| **Student Response** | Time after instructor starts the timer during which students read the question, processes the information, and select the answer he or she believes is correct. This processing and answering period can take anywhere between 10 to 30 seconds depending on the student's knowledge and information recall ability. Students tend to switch directly to off task behavior after they have selected an answer. |
| **Answers Revealed** | Point after the end of the 30 seconds, the instructor reveals the students' answer choice distributions and asks students if they are ready to move on or if they would like to discuss their answers with their peers. If answer split is greater than 20% of students selecting an incorrect answer, the instructor mandates turn and talk as opposed to giving the option. |
| **Turn and Talk** | Time during which students talk to each other about their answer choices. Discussions occur between lab group members and other groups in the immediate proximity of that group. Depending on student confidence in their answer choice, this can last one to several minutes. |
| **Whole Class Discussion** | Time when after the instructor is satisfied that students have come to a consensus, he asked if there were still remaining questions and if so addressed them. |
| **Re-poll Question** | Point when the instructor re-presented the question to students a second time (repeat of student response and answers revealed steps). |

The pattern of behavioral engagement I observed has been hypothesized by several previous studies (Blasco-Arcas et al., 2013; Campbell & Monk, 2015; McDonough & Foote, 2015). Research on clicker usage has shown that between questions there is a great deal of interaction with the professor and other students (Blasco-Arcas et al., 2013; McDonough & Foote, 2015). This research could explain why student off-task behavior declines after the question -students rapidly switch to talking to their peers about non-academic related things or that one student or group of students is monopolizing the instructor's attention and therefore everyone that is not listening to the instructor's explanations would also be off-task. This result was first discovered through student self-reported surveys on clicker use (Blasco-Arcas et al.,

2013) and later confirmed by audio analysis of student conversations during clicker questions (McDonough & Foote, 2015). Henningsen and Stein (1997) found that one major factor maintaining behavioral engagement was how often a student were asked questions. Implementing active learning alone is not adequate for maintaining high levels of behavioral engagement over time. Instead, based on the decrease in on-task behavior during group activities vs. increase in on-task behavior during clicker sessions, seen after 10 minutes, I argue one must also consider using spaced, periodic re-stimulation about every ten minutes to maintain behavioral engagement.

Overall, the most common on-task behavior was listening. While it is encouraging to note that fewer students engaged in off-task behaviors during active learning than during traditional passive lecture, instructors should consider where this behavior lies on a range of behavioral engagement. One could speculate that this behavior is only one degree of separation from non-engagement and therefore it is easier to switch from listening to non-behavioral engagement then to switch from a task that requires more cognitive and physical behavioral engagement, such as a group activity. Is getting more students to listen the goal for which instructors should be striving or should we be pushing them to engage in other ways? When listening attentively, are the students only absorbing the information or are they processing it as well, a sign that they will better remember the information? Unfortunately, while this study's findings support the effectiveness of the four methods of active learning at eliciting behavioral engagement, I can only infer cognitive engagement.

Previously, researchers have been skeptical about the influence that direct observation can have on student behavior (Repp, Nieminen, Olinger, & Brusca, 1988). However, I found students quickly habituated to observer presence in the classroom. I observed that students were just as apt to exhibit off-task behavior (such as shopping or checking social media) when an observer was standing nearby, as they were when students were seated at outer limits of the researcher's view These observations provide evidence that behavioral data can be collected without biasing the data.

While this study provides evidence that active learning promotes behavioral engagement, it does not provide evidence that this results in students retaining, processing, and using information better than other methods. However, studies show that active learning results in higher performance (S. Freeman et al. 2014) and my data indicate that they also result in higher rates of behavioral engagement. Previous research has attempted to articulate the connection between behavior and cognitive engagement (Chi & Wylie, 2014). Chi and Wylie (2014) synthesize results from studies on note taking, concept mapping, and self-explaining and theoretically link the behavioral engagement described in those studies to cognitive engagement using a framework that allows them to separate students' engagement with instructional activities based on their overt behavioral engagement and link those behaviors to cognitive outcomes.

Cell phone use was the most common off-task behavior observed during any of the instructional activities (Fig. II.2). Students' use of cell phones in the classroom is a topic of much concern and interest to researchers, instructors, and students alike (Gingerich & Lineweaver, 2013; Kuznekoff, Munz, & Titsworth, 2015; O'Bannon & Thomas, 2014; Tessier, 2013; Tindell & Bohlander, 2012). While students tend to think that cell phone use in the classroom can help promote behavioral engagement, enjoyment, and only minimally distract (Tessier, 2013), other studies have shown that students who use phones in class experience lower recall ability and do not feel as confident of their knowledge after class (Gingerich & Lineweaver, 2013; Kuznekoff et al., 2015). Students also have a tendency to try hide their cell phone use from their instructors believing that by doing so instructors are less likely to see them using their phones (Tindell & Bohlander, 2012). This study demonstrates the strength of students' desire to use their cell phones implying that any instruction that dissuades students from them using their phones must be highly motivating to be able to overcome those desires. Based on this study's findings, instructors who choose to allow students access to cell phones during class, should consider switching active learning activities when phone use increases.

*Limitations and future directions*

This study is limited in that data were not collected in a continuous manner and therefore underestimates short duration behaviors. Collecting continuous would provide a more complete picture of the true length of time students perform any single behavior. This type of continual behavioral analysis may be better suited for video scoring than live observation as continuously focusing one's attention on any single subject may be distracting enough to alter the behavior of the student being observed. The benefit of collecting observations in real time is that it is much easier to record contextual information. Reducing the interval between samples to 2 minutes or less would be a compromise. Another possible solution to this problem would be to modify an existing behavioral monitoring program to measure the behaviors as modeled by Russell and French (2001). Russell and French (2001) modified the EthoScribeTM software on a personal data assistant allowing the researchers to collect student data on laboratory engagement. Specifically they used the modified software to collect multiple types of TA and student interactions, which could be modified to collect active learning on and off-task behavior.

Using PROSE, it is possible to quantify behavioral engagement occurring during other types of active learning instruction exhibit not addressed in this study (such as muddiest point or diagramming processes). Their similar or distinctive behavioral engagement patterns may provide insight that could optimize the execution of those techniques. Logically, knowing the amount of behavioral engagement an instructional method elicits, one can compare impacts of different types of on-task behavior, ranked by the amount of behavioral engagement they elicit, on student performance. This could be used to determine if student participation during instructional activities that elicit more behavioral engagement (such as clickers) more predictive of performance than student participation in instructional activities that require less behavioral engagement (such as whole class discussion)?

## CONCLUSION

Behavioral engagement (as measured by performance of on- and off-task behaviors) varies depending on type and length of classroom activity. There is less off-task behavior during active learning than during lecture, lending support to the hypothesis that behavioral engagement plays a role in what makes active learning work. Moreover, even during active learning, behavioral engagement varies, but the decline in behavioral engagement may be mitigated through re-stimulation – posing new questions, changing tasks. Instructors should consider the duration of activities when choosing the instructional method to use in their course and for designing and structuring the activities for each class meeting. They should also observe students' behaviors methodically to assess whether their choices and delivery are effective. The PROSE protocol should prove useful for such assessment.

# CHAPTER III

## STEP 2: USING PREPERATION AND PRACTICE PARTICIPATION AS PREDICTORS OF PERFORMANCE IN FLIPPED CLASSROOMS


### ABSTRACT

In flipped learning, students are expected to acquire basic knowledge outside class, typically through instructional videos, then increase their mastery of and ability to apply that basic knowledge through active learning during class. Clickers (personal response systems) are a common tool used in college-level flipped classes to assess whether students have acquired the basic knowledge before class and drive active learning involving group discussions in which students practice what they have learned. Implicit in the flipped model is that quality participation in in-class activities is dependent on students watching the videos (preparation), while test performance in the course is dependent on a combination of preparation for and participation during the activities. For this reason, many instructors choose to offer credit for participation. Few studies have assessed the predictive nature of the preparation then practice model of participation on student exam performance. In this study, I examined how well the students' participation model of preparation and practice predicted their exam performance and found evidence that voluntary participation is highly predictive of performance.

INTRODUCTION

With the ever-growing popularity of flipped learning, it is becoming increasingly important to identify factors that influence students' successes in these classes. Flipped learning classes are classes in which information dissemination occurs outside the classroom freeing class time for activities that help students rehearse, retain, and retrieve information they learned previously (Bergmann & Sams, 2009; van Vliet, Winnips, & Brouwer, 2015). Typical activities used during these classes are considered active learning, a type of instruction designed to elicit both behavioral and cognitive engagement from students (Bonwell & Eison, 1991). Considerable evidence indicates active learning has a positive effect on student test performance (S. Freeman et al., 2014) in a variety of courses from biology (S. Freeman et al., 2007), to chemistry (Paulson, 1999), to psychology (Stowell, Oldham, & Bennett, 2010), to microeconomics (Hayter & Rochelle, 2013).

There has been a recent move away from investigating overall impact of classroom instructional techniques to examining why instructional techniques are effective (Dolan, 2015). Dolan (2015) proposed two questions that will provide better insight into why instructional techniques are effective, "What is happening during active learning that makes it work?" and "What does 'working' mean, for whom, and in what context?" The current study addresses the second question by defining "what is happening" as levels of participation. If students receive an academic benefit (i.e. higher performance) by participating during active learning, then participation should predict performance, which in turn supports the hypothesis that the act of participating contributed to what makes active learning work.

If the premise of active learning is for students to be active participants in their own education, then those who participate should see a performance benefit. Another way to conceptualize student participation in a classroom is to think of participation during active learning as a representation of student behavioral engagement (Chi & Wylie, 2014). Increasing student engagement in courses is widely discussed by professional educators, researchers, and parents alike as it is widely accepted as key to academic success. Increasing engagement in courses has a positive effect on college student performance and persistence (Kuh, Cruce, Shoup, Kinzie, & Gonyea, 2008). Engagement consists of three forms: cognitive, behavioral and motivational (Linnenbrink & Pintrich, 2003). In this study I investigated the form of behavioral engagement known as participation.

Active learning is designed to help students practice (retrieve) what they are learning and the benefits of retrieval practice are well documented (Karpicke & Blunt, 2011; Karpicke & Roediger, 2008). Therefore, a second premise is that for active learning to be beneficial, students must come to class prepared, i.e. equipped with appropriate background knowledge, to participate (Bonwell & Eison, 1991). If this second premise is correct, then those who have at least attempted to equip themselves with the appropriate background knowledge before participating in active learning should see a performance benefit. Therefore, we have a "prepare then practice" model of active learning instruction participation.

*Quantifying engagement*

For the purposes of this study, I chose to assess behavioral and cognitive engagement through two measures of participation that were reasonably easy to record without additional input from the research subjects. Both cognitive and behavioral engagement are typically assessed via direct observation of student responses to instruction (Sinatra, Heddy, & Lombardi, 2015). Observational research conducted on student engagement behavior has shown variation in patterns of on- and off-task engagement behavior during the active learning instructional methods of clickers, small group activities, Verso, and whole class discussion (Chapter 2). However, using that method, behaviors could be recorded for only 30 - 40% of the class of 120 students per class period. That study showed the highest, most consistent levels of student engagement behavior occurred when students used classroom response devices (“clickers”). As clickers can record all students’ responses, using clicker data as an indicator provides a good proxy for measuring in-class participation.

**Types of Interactions.** This study focuses on three basic modes of interactions occurring during active learning, defined based on the primary focus of the interaction. The first is student-to-technology interaction as represented though the use of clickers. During clicker questions even though professor introduces the question to students and solicits their responses, the main focus of this activity is for students to push a button on a device as a representation of their knowledge, after which the distribution of all student answers are displayed for all to see. In this interaction, it is the students’ commitment to and ownership of their choices that is crucial to them accepting whether or not they have comprehended the information (Blasco-Arcas, Buil, Hernández-Ortega, & Sese, 2013; Hayter & Rochelle, 2013).

Student-to-student interactions occur when students communicate knowledge to peers. An example of student-to-student interactions is Think-Pair-Share instruction, where students are sequentially: instructed to think of an answer to the posed question, share their response with a peer, produce a collective answer, and then share their knowledge with a nearby pair of students. This process continues until the groups are too large to facilitate easy exchange of knowledge, at which point the groups share their learned knowledge with the class (Azlina & Nik, 2010; Lyman, 1987, 1992). In this method of instruction, the crucial moment of student knowledge representation occurs when the student verbalizes his or her knowledge to a peer (Kothiyal, Majumdar, Murthy, & Iyer, 2013).

The third type of interaction is student-to-instructor interaction. It occurs when an instructor elicits a verbal or written response of a student’s knowledge, then gives that student direct verbal feedback on their knowledge representation. This direct feedback can be to the individual, such as when an instructor asks an individual student a question in class, or can be given in a more general format, such as when an instructor collects and discusses answers written on note cards with the class. Here the crucial moment of knowledge representation occurs when students verbalize or write down their answers for the instructor. Of these types of interactions, student-to-technology is the easiest to quantify, as most educational technologies are equipped with the functionality to track and export student interaction data in the form of participation and performance data.

**Online engagement.** In flipped classes, course material is delivered outside scheduled class times, by content delivery methods such as video, book, audio, or internet (Betihavas, Bridgman, Kornhaber, & Cross, 2016; O'Flaherty & Phillips, 2015). Although there is little consensus on the best method for delivery, of these methods, the most widely reported is video.

There are two basic strategies for making lecture videos. The first is to make short videos designed specifically to teach a single concept as concisely as possible. The second is to use recordings of lectures given previously.  Many student-perception studies indicate students prefer live lecture overwhelmingly when given a choice between live lecture and online instruction (Beard & Harper, 2002; M. K. Freeman, Schrimsher, & Kendrach, 2006). Common reasons stated for that preference were interaction with the instructor, concerns with potential technology failure, and a perception of excessive workload. In interviews I collected previously, students indicated they commonly expected to spend one hour on homework for every three hours of class time for a typical introductory course with a lab component (Moore, unpublished data). Thus, students would consider any regular course assignments that required students to complete more than an hour of homework per week outside class excessive. Studies report students prefer videos of no longer than 10 minutes. (Guo, Kim, & Rubin, 2014; Kay, 2012; Schreiber, Fukuta, & Gordon, 2010). Research is conflicted about the benefits of using online video-lectures as a supplement for in class instruction. Some studies show that students can experience a performance benefit from watching lecture videos (Wieling & Hofman, 2010) and while others have shown video-lectures offer no improvement in grades when compared to face-2-face lectures (Lewis, 1995) (however this could be representative of the state of video lectures in the early 90s), or textbook reading (Waschull, 2001).

**In-class engagement.** Watching videos outside class allows class time to be used to help students sharpen their knowledge of biology through retrieval practice and elaboration in the form of small group activities, classroom response devices (clickers), and whole class discussions. Retrieval practice (Karpicke & Blunt, 2011; Karpicke & Roediger, 2008) and elaboration (Hall, Hladkyj, Perry, & Ruthig, 2004; Hall et al., 2007) are critical facets of student learning. Students who used these learning practices are more likely to retain information longer and be able to make connections between previously-learned and new information, providing students with the knowledge and tools to help them perform better on course examinations (Hall et al., 2004; Hall et al., 2007; Karpicke & Blunt, 2011; Karpicke & Roediger, 2008). Clicker participation was chosen as the measure for in-class engagement behavior. There are many studies currently available on clickers on such topics as showing evidence of their impact on student engagement behavior (Campbell & Monk, 2015), learning (McDonough & Foote, 2015), and academic performance (Blasco-Arcas et al., 2013; Hayter & Rochelle, 2013). They also provide a framework for proper use (Knight, Wise, Rentsch, & Furtak, 2015; Lewin, Vinson, Stetzer, & Smith, 2016; Morrison, Caughran, & Sauers, 2014). Proper implementation of clickers in classes include such elements as peer discussion (Lewin et al., 2016) which can be supported by collaborative clicker use (McDonough & Foote, 2015) and facilitated by good question prompts from instructors (Knight et al., 2015) for use in an interactive, inquiry classroom (Morrison et al., 2014). Most studies on the effect of clickers on student engagement, learning, and performance have used student self-report measures (Campbell & Monk, 2015; McDonough & Foote, 2015; Blasco-Arcas et al., 2013). Such measures are inherently biased as survey respondents are apt to select answers they think the surveyor wants to make the surveyor think better of them (Hindelang, Hirschi, & Weis, 1979). By collecting student clicker and using the learning management system to collect video-watching behavior data, I could avoid student response bias.

*Study aim*

The goal of this research is to assess the effects of online (lecture video watching) and in-class (clicking) participation on academic performance. Logically, to answer clicker questions background knowledge must be acquired. In this course, the lecture videos provide background knowledge making video watching behavior an important factor in the predictive model. To assess the impact of participation I addressed two research questions,

- Is participating in class, as measured through clicker use, a predictor of student performance?
- Does watching videos improve clicker participation as a predictor of student performance?

## MATERIALS AND METHODS

*Human subjects protocol*

Archival data provided for this study by the instructor of record had no identifiers so this work was deemed non-humans subject research by the IRB office prior to conducting the research and thus required no further review or approval of the protocols.

*Research subjects*

I acquired de-identified data on student clicker use and video watching from the instructors for one large-enrolment non-honors (120 students) and three medium and small enrollment (two Fall sections of 80 and one Spring section of 40) honors, introductory, mixed-majors biology course at a large, land-grant, research intensive south-central university. Data on 310 students were suitable for use. Students in this introductory course were predominantly freshmen and sophomores with a large portion of students having declared a science major. Admission requirements for students enrolled in the Honors College are GPA of 3.75 with an ACT composite score of 27 and for the non-honors students, a GPA of 3.00 with composite ACT score of 24. Introductory Biology was a requirement for majors in life-science and pre-health major tracks. The class met three 50 minutes periods each week for a total of 38 periods. For most students, Introductory Biology was their first exposure to a university-level science course, a flipped classroom setting, and a course that required regular lecture-video watching.

*Course structure*

**Online environment.** The instructors used edited, previously-recorded lectures for the content videos. Students received content knowledge via videos of an instructor teaching 50-minute inquiry-based biology lectures, displayed using the Desire-2-Learn (D2L) learning management system. The videos were edited to remove segments during which the instructor was not lecturing or interacting with the class, producing 35-45 minute videos. Videos exceeding 40 minutes were cut into two, in response to requests from students for shorter videos. Because this was a flipped learning course, students were required to view one to three videos, equivalent to one lecture, prior to each class meeting to gain the content knowledge preparing them for in-class active learning. Embedding the videos in the Desire-2-Learn® learning management system (LMS) allowed recording the time students spent watching and for students to access and watch lectures whenever and wherever an internet connection was available. Students described various video watching strategies they employed including watching them prior to attending class, watching them on the weekends, and binge watching them the night prior to an exam (Moore, unpublished data). During the course of the semester, students had sixty-three individual lecture videos they could watch.

A question packet, designed to help students follow the lecture, accompanied each video lecture. Instead of chapters or units, the course was designed around scenarios or stories used to connect multiple topics to one central theme, with three to six lecture periods to cover each scenario. After each scenario, students were required to take a short quiz to help them reflect on their learning and unlock the next scenario. Importantly, students did not receive points for these quizzes, as it was the intent of the instructor to emphasize practice over completion. Desire-2-Learn recorded how much time a student spent watching each video. Over the course of the four semesters of data collection, the instructor used two different formats for encouraging students to engage with online materials. The first format allowed students to choose which videos to watch or question packet to complete without fear of losing points for either, again emphasizing the importance of practice over completion. The second format awarded students 60 points out of a total possible 590 lecture points for completing all videos and submitting all packets. Points were awarded at the end of the semester to minimize the externalization of students' motivation to complete these tasks.

**In-class instruction.** The instructors conducted several types of in-class activities, always performed in assigned groups, which varied between class periods. These included clicker-based activities, drawing processes, arranging sentences, editing explanations, predicting outcomes for or posing hypotheses to explain situations, arranging words to form concept maps or flow charts, and solving genetics or population growth problems. This course has used clickers since 2003 making it an obvious choice to use as a measure of classroom engagement behavior. Clicker-based activities were conducted almost every session.

The instructors structured clicker questions as follows.  The instructor posed a question, allotted students thirty seconds to answer, then displayed the distribution of choices. If fewer than 80% of the students clicking selected the correct answer, the instructor would ask the class to discuss the answers in their assigned groups for 2-5 minutes after which the instructor re-polled the question to see if there was a shift in the answer distribution. Typically, this process would continue until 80% of the answers submitted were correct and then the next question was asked. On occasions when two or three rounds failed to reach the 80% criteria, a whole class discussion was conducted before re-polling.

*Data collection*

**Data sources.** Data were collected from the non-honors introductory biology course in the Spring 2015 and in the honors biology class from the Fall 2015 through Fall 2016 semesters. To be included in the model calculation, students had to have taken all four lecture exams (3 regular cumulative tests and 1 comprehensive final). To assess students' rate of clicker participation for those who attended class, the number of students in attendance was compared against the number of students clicking. I used video-watching data as a proxy for online participation. I used progress logs from D2L to determine whether students had watched the videos. Students were counted as having watched a video after they had spent at least half the amount of time required to watch the lecture video. Half the amount of time of a lecture video was chosen because many students indicated in interviews that they had watched the lecture at double speed (Moore, unpublished data).

The instructors used the TurningPoint 5.0 software that accompanied clickers to record students' answers and provide in-class engagement behavior data. In a single class period, the instructor posed two to ten clicker questions, depending on the time needed for the class to reach a consensus on the correct answer. I recorded students as having participated during a particular class period if they clicked at least once during that period. The one-click criterion was chosen because I observed that at times students would not answer all the questions. Clicker questions were asked on an average of twenty-eight of thirty-eight possible days on which they could have been asked each semester.

**Data Analysis.** I used IBM SPSS® version 23 for all statistical analysis. I used a one-way ANOVA to test for differences in rates at which student engagement declined for online and in-class engagement. I conducted multiple linear regression to determine whether video-watching and clicking were significant predictors of performance. I tested that the data met the assumptions of homogeneity of variance by examining an xy scatterplot of the observed vs. predicted residuals, normality of residuals through examining a histogram of the frequency of the residuals, and model specification by examining the $R^2$ value (Pedhazur, 1997). To determine how much of the variation in grades was accounted for by amount of time spent video-watching and clicking, I examined the adjusted $R^2$ value to correct for number of predictors in the model (Cohen, 1988). Because the numbers of possible videos to watch and clicker sessions offered differed, I examined the $\beta$ values in the predictive equation (Pedhazur, 1997).

## RESULTS

Students on average participated in clicker session 71 % of the time and watched 58% of the videos available. Student use of the video lectures decreased as students progressed through the semester across all semesters. Upon examining the results of the one way ANOVA, I determined that clicker use declined at a similar rate ($F(6) = 1.060$, n.s.). The proportion of clicker sessions in which students participated was greater than the proportion of lecture videos they watched (paired- t-test, $t(311) = 7.87$, $p<0.001$) (see figure III.1). On average, 20% of students did not click and 42% of the students failed to watch a particular lecture video. Around 5% of the class consistently did not watch videos or participate in, or even attend, the in-class active learning.

However, the majority (80%) of the inactivity came from different students at different times in an unpredictable pattern. Students' total number of clicker session participation and total number of lecture videos-watched are highly correlated ($r = 0.574$, $n = 312$, and $p < 0.001$) suggesting that video watching and clicker participation should be assessed together.

Table III.1. Average percent of possible interaction in which students participated. The columns represent the period before each exam during which the data were recorded. Spring 2015 data were collected in a non-honors class while all other data were collected in honors classes.

| | **Video-watching** | | | | **Clicker Participation** | | | |
|---|---|---|---|---|---|---|---|---|
| **Semester** | Period 1 | Period 2 | Period 3 | Period 4 | Period 1 | Period 2 | Period 3 | Period 4 |
| Spring 2015 | 64% | 38% | 29% | 25% | 68 % | 51 % | 25 % | 18 % |
| Fall 2015 | 79% | 64% | 64% | 55% | 87% | 90% | 83% | 76% |
| Spring 2016 | 88% | 85% | 81% | 61% | 94% | 82% | 68% | 76% |
| Fall 2016 | 84% | 72% | 71% | 72% | 94% | 84% | 85% | 77% |

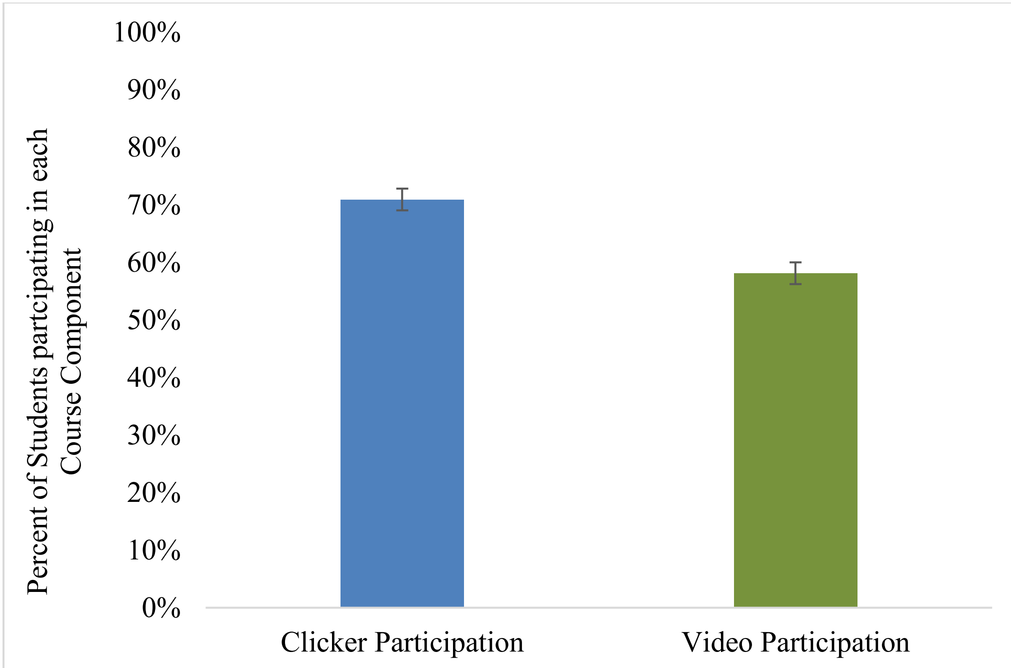


Figure III. 1. Mean percent participation for the two instructional activities, clickers and video lectures. There were 28 clicker sessions offered and 63 videos to watch. The average participation in clicker sessions was significantly higher than participation in video watching (paired $t(311) = 7.87$, $p<0.001$).

*Predicting exam performance from participation*

Data met assumptions necessary for linear regression analysis (see Appendix II.1 for supporting charts and graphs). Initially, I entered video watching, lecture packet submission, and clicking into the predictive model. The output was examined for change in $R^2$ and collinearity to determine model accuracy. The 95% confidence intervals for packet submission were -0.021 for the lower bound and 1.120 for the upper bound. I removed packets from the final statistical model as they violated the 95% confidence rule (Calder, 1953). The subsequent linear regression analysis produced the results found in table III.2.

Table III.2. Results from the linear regression analysis exploring the ability of the preparation then practice model of participation to predict overall test grade. Students had the opportunity to watch 63 lecture videos and click in 28 different class periods on average over the course of the semester.

| Explanatory Variable | Beta | t- Value | Significance | 95% Confidence level | |
|---|---|---|---|---|---|
| | | | | Lower Bounds | Upper Bounds |
| Videos Watched | 0.302 | 6.38 | < 0.001* | 0.43 | 1.38 |
| Clicker Participation | 0.514 | 10.86 | < 0.001* | 4.26 | 6.27 |
| **All measurements of collinearity fell within the acceptable parameters [Tolerance > 0.200 and VIF below 5 (Menard, 2002)]. * Indicates variable significance (p-value < 0.001).** | | | | | |

The model for predicting total exam performance using video watching and clicker participation was significant $F(2,309) = 177.369$, $p < 0.001$. The $R^2 = 0.53$ indicated a large effect size (Cohen, 1988).

The final predictive model for exam performance was ($\hat{y} = 244.803 + 1.20x_{video} + 5.445x_{clicker}$). Because the number of clicker sessions in which students could participate was much lower than the number of lecture videos they could watch, the equation overinflates the important of clicking in class. Therefore, I report the standardized z-score model: ($z_{\hat{y}} = 0.302z_{videos} + 0.514z_{clicker}$). This equation can be interpreted as a one standard deviation increase (SDI) in video watching increases overall exam score by 0.302 points and a one SDI in clicker participation increases overall exam score by 0.514 points. The baseline grade that one would receive if he or she did not participate either in class or online is 244.80 points out of a possible 590 (which would amount to 41% or a letter grade of F). Interestingly, while video watching does not have as great an impact on students' grades as clicker participation (0.302 vs.

0.514 grade increase per SDI), both components highly influence student's overall performance in their flipped biology course.

Upon examining the model summaries using hierarchical linear regression (Lindenberger & Potter, 1998), difference in change in $R^2$ and F values in the predictive model become readily apparent. When first adding video watching, $R^2$ change = 0.357 and F change = 172.041) and then adding clicking the $R^2$ change = 0.178 and F change = 117.849. Conversely when first adding clicking, $R^2$ change = 0.473 and F change = 278.389 and then adding video watching second, $R^2$ change = 0.061 and F change = 40.698. One can clearly see that clicking is the more impactful variable in the model (model summaries in Appendix II.2)

*Student Video Watching and Clicking Choices*

Interestingly, after dividing videos and offering students the choice to watch either several shorter 5- to 6-minute videos or one to two 30-minute videos, students overwhelmingly chose to watch the longer videos. In fact, over the course of the four semesters during which data was collected, in 80% (555) of recorded video watching instances, students chose to watch longer videos for the two scenarios in which the shorter video options were available. This means not only did they watch it once for initial content acquisition, but they also used them for review instead of using the smaller, topic specific videos. For the first scenario, 80% (296) of the video watching instances were the two longer videos with an average run time of 38 minutes as opposed to watching nine shorter videos with an average run time of 7 minutes. For the second scenario, in 81% (259) of video watching instances students chose to watch the six longer videos with an average run time of 24 minutes as opposed to watching twenty-one videos with an average run time of 4 minutes.

On any given day, an average 6% to 9% of the students in the class were not clicking. Some students were consistently choosing to not click and yet still attend and some clicked in on some bays but not others. No trends in clicker participation were noticed expect for those who were consistently not in attendance and not clicking.

## DISCUSSION

Our results provide evidence that not only is participation predictive of overall performance, but it also accounts for a large portion of the variation in course grades with an $R^2$ value of 0.53. S. Freeman et al. (2014), Ruiz-Primo, Briggs, Iverson, Talbot, and Shepard (2011), and Van Gorp and Grissom (2001), showed the performance benefit of being in an active learning class. This research expands upon those studies through providing evidence of the importance of preparation before practice in making active learning instruction effective. These results satisfy Dolan (2015)'s call to investigate what makes active learning work. Previous studies compared the the influence of active learning at the course level – did the instructor implement or not. Here we can see that the degree to which students prepare for active learning before class (watching videos) and participate in active learning during class (clicking) play a role in or at least predict the performance benefit. The driving force behind the improvement, what is causing the students to want to participate during active learning instruction, remains unknown.. This study provides quantitative evidence of the performance benefit stemming from student's behavioral choices. Students are prone to attribute academic performance to external factors when there is not contradictory evidence (Weiner, 2001). This study provides evidence that it is the students' actions (i.e. participating) playing a substantial role.

A question frequently asked on internet discussion boards about flipped learning and other instructional methods that incorporate an online component is, "How do I get my students to watch the videos?" This study provides data for those trying to make the argument to their students that online and in class participation are important behaviors that affect their performance. In addition, it provides further support that clicking in itself can have a positive impact on grades even in the absence of video watching and can account for a larger portion of the variance in grades than video watching does. Two interpretations of these results are that showing students their knowledge gaps facilitates students' knowledge acquisition during the clicker session itself or the ways that students gain background knowledge are more varied than are students' choices for practicing. These two findings support investing substantial time developing both online and in-class course elements and the need to investigate what other sources students are using to learn concepts, e.g. peers, textbooks, other online resources.

The gradual decrease in students watching lecture videos is a trend common in flipped learning and online courses (Hotle & Garrow, 2016; Romanov & Nevgi, 2007). The total number of students watching lecture videos at the beginning of the semester is less in the non-honors class (64%) than in the honors class (83%), and the drop in video watching is higher in the non-honors class (39%) than in the honors class (21%). Several factors could account for these difference. A higher percentage of biology majors were in the honors class, the honors class size is smaller, and the students in the honors class tend to be more driven. To be able to say whether one reason accounts for more variance than the others will require more testing. Some have tried to combat this decrease in video watching by awarding points for video watching; however, offering students points for completing a task makes their motivation for completing that task inherently extrinsic (Patrick, Ryan, & Pintrich, 1999). It is likely that making students watch videos for points would greatly limit the predictive power of video watching on performance as students would simply be watching to get points instead of knowledge (Kohn, 2011).

As previously mentioned, on any given day, an average 6% to 9% of the students in the class were not clicking. Examining the clicker data revealed that different students chose to click or not to click on different days so that there was no predictable pattern of class-attending, non-clicking students. Possible reasons a student might not click include: A) students were not prepared to participate, B) student forgot to bring their clicker to class, or C) students were busy copying down the question and not leaving enough time to submit an answer. Students with reason A must learn/accept the importance of studying and not cramming and time management. Other research has indicated that students watch instructional videos as they would a television show (i.e. not taking notes, being distracted by social media on their electronic devices, and attempting to multitask while watching) (Euzent, Martin, Moskal, & Moskal, 2011; Guo, Kim, and Rubin, 2014). This research indicates that students need to change their lecture video behavioral engagement with these videos to be more in line with acceptable student face-2-face engagement behavior. Students with reason B need to learn about and implement a time management plan. Reason C illustrates students' lack of understanding of the benefits of retrieval practice. Current research suggests that student buy-in is correlated with self-regulated learning and course performance (Cavanagh et al., 2016).

*The benefits of retrieval and spaced practice*

One reason this pattern of learning via video lecture and retrieval practice using clickers may be so impactful is that it forces students to recall previously learned material and thereby strengthening neural connection in their brains. The more retrieval practice they get, the better they should recall during tests what they learned (Karpicke & Roediger, 2008). For there to be information to retrieve, one must first internalize the information (prepare for retrieval practice). This could explain why watching lecture videos, even though clickers had a slightly higher impact on performance (0.514 points per SDI) than video lectures (0.304 points SDI), are such powerful indicators of performance - because preparation is important. Students who attend class without preparing would most likely see little to no benefit from clicking (practice). One concept that could potentially strengthen this is effect of preparation before practice is the principal of spaced practice. The concept of spaced practice proposes that the time between learning material and retrieval practice is just as critical as the retrieval practice itself (Taylor & Rohrer, 2010). Research has shown the importance of space between initial learning and retrieving that information on student performance (Kornell & Bjork, 2008; Rohrer, Dedrick, & Burgess, 2014). Students' patterns of video watching included (but were not limited to): the night before lecture, the morning before lecture, watching the videos during the weekend, binge watching ten to fifteen videos a few days before the exam, and not watching them at all. Students who watched videos in the few hours (or sometimes minutes) prior to attending class should not have benefitted as much from their retrieval practice as those who watched the videos the night or day before. Those who watched the videos earlier have to work harder to retrieve that memory, thereby strengthening synaptic connections.

*Proper clicker usage*

How clicker questions are executed is most likely the key to why clickers are so impactful. Lewin et al. (2016) described three separate instructional modes for using clickers in the classroom. The first mode is "peer discussion," in which students deliberate about the answers immediately follows a clicker question. The second mode is "individual thinking," where there was no discussion among students at any point during the class. Third, "alternative collaborations" are classes in which there was no discussion after clicker questions; however, activities later in the period are designed around the clicker questions giving students another chance to process the information (Lewin et al., 2016). The classes in this study used the peer discussion mode. The Lewin et al. (2016) study noted classes that used the peer discussion mode tended to have three characteristics in common: less lecture, more challenging questions, and more opportunities for peer discussion. Taken together these three characteristics can be tied again to the benefits of interleaving (less lecture so there is more space between information dissemination and recall) and elaboration (peer discussion) as well as the principal of desirable difficulties (more challenging questions) which states that students learn best through struggle (Bjork, 1994; Hall et al., 2007; Taylor & Rohrer, 2010).

As these desirable clicker characteristics are the same as the principals around which flipped learning courses were originally designed (less lecture with lots of peer discussion while taking on more challenging questions with an expert in the room to assist when needed), these benefits should be amplified in the properly designed flipped learning course. When designing clicker questions for flipped learning classes, content choice should promote spaced and interleaved practice, i.e., instructors should mix questions on older material with their question over the current material. Mixing old and new content questions will not only strengthen connections to old information through forcing students to recall old information, but it will help students establish new connections between the new and old material thus making both pieces of material easier to recall later (Taylor & Rohrer, 2010).

*Connecting participation to motivation*

When considering why students chose to participate significantly more in clicker sessions (71%) than video watching (58%), two hypotheses present themselves. First, because students use their clickers in class, their behavior is influenced by peers. Students' see peers participating and participate so they do not stand out. Students are also likely to be asked what choices they made during the peer-discussion component of clicker use. Students will feel pressure to have information to contribute to the discussion. Video watching is a solo activity and therefore there is little accountability outside class to get them done. However, if lack of accountability were the predominant factor one would expect to see a much greater difference in participation percentages between the two instructional activities. Perhaps the relative difference (13%) in video watching and clicker participation percentages reflects the presence of some accountability in addition to video watching being the predominant way students received information.

A second hypothesis is clickers could be better than video watching at supporting student motivation. Using the self-determination theory of motivation as a basis, Abeysekera and Dawson

(2014) proposed that active learning has such an impact on student performance because active learning is intrinsically (internally) motivating. The self-determination theory of motivation states that students have three basic psychological needs that when met increase the likelihood that they will be intrinsically motivated. Those needs are autonomy (a sense of choice), competency (a sense of task proficiency), and relatedness (a sense of connection) (Deci & Ryan, 1985b). The instructor's protocol for clicker use likely supports competency and relatedness. The need for competency could be satisfied when students realize they did or did not know the correct answer to the posed question. Satisfying the need for relatedness should occur when students discuss their answers with peers and work toward a consensus as to the correct answers to the clicker questions. Video lectures, by comparison, may only support each student's competency needs, which may explain why fewer (58%) students choose to watch them. Both components may also support autonomy, as students choose not to participate in either activity. However, if students perceive participating in either component is required to achieve a good grade, then they might not perceive that autonomy is supported even though they can choose not to participate in the activity. In this specific instance the students' motivation would be external as they are more focused on getting the points from participating then they are in in the participation itself. More evidence is required to determine applicability of SDT.

*Limitations and future directions*

Because the number of questions per clicker session varied and may have included as few as 2, this study used a binary value for each session. Thus, participation and attendance were not as clearly disentangled as they would have been if a measure indicating degree of participation (proportion of questions answered) could have been used. Such a measure may have strengthened the predictive power of clicker participation. Incorporating proportion of correct clicker responses may serve to increase our understanding of the importance of video-watching as would have incorporating behavioral observations of student participation in clicker session discussions or other group activity Another limitation was that there no direct way of assessing students' levels of engagement behavior while watching the videos. This issue could be resolved by asking students to keep a time diary of their video watching or randomly embedding questions during the video asking students about their video watching behavior. In interviews I have conducted, students have commented "I watch the videos at night, in my pajamas, in my bed as I am falling asleep," "I prioritize the assignments I do by their impact on my grade and since there was no grade penalty for not watching the videos, I often did them last," or "I watched the videos in my room, but when anyone can in my room while I was studying would get distracted, which happened often." (Moore, unpublished data). When students view the videos in suboptimal conditions, they are much less likely to remember what they have learned and in turn be less prepared to learn during the next class period. More research is needed on how students use the on-line or out-of-class components in flipped classrooms and how to encourage optimal use.

To further test the preparation before practice model of participation, future studies should find ways to separate the two activities. One way may be to manipulate the spaced practice effect by varying the time between lecture exposure and clicker practice and measuring student performance. The results of such a study would be useful in designing flipped and hybrid classes. As stated in the discussion, what drives or motivates these students to participate in active learning instruction is still unknown. Future studies should try to measure student's level of motivation to participate in clicker questions and watch video lectures to see if student levels of motivation can be used as an explanation for participating during active learning instruction.

## CONCLUSION

As flipped learning courses continue to increase in popularity, it becomes necessary to understand how student participation in on-line and in-class activities influences their performance. This study is a first attempt at quantifying that behavioral effect. It has shown that participation in both components is a significant predictor of performance. Therefore, researchers and teachers are justified devoting effort to encouraging student engagement behavior as a way to boost student test performance.

# CHAPTER IV

## STEP 3: THE EFFECT OF USING ACTIVE LEARNING TECHNIQUES ON BIOLOGY STUDENT MOTIVATION


### ABSTRACT

One hypothesis as to what drives students to participate during active learning instruction is the ability of an instructional method to support student self-determination. Students who have a high degree of self-determination are said to be intrinsically motivated and more likely to participate during instruction than those who possess a low degree of self-determination. Currently, no evidence supports the claim of a relationship between instructional method and student self-determination. The goal of this study was to test this claim by measuring student motivation in two different introductory biology courses (an honors, mixed-majors course and a majors-only course) at two different universities. This study used student self-report surveys during the final two weeks of instruction to collect data on students' perceptions of the ability of four active learning instructional strategies to meet the psychological needs (autonomy, competency, relatedness) that lead to intrinsic motivation. Findings indicate that active learning has the capacity to support psychological needs, with the need for competency most strongly met. However, further refinement of the measure for assessing the ability of instructional methods to be supporting agents of psychological needs is warranted.

# INTRODUCTION

Student engagement with and participation in different types of active learning is a significant predictor of persistence (Tinto, 1997) and performance (Kuh, Cruce, Shoup, Kinzie, & Gonyea, 2008; Chapter 2). Previously (Chapter 2), I showed that the participation model of preparation and practice significantly predicted student performance. Abeysekera and Dawson (2014) suggested flipped learning improves performance because it allows more active learning instruction to be done during class and that active learning instruction possesses characteristics that stimulate an increase in students' levels of intrinsic motivation. Ryan and Deci (2000) state that to be intrinsically motivated to learn is to be motivated by the enjoyment or satisfaction of learning. It is an internal locus of motivational control. Instructional methods that increase students' intrinsic motivation should increase students' willingness to engage in class, which should increase student persistence in science courses and retention in science majors (Lavigne, Vallerand, & Miquelon, 2007). Over the last decade, increasing persistence and retention in biology courses and majors has been an area of focus for organizations and government agencies that support higher learning, such as the National Science Foundation, the National Research Council, and the American Association for the Advancement of Science (Brewer & Smith, 2011; Council, 2003). One key to improving undergraduate education in biology specifically identified in Vision and Change (Brewer & Smith, 2011) and BIO 2010 (Council, 2003), is to make students more engaged in the learning process. These reports recommend using several different research-supported educational techniques that have been shown to be effective at increasing student persistence, one of which is active learning.

## *Active Learning*

A well-supported method of instruction used to increase classroom engagement behavior is active learning (see reviews S. Freeman et al., 2014; Prince, 2004). In a meta-analysis of two hundred studies, S. Freeman et al. (2014) concluded that active learning had such a significant and sizeable positive impact on student performance in science, engineering, and math courses that all instructors should be using this technique. However, much less evidence exists about how and why active learning works. Dolan (2015) recommended two guiding questions: "What is happening during active learning that makes it work?" and "What does 'working' mean, for whom, and in what context?" This study of intrinsic motivational support attempts to answer that first question in two different class types: a traditional active learning (TAL) course and a flipped active learning (FAL) course. In flipped learning classes material traditionally taught in lecture is presented outside class leaving additional class time for active learning instruction. In Active learning instruction, students perform activities and then think about the process or outcome of the activities during or after their performance (Bonwell & Eison, 1991). The TAL course incorporated short periods of lecture, sometimes called micro-lectures, and three different active learning: classroom response devices (clickers), small group discussions, and whole class discussion. The FAL incorporated online lecture videos and the same three types of active learning.

*Connecting Active Learning to Motivation*

Abeysekera and Dawson (2014) proposed that different types of active learning were effective because they increase students' intrinsic motivation to learn. This increase is accomplished through meeting students' psychological needs for autonomy (a sense of choice), competency (a sense of what one does and does not know), and relatedness (a sense of connection or belonging). Self-determination theory (SDT) states that when these needs are met, an individual will become intrinsically motivated to engage in a task (Deci & Ryan, 1985b). For example, students may be intrinsically motivated to use classroom response devices, because committing to an answer before the correct answer is revealed helps students ascertain what they do or do not know thereby increasing competency (Jeno, Grytnes, & Vandvik, 2017). Discussion among group members increases students' sense of connectedness to each other, thus fulfilling their psychological need for relatedness. A professors' acknowledgment of a student for a good explanation given during whole class discussion could simultaneously strengthen the perception of connectedness between the professor and student (relatedness increase) and confirm that he or she has grasped the concept highlighted in class that day (competency increase).

*Self-Determination Theory*

Student levels of self-determination result in a motivational continuum ranging from amotivation to extrinsic motivation to intrinsic motivation (see Appendix III.1) (Deci, 1980; Deci & Ryan, 1985b). In a new opportunity or situation, one's willingness to engage with that opportunity or in that situation lies somewhere along this continuum and can be influenced by either external forces, such as points on an assignment, or internal forces, such as the sense fulfillment experienced from a task well done. One's position on this continuum is fluid for any situation as it is easy for outside actors to externalize one's determination (Ryan & Deci, 2000). Self-determination levels have been found to be significant influencing factors in such areas as health profession education (Orsini, Binnie, & Wilson, 2016), predicting achievement (Jeno et al., 2017; Taylor et al., 2014), hybrid learning (Butz & Stupnisky, 2016).

Traditionally, science education researchers have examined students' motivations from the standpoint of how the characteristics of others support one's psychological needs (examples: Black & Deci, 2000; Lavigne et al., 2007; Standage, Duda, & Ntoumanis, 2005). The focus of prompts used to gather data on perceptions is on a person initiating the action and might be I don't feel very good about the way my instructor talks to me or I am likely to follow my instructor's suggestions for studying chemistry. The data they provide might indicate the relational capacity of the instructor and how students feel about their relationship with the instructor, but provide no insight about their other psychological needs. To determine if certain types of instruction may meet these needs, it is necessary to keep searching for a proper method of needs assessment.

SDT question prompts are also designed to assess whether psychological needs support learning a particular skill or content area, {e.g. "I feel close to others when learning biology in this course" (relatedness measure), or "I am good at biology" (competency measure), or "In this chemistry class, I had some choice about what activities I could do" (autonomy support)} (Williams & Deci, 1996; Williams, Wiener, Markakis, Reeve, & Deci, 1994). While it is important to know if a class supports students' psychological needs, it is equally important to identify instructional methods that may support or distract students from learning.

*Intrinsic Motivation Inventory*

The Intrinsic Motivation Inventory (IMI) is one of several questionnaires designed to measure student motivational affect and has been used to measure motivation in undergraduate courses (Black & Deci, 2000). The IMI is the only questionnaire that incorporates all three subscales of SDT (autonomy, competency, and relatedness). The history of the IMI is not known; however, the first major publications to discuss the inventory examined its psychometric properties using confirmatory factor analysis (McAuley, Duncan, & Tammen, 1989; McAuley, Wraith, & Duncan, 1991). The IMI is a multidimensional survey instrument designed so researchers may choose which of its seven subscales to use when creating an assessment (see examples Deci, Eghrari, Patrick, & Leone, 1994; Ryan, Koestner, & Deci, 1991).

*Goal*

This study's goal was to determine if students perceive active learning as intrinsically motivating. To accomplish this, I modified Intrinsic Motivation Inventory questions and used them to measure student perceptions of the ability five instructional techniques (four active, one passive) to fulfill the psychological needs of autonomy, competency, and relatedness. The resulting scores serve as indicators of a technique's ability to motivate students intrinsically to engage during active learning instruction in their undergraduate biology course. In addition, I used students' perceptions to provide insight into how well the design and execution of different types of active learning worked.

## MATERIALS AND METHODS

### *Human Subjects Research*

The IRB of the TAL institution provided approval (MTSU 16-1004). The data from the FAL institution had been previously collected and de-identified so no link existed between the data and the participants, thus the FAL institution's IRB office confirmed this study as non-humans subject research.

### *Study Participants*

The flipped active learning (FAL) course was a mixed-majors, introductory biology course at a large, land-grant, south-central, research-intensive institution. Two different types of FAL sections were surveyed: one large, regular section (n = 120) and two honors section (1 medium (n = 80); 1 small (n = 40)). Guaranteed admission requirements for honors was a H.S. GPA of 3.75 and for the non-honors students, a H.S. GPA of 3.00. The majority of students were freshman and sophomores with a large portion being life-science majors (see Table IV. 1). A full professor, who had taught course for more than two decades, instructed the honors section. The non-honors course was taught by a Ph.D. candidate who was completing his capstone teaching practicum for the University Faculty Preparation Program. For many enrollees, this was their first college science course and first flipped course.

The traditional active learning (TAL) course was conducted at a large, mid-western, moderate research activity doctoral university. This class was a major's only introductory biology course with an average enrollment of 200 students. The students were predominantly freshman and sophomores (see Table IV. 1). Instructing this course was a recently-tenured associate professor with five years of teaching experience. The average GPA for students entering the university was 3.35.

Table IV. 1. Sample sizes and distribution of participants' class standings. Out of the FAL participants, 187 participants were initially offered the survey (94 non-honors and 93 honors). For the second round utilizing the shorter survey, 68 honors students were surveyed.

| Institution | Number of Participants | Freshmen (%) | Sophomores (%) | Juniors (%) | Seniors (%) |
|---|---|---|---|---|---|
| **FAL** | 255 | 83.3% | 16.7% | 0 | 0 |
| **TAL** | 98 | 54.2% | 22.9% | 10.2% | 12.7% |

*Course Characteristics*

In the FAL course, which met three days a week for fifty minutes. students viewed lecture material outside class on videos and practiced, applied, and rehearsed material in class (Bergmann & Sams, 2009). The active learning employed were classroom response devices (clickers), small group work, whole class discussion, and Verso® (a web-based app that allows professors to post content or questions and in return get students' responses or thoughts). Verso® allowed students (whose predecessors had indicated frustration because they could not ask questions while watching the online lecture videos) to ask questions anytime. Students would post their questions before class and then select ("up-vote") and post answers to their peers' questions that they wanted to be answered in class. Questions and answers were kept anonymous to all but the instructor. The instructor began class by answering the most up-voted questions first and acknowledging the explanations students provided. Students in all sections took four common exams with most questions on the apply and analyze levels of Bloom's revised taxonomy (Anderson & Krathwohl, 2001).

In the TAL course, which met three days a week for fifty minutes, students' predominant source of content knowledge was the assigned reading and targeted questions outside of class. The TAL also included mini-lectures in class which expanded on topics students had read about in their focused textbook readings. In class, students practiced and applied what they had learned from their textbook reading using active learning techniques (clickers, small group work, and discussion). There were six summative assessments of student learning in the TAL, the lowest of which was dropped.

The instructors and I discussed the active learning techniques (use of clickers, small group work, and whole class discussion) and concluded they were executed in a reliably, similar enough fashion in both courses to allow us to compare student motivational impact at both institutions. Clicker instruction followed the peer-discussion model where students interact to evaluate answers. This has been shown to be a better clicker-use model for student learning (Lewin, Vinson, Stetzer, & Smith, 2016; Prather & Brissenden, 2009). Group activity was any activity occurring in a group of 3 to 5 individuals, including sentence sorts, completing worksheets, diagramming a cellular process on a white board and giving feedback to peers based on their drawings. In whole class discussions, either the whole class worked together to solve the instructor presented or groups presented their work from small group activity to the whole class.

*Survey Instrument Design*

I used three subscales from the Intrinsic Motivation Inventory (IMI): perceived competence (seven items), perceived choice (six items), and relatedness (six items) (see Appendix III.2 for full IMI) and ordered the nineteen items randomly using Excel to reduce question order bias (Mitchell & Carson, 1989). The IMI asks students to indicate how true they perceive each statement is, on a Likert scale from one = not at all true to six = very true. Values that exceed 3.5 indicate that students are likely to be intrinsically motivation, and values below do not. I summed autonomy (perceived choice), competency, and relatedness scores to produce a psychological-needs satisfaction score ranging from 3 to 18.

The IMI was designed so question stems could be modified to test for motivational effect as per my research needs. For example, "I think I am pretty good at this activity" (www.selfdeterminationtheory.org) can be modified into "I think I am pretty good at watching lecture videos." I modified the questions to direct student thinking to how they perceived the course was influencing their motivation to learn biology (See Appendix III.3). An example of a rewritten autonomy question asked is, "While studying biology in this course, I felt like I had to do this." An example of a rewritten competency question is, "While studying biology in this course, after working at this activity for a while, I felt pretty competent." An example of a rewritten relatedness questions is, "While studying biology in this course, I felt like I couldn't trust others to do this activity with me."

*Data Collection*

**Data Sources**. Data for this research were collected using the modified version of the IMI (for a complete list of the questions asked sorted into their respective self-determination categories see Appendix III.3 and for forms 1, 2, 3 and 4 of the motivation survey students received, see Appendix III.4). Surveys were distributed during the final two weeks of the FAL course during the Spring 2015, Fall 2015, Spring 2016, and Fall 2016 semesters and of the TAL course during the Spring 2015 semester. Based on student responses, I added questions beginning in the Spring 2016 survey to examine correlations between each of the three motivational factors and a similar reference scale. I tested for a correlation between competency and test performance. I tested for a correlation between the relatedness subscale and sense of belonging to a scientific community (Chemers, Zurbriggen, Syed, Goza, & Bearman, 2011) as a sense of belonging has been shown to have a high degree of association with college student intrinsic motivation, academic self-efficacy, and utility value (T. M. Freeman, Anderman, & Jensen, 2007). Autonomy should be highly correlated with interest (Black & Deci, 2000), therefore I examined that subscale's correlation with questions I developed about students' interest in a science major or course.

**Data Analysis**. All data were analyzed using IBM SPSS® version 23. To establish reliability, I calculated Cronbach's alpha to look at internal consistency. I then compared patterns in the student's responses to determine whether the similarities between the two institutions support a claim of reliable consistency (American Educational Research, American Psychological, National Council on Measurement in, Joint Committee on Standards for, & Psychological, 2014). To establish validity, I conducted an exploratory factor analysis (EFA) on the student responses to determine if the survey retained the three dimensions (autonomy, competency, and relatedness) from the IMI or if students perceived more or fewer dimensions than SDT predicts (Koch, 2014). I then compared SDT component scores among the instructional techniques used in both courses (lecture, clickers, small group activity, whole class discussion, and assessment) using MANOVA, after using a two-step transformation to normalize non-normal data (Templeton, 2011). Data were analyzed using IBM's SPSS version 21. Differences between student responses in the two different courses were considered significant at $\alpha = 0.05$.

RESULTS

*Establishing Reliability*

Table IV.2 contains the results from Cronbach's α (Tavakol & Dennick, 2011). Thirteen measures exceeded values that would indicate internal consistency, seven did not. Notably, Cronbach's α for competency for all activities exceeded the criterion for internal consistency, while only that for whole class discussion did so for relatedness. Calculated α values from constructs composed of few questions will sometimes result in low α values, which do not represent their true α value (Cronbach, 1951; Vallerand, Fortier, & Guay, 1997), thus I chose to proceed, tentatively treating the constructs that failed to reach the criterion as reliable.

Table IV. 2. Cronbach's alpha rating for all constructs used in the survey. For the IMI measures: V = Verso, VL = Video Lecture, C = Clicker, GA = Group Activity, CD = Whole Class Discussion, and E = Exam. *=Significant α (=> 0.700).

| Construct | Cronbach's alpha | |
|---|---|---|
| IMI: Competency | V = 0.778*<br>VL = 0.888*<br>C = 0.866* | GA = 0.876*<br>CD = 0.882*<br>E = 0.938* |
| IMI: Autonomy | V = 0.657<br>VL = 0.712*<br>C = 0.723* | GA = 0.705*<br>CD = 0.662<br>E = 0.680* |
| IMI: Relatedness | V = 0.543<br>VL = 0.410<br>C = 0.579 | GA = 0.593<br>CD = 0.613*<br>E = 0.505 |
| Belonging to a Scientific Community (Chemers, Zurbriggen, Syed, Goza, & Bearman, 2011) | 0.900* | |
| Interest in a Science Major (developed locally) | 0.981* | |

*Establishing Validity*

I established construct validity by conducting an Exploratory Factor Analysis using Principal Axis Factoring (Koch, 2014) with a direct oblimin rotation because motivational concepts are related to one another. Appendix III.5 displays the factor loadings from the EFA. While some questions loaded cleanly onto single factors such as competency, others had significant cross-loadings (i.e. exceeded values of 0.32; Tabachnick & Fidell, 2007), when it was predicted they should only load on a single factor. This was especially true for relatedness questions. This suggested a need for modification, however, as previous research had established psychometric properties (McAuley et al., 1989) and temporal stability (Tsigilis & Theodosiou, 2003), I decided to accept the validity and interpret further results cautiously.

*MANOVA*

Mean IMI scores are presented in figure VI.1. All but FAL exams exceeded 3.5. The results from the MANOVA showed significant differences $[Pillai's\ Trace = f(5, 175) = 4.207, p < 0.01]$ with a small effect size of $\eta^2 = 0.107$. A further univariate examination yielded two significant differences. The mean for the autonomy motivational variables for the TAL Exams was higher than that for the FAL $[F(1{,}179) = 6.372, p < 0.05]$. The mean for the competency motivational variables for the TAL Direct Lecture/Video was higher than that for the FAL $[F(1{,}179) = 6.333, p < 0.05]$ (see Appendix III.6 for MANOVA summary). However in both cases the effects sizes were small ($\eta^2 = 0.034$; $\eta^2 = 0.034$).

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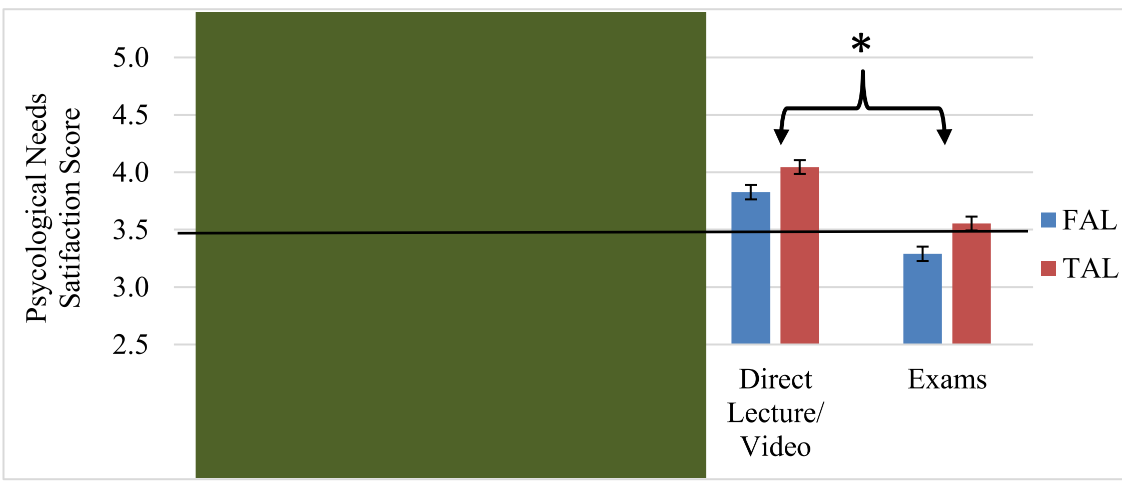


Figure IV. 1. The mean Psychological Needs Satisfaction Scores as perceived by students in TAL (red) and students in FAL (blue) for each course component. The line at 3.5 represents the threshold for positive views of need fulfillment. Error bars represent the standard error of the means. The asterisk indicates the two instruction couplets with a significant difference between course types at α = 0.05 level. Shaded area indicates the active learning components.

*Active v. Passive Learning*

The mean psychological needs satisfaction scores for all instructional activities except exams in the FAL crossed the threshold of positive perception (3.5). To determine if there was a significant difference between the three types of active learning and the other two components, I ran a repeated measures ANOVA with a Greenhouse-Geisser correction. This indicated a significant difference between instructional components at both the FAL $[F(3.011, 279.993) = 52.420, p < 0.001]$ and TAL $[F(2.259, 194.262) = 75.351, p < 0.001]$ institutions with both institutions also having moderate effect sizes $(FAL\ \eta^2 = 0.448\ and\ TAL\ \eta^2 = 0.379)$. Post-hoc tests using the Bonferroni correction indicated that the three types of active learning were not significantly different from one another in either course, but all had significantly higher psychological needs perception scores than lecture or exams (see Table IV.3 and Appendix III.7 for pairwise comparisons).

Table IV.3. Pairwise comparison of TAL and FAL course component psychological needs satisfaction scores comparing active learning instruction to lecture and exam instruction. Post-hoc test run using a Bonferroni correction. * = significant difference where $p \leq 0.005$.

| **Pairwise Comparisons of Psychological Needs Satisfaction Scores** | | | | | | | |
|---|---|---|---|---|---|---|---|
| Motivation Comparisons | | Mean Difference | | Standard Error | | Significance | |
| | | FAL | TAL | FAL | TAL | FAL | TAL |
| Lecture vs. | Clickers | -0.389* | -0.170* | 0.062 | 0.047 | 0.000 | 0.005 |
| | Group Activity | -0.296* | -0.217* | 0.056 | 0.048 | 0.000 | 0.000 |
| | Whole Class Discussion | -0.370* | -0.116 | 0.063 | 0.051 | 0.000 | 0.251 |
| | Exams | 0.537* | 0.492* | 0.075 | 0.063 | 0.000 | 0.000 |
| `Exams vs. | Clickers | -0.926* | -0.663* | 0.077 | 0.074 | 0.000 | 0.000 |
| | Group Activity | -0.833* | -0.710* | 0.078 | 0.077 | 0.000 | 0.000 |
| | Whole Class Discussion | -0.907* | -0.609* | 0.075 | 0.074 | 0.000 | 0.000 |
| | Lecture | -0.537* | -0.492* | 0.075 | 0.063 | 0.000 | 0.000 |

The lack of significant differences in psychological needs satisfaction scores for the three common types of active learning used in both courses adds further evidence that the techniques met needs equally. Notably, there was no significant difference in intrinsic motivation between in-person (direct) and online (video) lectures [$F(1,146) = 2.107$, N.S.]. As both values have exceeded the 3.5 intrinsic motivation threshold, both direct lecture and video lecture intrinsically motivate, similarly.

To meet MANOVA assumptions, I used a two-step data transformation (Templeton, 2011) to normalize the data, before conducting a MANOVA to compare IMI subscale scores across instructional techniques (clickers, group activity, whole class discussion, lecture, and exams). Instructional techniques varied significantly in their ability to meet student needs [$Pillai's\ Trace = F(15,166) = 7.881, p < 0.001$] with a medium effect size ($\eta^2 = 0.416$). Noteworthy results from the MANOVA on the SDT subscales were video and direct lecture methods comparisons, where the mean relatedness scores were significantly different [$F(1,180) = 12.692, p < 0.001$] with a small effect size of ($\eta^2 = 0.066$) while mean competency and autonomy scores did not differ significantly. Students at the TAL institution had a significantly higher psychological needs satisfaction scores than students at the FAL [$F(1,180) = 11.571, P < 0.01$] with a small effect size ($\eta^2 = 0.060$). Students in the TAL institution has a significantly higher perception of autonomy needs support than did the FAL students and the FAL students have a higher perception of competency needs support than the TAL students [$autonomy = F(1,180) = 34.045, P < 0.001\ with\ an\ effect\ size\ of\ \eta^2 = 0.159, and\ competency = F(1,180) = 7, P < 0.01\ with\ a\ small\ effect\ size\ of\ \eta^2 = 0.037$].

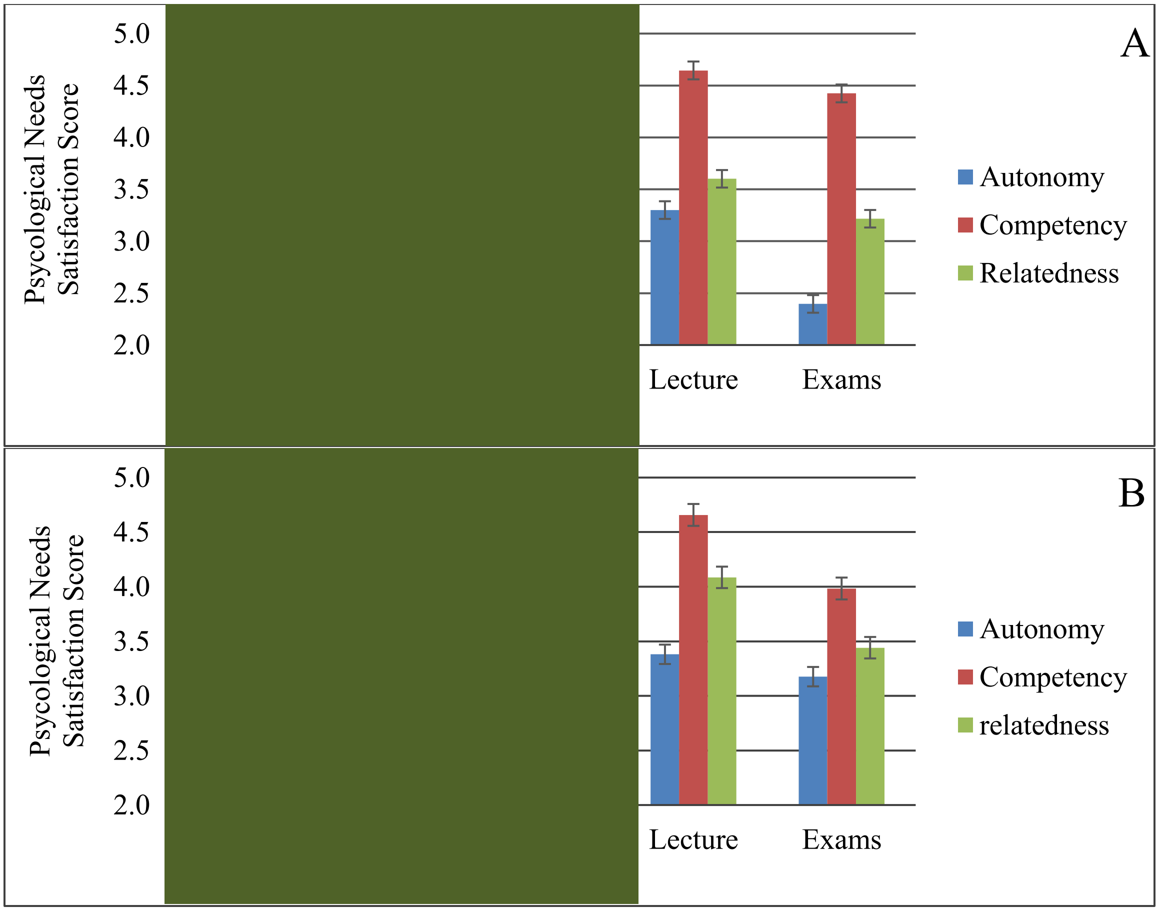


Figure IV. 2. Student's perceptions of how the different instructional activities met their needs for autonomy, competency, and relatedness. The FAL student perceptions are in Fig. IV.2.A and the TAL student perceptions are in Fig. IV.2.B. Error bars represent the standard error of the mean. The threshold for positive views of needs fulfillment was 3.5. The shaded areas indicate the different types of active learning instruction.

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*Correlating motivation with related outcome variables*

Table IV.4 presents the Pearson correlations for each SDT subscale for each instructional activity and a reference instrument that corresponded to an expected outcome if that psychological need were met. The correlations were between: perceived competency support and course performance (exam average), perceived autonomy support and interest in a science major (based on a set of questions  developed locally) and perceived relatedness support and a sense of belonging to a scientific community (Chemers et al., 2011). The only STD component that correlated with its related variable was students' perceptions of competency needs support with course grade, for which the correlations were significant for all instructional activities and ranged from small correlation 0.189 (group activities) to high correlation 0.627 (exams) (see table IV.4). Student perceptions of competency needs support from video watching positively correlate with both video watching ($r = 0.351$, $n = 280$, $p < 0.001$) and clicker participation ($r = 0.187$, $n = 280$, $p < 0.005$) (Appendix III.8). Additionally, student clicker participation positively correlated with their perceptions of competency needs support ($r = 0.217$, $n = 275$, $p < 0.001$) and perceptions of relatedness needs support($r = 0.155$, $n = 275$, $p < 0.01$), but negatively with their perceptions of autonomy needs support($r = -0.137$, $n = 275$, $p < 0.05$).

Table IV. 4. Pearson's correlation between self-determination subscale and related variable measured for each of the instructional activity. * = significant result

| | | **Pearson's Correlations** | | |
|---|---|---|---|---|
| | **Course Component** | **Autonomy/Interest** | **Competency/Grade** | **Relatedness/Belonging** |
| Active Learning | Clickers[+] | -0.194 | 0.279* | 0.177 |
| Active Learning | Group Activities[+] | -0.228 | 0.189* | 0.149 |
| Active Learning | Whole Class Discussion[+] | -0.182 | 0.210* | 0.180 |
| | Lecture Direct/Video | -0.159 | 0.363* | 0.056 |
| | Exams | -0.148 | 0.627* | 0.123 |

*Improving validity and reliability*

To address the issues of reliability and validity that the pattern of factor loadings and Cronbach's alpha revealed, I revised the survey for Fall 2016 by omitting all questions that had cross-loaded in past iterations of the survey (see table 2). This reduced the number of questions on the survey from nineteen per course component (133 questions in total) to fourteen per course component. Reducing the number of questions was also meant to reduce the level of fatigue associated with taking a lengthy survey and increase the accuracy of student responses. I analyzed the Fall 2016 data using EFA with the same parameters described previously. Removing the items did not totally eliminate cross-loadings(Appendix III.9). However, this may be an artifact of the sample size (n = 69) of students offered the new format survey, which fell below the recommended number (100) of respondents for accurate EFA (Arrindell & Ende, 1985; Gorsuch, 1983) and reliability analysis. Further sampling is required to establish reliability more definitively.

## DISCUSSION

The purpose of this research was to determine if students perceive different types of active learning as fulfilling their motivational needs, which in turn may account for students increased participation in and therefore the effectiveness of active learning in undergraduate biology classrooms. To do this, I conducted surveys with questions measuring students' perceived levels of autonomy, competency, and relatedness to specific instructional techniques. In doing so, I made novel use of the Intrinsic Motivation Inventory.

The Intrinsic Motivation Inventory had previously been shown to be an acceptable device for measuring autonomy, competency, and relatedness. However, traditionally it is used to measure student thinking on the ability of individuals to support motivation needs. The questions were modified to focus student thinking on the ability of the instructional activity to support student motivational needs. I argue that if students perceive that 1) they are competent to do an activity, that 2) they are able to choose to participate in that activity, and that 3) they are working closely with their peers and instructor, then there is a strong likelihood for those students to be intrinsically motivated. To my knowledge, this is the first to attempt to use questions modified in this way. Although EFA and Cronbach's alpha analyses indicated issues, because the survey components had been previously reported as valid and reliable (McAuley et al., 1989; McAuley et al., 1991; Tsigilis & Theodosiou, 2003), I cautiously continued with the analysis. What follows is a discussion of the preliminary findings and implications of this shift in question orientation.

*Differences in motivation support perception*

In-person lecture and video lecture did not differ in their perceived ability to support student autonomy and competency, however they differed in students' perceptions of relatedness support. This finding shines new light onto the ongoing debate on learning from video lectures. Several studies that have queried students about their preferences for learning and found that they prefer in-person lecture to video lecture even if their grades improved as a result of being in a flipped class (Hanson, 2016; Hao, 2016). In these studies, students indicated they perceive that they "learn better from live lecture." These results contradict those statements and instead indicate that perhaps the preference for in-person lecture is predicated on students feeling a sense of connection to their professor. If it is their perception of relatedness, then one can make a case that for a teacher, possessing a relatable personality is just as important as being able to disseminate content effectively.

Results here show in-person lecture is as effective as video lecture in helping students feel competent (proficient). This is an important finding in that I have provided evidence supporting the effectiveness of online instruction. This evidence further supports the use of flipped classrooms in that logically if both in-person and online lectures are just as effective at helping students gain content knowledge, then the fact that students in flipped classes have the opportunity to practice what they have learned should have a greater impact on student performance. This finding also has the potential to support a new thread of online learning research into assessing student feelings of relatedness during online instruction. More traditional threads of student's perceptions of online learning are focused on student's satisfaction levels and performance scores (Wallace, 2003).

The second major difference in need perception occurred during exams, which might reflect the difference in summative assessment at the two institutions. At the FAL institution, four common cumulative exams accounted for 53% of their overall course grade. At the TAL institution, five unit tests accounted for 53% of their overall course grade and the lowest score was dropped. Perhaps because they could drop a test and therefore choose into which exam they would put the effort to study, the TAL class perceived a significantly higher degree of autonomy support for exams. There was also a significant difference in competency support between course formats. Here the option of dropping a test grade may have been a factor, positively influencing students' perceptions of competency support. If students put in the time and effort to study for the FAL cumulative exams and then do well, they would perceive themselves as being competent in all the knowledge covered over the course of the semester. Also, as half of the FAL students I assessed were honors students, they are constantly reminded how well they perform when compared to the non-honors sections as they all have common exams. Because they can see that they consistently do better than the other sections, it is logical to think that their feelings of competency would be high. However, this data is very nuanced and warrants further investigation.

*Linking motivation, active learning, and rehearsal*

All instructional techniques appear to support student psychological needs, as evidenced by each technique exceeding the threshold for intrinsic motivation (within standard error) (Fig. IV.1). However, there is evidence that the three types of active learning significantly outperformed the direct lecture/video and exam instructional activities in their ability to satisfy needs. This may explain the substantial evidence for the effect of these techniques in the classroom (S. Freeman et al., 2014; Prince, 2004). The more students perceive that a method of instruction meets their psychological needs, the more likely they are to be intrinsically motivated to engage in it.

*Motivation and Behavior*

This study provides evidence that students' perceptions of psychological need support positively correlate with their engagement behavior. Specifically, students' perceptions of video watching competency positively correlated with both videos watching behavior and clicker participation (Appendix III.8). If the primary way to get the background information necessary to answer exam questions is from video lectures, then students should perceive that watching video lectures would increase competency (Frederickson, Reed, & Clifford, 2005). The correlation between participation and perception provides evidence for this.  The fact that clicker participation behavior positively correlated with students' perceptions of competency and relatedness explains why clicker participation is so high (Chapter 2 and Appendix III.8). Clicker participation may correlate positively with perception of lecture competency because students may be reluctant to participate unless they have obtained sufficient background knowledge. This effect would be exacerbated if student clicker answers were graded. While several studies have shown that students in classes that use clicker experience a performance increase (S. Freeman et al., 2007; Trees & Jackson, 2007), no one has yet attempted to correlate clicking behavior with students' perception of competency. In flipped courses, knowledge acquisition occurs outside the normal class period through such means as textbook reading or lecture video watching (Bergmann & Sams, 2009). In this study, video lectures were used to provide background information. Students confident enough to represent knowledge through answering a clicker question (clicking), may attribute their competency to the lecture videos as the source of that background information.

These results also explain why students were more engaged (on-task) and exhibited less off-task behavior (behavior that is not relevant for the method of instruction being used at the time of observation) during active learning than during lecture, as the results indicated in chapter 2. There was also more variation in on-task behavior over time for active learning (Fig. II.1). Considering how psychological needs are met may explain the decrease in on-task behavior after ten minutes of group activity. At the beginning of a group activity, students are recalling information (competency support), discussing material with their peers (relatedness support), and letting group members contribute based on their knowledge base (autonomy support). At the ten minute mark, students: have either finished the activity or reached a point of confusion (low competency support), have run out of their shared knowledge base and are either talking about something completely different or more likely not talking at all (reduced relatedness especially relatedness directed to learning), and are waiting for further instructions from (autonomy support, but for disengagement). There is a switch from high levels of needs being supported to none being supported, which could explain the drop in on-task behavior.

*The Problem with Autonomy Perception*

Clicker and group activity autonomy scores were below the threshold for positive perception. There are several reasons students could perceive these two activities as not being autonomous. Students in the FAL class were not awarded points for anything they did in class, specifically so students would not feel anxious about participating. Yet students often continued to ask how many points these activities were worth, indicating that some might have had perceptions influenced by incorrect information. Additionally, I argue for two potential forces helping to externalize student motivation. The first is peer pressure. If peers are clicking, then perhaps students participate because they want to avoid feeling like outsiders or perceive they would otherwise miss some benefit others get. Secondly, students may perceive they have to click to avoid a negative reaction from the instructor, such as being required to click again or having the professor complain about low participation rates.  In either case, student's motivation to participate has been externalized. Perhaps students resent or fear being called on to answer questions in class during the group activity or to explain their clicker answer choice, a situation in which they have no control (McKeachie, 1951).

One final reason that autonomy scores were low could be that traditionally questions about autonomy are designed to assess whether or a not students perceive that they are presented with choices in a given situation (Ciani, Middleton, Summers, & Sheldon, 2010; Jang, Reeve, & Deci, 2010; Ting, 2015). Consider, if students perceive a class as an ordered set of activities (first I answer questions, then I do a group activity, and finally I end with clicker question) they may not perceive they have a choice about what or when to participate, even though the instructor is providing three different practice methods and not grading students based on participation. Conversely, research has indicated that students desire that their courses have structure (Crews & Butterfield, 2014; Jang et al., 2010). Taken together, striking some balance appears to be the best strategy.

*Locus of Needs Support*

Psychological needs support questions are traditionally written with a focus on individuals as the agent supporting or not supporting psychological needs (Pintrich et al., 1991; Williams et al., 1997; Williams et al., 1994). This study examined if instructional methods can serve as psychological support agents. This modification in question-wording from the original IMI was an effort to examine whether students perceive an instructional activity as something separate or different from the faculty member or as a characteristic or extension of the faculty member. If so, we could be more confident that the benefits of active learning are independent of the instructor. The results provide some evidence students have this perception, but the evidence is inconclusive and requires more testing.

*Limitations and Future Directions*

Arguably, the biggest limitation of this paper is that the motivation questions did not exhibit the expected factor structure or high levels of Cronbach's alpha, thus may require rewording to achieve greater confidence in their validity and reliability in this context.  Students appear to have interpreted some questions, especially the competency questions, as I predicted based on SDT. In other cases, it may not have been clear whether students interpreted the questions about the subscale component as being applied to the activity, the course, or the subject matter. Future research will be required to develop questions that accurately elicit student perceptions of psychological needs satisfaction for different instructional types. Interest, an IMI subscale not used in this study, may also be a good proxy for determining intrinsic motivation (Jeno et al., 2017), so adding an interest subscale could help explain more about student instructional engagement behavior choices. Adding more specific language to direct students thinking could help resolve this issue (see Appendix IV.1 for current format). For example, instead of asking "When studying biology in this course....I feel close to others when I do this activity....Clickers" I could instead ask "I feel close to others in my biology course when I use clickers." Additionally, switching to several smaller surveys could increase accuracy as there may very well be an element of survey fatigue for students answering all eighty-four needs support questions at the same time (Adams & Umbach, 2012; Porter, Whitcomb, & Weitzer, 2004).

There are other subscales included in the IMI, such as interest, , as well as subtheories of SDT that were not included in this study. SDT is composed of six mini or sub theories: cognitive evaluation theory (CET), goal content theory (GCT), organismic integration theory (OIT), basic needs theory (BNT), causality orientation theory (COT), and they theory of vitality (Vlachopoulos et al., 2013). While all are tangentially relevant to this study, two subtheories stand out as potentially aiding in future research on active learning instruction - CET and COT. CET focuses on elucidating that which thwarts or supports the psychological needs of autonomy and competency (Deci & Ryan, 1985b). This could be particularly useful in gaining a better understanding of how autonomy perception, as it was the most difficult need to assess in my study, is influenced in biology classes.

Possibly the more useful of the two subtheories, COT states that strength of one's motivational orientation determines one's behavior, meaning that multiple orientations can simultaneously be expressed, but the orientation exhibiting the most influence over an individual ultimately determines the behavior for that individual (Deci & Ryan, 1985a). Deci and Ryan (1985a) define COT's three orientations as follows:

1) Autonomy orientation – people who are autonomy oriented seek out opportunities that offer the widest range of choices.
2) Control orientation – people who are control-oriented tend to be motivated more by extrinsic rewards (such as jobs that are higher paying as opposed to more interesting) than by intrinsic ones.
3) Impersonal orientation – people who exhibit an impersonal orientation perceive themselves as having no control over their behavior, typified by feeling of depression because they perceive an external force is controlling them.

Causality orientation acts as a lens through which one's experiences are filtered and one's ability to perceive psychological needs satisfaction. For example, say someone with control orientation is asked questions about the level of autonomy support active learning instruction affords him or her. If the reason he or she is participating in active learning activity is because he or she perceives it is expected of him or her, then he or she would not perceive that activity as supporting autonomy and more importantly would not want it to be supportive of autonomy. Understanding students' causality orientations and possibly using them as co-variates could help explain some of the students' interpretations of the questions I wrote and provide better insight into how to rewrite them so that students interpret them as intended.

Comparing engagement behavior to active learning motivation results could help us understand more about biology students' observable engagement behaviors. This could allow a description of recognizable signs of unmotivated or externally motivated students. Action could then be taken to support the students' psychological needs moving students from being unmotivated or externally motivated to intrinsically motivated. The consistency of student responses adds reliability to the measure; however, further testing at other institutions would increase the validity.

## CONCLUSION

The goal of this research was to determine if students perceived active learning as an agent of psychological needs support. Despite the limitations imposed by the suboptimal reliability of the instrument created to measure the ability of active learning to fulfill psychological needs, this study provided some evidence that the types of active learning instruction we assessed showed evidence of being able to support student psychological needs. This result suggests that other types of active learning may have this same ability and warrants further investigation. My measure of the competency construct appears valid and reliable and is therefore useful for assessing the ability of other types of active learning instruction to support students' psychological needs. The types of active learning instruction I assessed all supported students' psychological needs for autonomy, competency, and relatedness differently, but the implications of those differences is yet to be determined. Just as it appears that studies of active learning without considering what form or how much all had a positive (S. Freeman et al., 2014) so too, it may be that differences in the levels of psychological needs satisfaction subscales among different types of active learning may not matter as long as the sum of the subscales is the same. Then again, they may matter, affecting different people in different ways.  Overall, we are only just beginning to get a glimpse of why active learning instruction is effective. I hope that this research has indicated promising new avenues for further investigation that could ultimately prove useful in answering this effectiveness question.

# CHAPTER V

# CONCLUSION

Based on S. Freeman et al.'s (2014) findings and Dolan's (2015) recommendation this work addressed the need for research on the mechanisms by which active learning achieves its effectiveness. It followed a three-step model (Fig. I.1), testing whether any of several active learning methods stimulated and maintained on-task behavior (engagement) more than lecture did (or each other), whether engagement in active learning predicted exam performance, and whether active learning instruction satisfied students' psychological needs (as described by self-determination theory) and thereby stimulated intrinsic motivation to participate in active learning,


Figure I.1. A three-step approach to link active learning instruction to motivation by answering three questions. First question: How does active learning instruction effect engagement behavior? Second question: Does engagement behavior affect academic (exam) performance? Third question: What effect does engagement behavior have on intrinsic motivation?

If the goal of active learning instruction is to engage students by eliciting active behavioral responses, (Bonwell & Eison, 1991) then there should be a significant difference in students' engagement behavior between classes in which instructors use active learning instruction and classes in which instructors do not use active learning instruction. This study found that active learning instruction elicited and maintained more on-task engagement behavior then lecture and showed a difference in the ability each type of active learning instruction for maintaining on-task engagement behavior (Chapter 2). This supports the hypothesis that active learning instruction impacts student performance significantly more than lecture (S. Freeman et al., 2014) because it elicits significantly higher levels of on-task engagement behavior.

If active learning works by increasing student participation (i.e. engaging in on-task behaviors; Chapter 2), perhaps by increasing their retention and ability to use information, then students who participate should perform significantly better on course exams than those who don't. This research showed that participation online and in class were highly predictive of performance (Chapter 3). This now supports the hypothesis that active learning instruction impacts performance (S. Freeman et al., 2014) because it increases student on-task (engagement) behavior (Chapter 2) and those behaviors increase students' ability to perform (Chapter 3). Furthermore, this study provides evidence that active learning is enhanced by the degree to which students have participated in learning material previously, since participation in active learning and live or video lectures together accounted for 53% of the variance in exam performance. The question remains, why do students engage in active learning?

Abeysekera and Dawson (2014) hypothesized flipped learning supports intrinsically motivated participation because it allows more time for active learning instruction, which supports students' psychological needs. Supporting students' psychological needs should increase students' intrinsic motivation to engage in active learning, which then leads to increased performance. Abeysekera and Dawson (2014) did not produce evidence to support their claims and therefore, therefore the third portion of this study was undertaken to examine whether active learning instruction supports student psychological needs. The findings offer some evidence, especially for competency support, that these active learning methods support student psychological needs more than other instructional activities (like lectures and exams). Not only does active learning instruction support needs, it also correlates with test performance and participation in engagement behaviors for both preparation (lecture video watching) and in-class practice (clicking) (Chapter 4). These findings lend support (to various extents) to the hypothesis that active learning instruction supports students' psychological needs (Chapter 4), therefore students are intrinsically motivated to participate in active learning, which impacts participation, as indicated by student on-task engagement behavior (Chapter 2), and this participation, which is associated with test performance, (Chapter 3) leads to increased performance in courses (S. Freeman et al., 2014).

Some other notable findings are the equivalency of online and face-to-face lecture and the variation in taskedness associated with the different types of active learning researched. In Chapter 2, I showed the three types of active learning instruction I assessed differed in their ability to elicit and maintain student on-task behavior. I proposed that the differences in the levels of on-task behavior were influenced by the frequency at which students' behavioral engagement was re-stimulated. I consider these findings important for three reasons. First, this study has shown that not all active learning instruction is equally successful at keeping students on-task, at least as their use is commonly described, and therefore one cannot say they are equivalent. Second, this study represents a fundamental shift in research from a traditional focus on the teacher and what he or she is doing to how the students are responding behaviorally to instruction. Also, I have shown that shifting focus from what instructors are doing to engage their students to how often student behavioral engagement is stimulated is a promising approach to understanding how active learning works. Third, these findings indicate the importance of instructors focusing on making students behaviorally active rather than focusing on the way content is disseminated.

The study in chapter 4, showed that student perceptions of face-to-face and video lecture autonomy and competency needs support were equivalent; however, student relatedness needs support perceptions were significantly different. This is an important finding in that I have shown that students feel they gain knowledge equally well from both online and face-to-face instruction, but the reason students may prefer face-to-face over video lecture is they feel a sense of connection to the instructor in the classroom that is not present online. As online classes become more prevalent, these results give online instructors insights as to what elements are important to include in their lectures if they want to stimulate student engagement. Perhaps having designated lecture watching times available where either an instructor or teaching assistant can be present to field questions could mitigate this lack of relatedness perception.

While this study could only provide limited data, there are other studies that could support the hypothesis that active learning instruction supports students' psychological needs (Chapter 4), therefore students are intrinsically motivated to participate in active learning, which impacts participation, as indicated by student on-task engagement behavior (Chapter 2), and this participation, which is associated with test performance, (Chapter 3) leads to increased performance in courses (S. Freeman et al., 2014). Investigating SDT subtheories could help shed more light on why students are intrinsically or extrinsically motivated. Specifically looking at the cognitive evaluation (CET) and causality orientation (COT) subtheories of SDT could prove useful (Vlachopoulos et al., 2013). A study designed to discover what external factors are either supporting or thwarting student intrinsic motivation (CET) could lead to better understanding of what external factors researchers need to control for in future research (Deci & Ryan, 1985b). For instructors, understanding the role of CET would help in planning instruction to avoid negative influences student motivation. A study designed to classify students' motivational orientation

(COT) could lead to better understanding of how students are interpreting their classroom experiences, potentially allowing researchers to use orientation as a co-variate in researching student motivation (Deci & Ryan, 1985a). If we can elucidate students' motivational orientation, then we will be better able to provide appropriate support or intervention to encourage intrinsic motivation. Another useful line of research would be to investigate the effect of participation in other types of active learning instruction, such as project-based learning (Blumenfeld et al., 1991) or peer instruction (Mazur, 1997), on student performance and to see of students' behavioral engagement choices during active learning instruction correlate with students' motivational perceptions.

*Final Thoughts*

The work presented here, what S. Freeman et al. (2014) calls second-generation research, is just the beginning steps in discovering why active learning is working and for whom it is working (Dolan, 2015).  There is much work still left to do on understanding how active learning instruction effects might be mediated through student engagement behavior. There are more types of active learning instruction to be investigated and different types of behavioral interactions in the classroom that could help understand more about those for whom active learning is effective. While studies on student intrinsic motivation are numerous (Malik & Parveen, 2015; McAuley, Wraith, & Duncan, 1991; Renninger, 2000; Ryan & Deci, 2000; Taylor et al., 2014), there have been few attempts to apply this motivational construct to active learning in biology courses and therefore further investigation is warranted. During this study, new applications of existing research methods were developed (such as PROSE and IMI focused on active learning activities) that should facilitate collecting types of data rarely collected previously. Such data along with the application of theories from related disciplines may lead to more rapid gains in understanding how students learn biology successfully, the optimization and individualization of active learning instruction, and an increase in persistence of a diverse population of students in the life sciences.

REFERENCES

Abeysekera, L., & Dawson, P. (2014). Motivation and cognitive load in the flipped classroom: definition, rationale and a call for research. *Higher Education Research & Development*, 34(1), 1-14. doi: 10.1080/07294360.2014.934336

Adams, M. J. D., & Umbach, P. D. (2012). Nonresponse and Online Student Evaluations of Teaching: Understanding the Influence of Salience, Fatigue, and Academic Environments. *Research in Higher Education*, 53(5), 576-591. doi: 10.1007/s11162-011-9240-5

Agresti, A., & Kateri, M. (2011). Categorical Data Analysis. In M. Lovric (Ed.), *International Encyclopedia of Statistical Science* (pp. 206-208). Berlin, Heidelberg: Springer Berlin Heidelberg.

Ainley, M., & Ainley, J. (2011). Student engagement with science in early adolescence: The contribution of enjoyment to students' continuing interest in learning about science. *Contemporary Educational Psychology*, 36(1), 4-12. doi: http://doi.org/10.1016/j.cedpsych.2010.08.001

American Educational Research Association., American Psychological Association., National Council on Measurement in Education., & Joint Committee on Standards for Educational and Psychological Testing (U.S.). (2014). *Standards for educational and psychological testing*. Washington, DC: American Educational Research Association.

Anderson, L. W., & Krathwohl, D. R. (2001). *A taxonomy for learning, teaching, and assessing : a revision of Bloom's taxonomy of educational objectives* (Complete ed.). New York: Longman.

Andrade, J. (2010). What does doodling do? *Applied Cognitive Psychology*, 24(1), 100-106. doi:10.1002/acp.1561

Arrindell, W. A., & Ende, J. v. d. (1985). An Empirical Test of the Utility of the Observations-To-Variables Ratio in Factor and Components Analysis. *Applied Psychological Measurement*, 9(2), 165-178. doi: doi:10.1177/014662168500900205.

Azlina, N. N., & Nik, A. (2010). CETLs: Supporting collaborative activities among students and teachers through the use of Think-Pair-Share techniques. *International Journal of Computer Science Issues*, 7(5), 18-29.

Beard, L. A., & Harper, C. (2002). STUDENT PERCEPTIONS OF ONLINE VERSUS ON CAMPUS INSTRUCTION. *Education*, 122(4), 658. Begin typing or pasting the rest of your chapter 1 text here.

Bergmann, J., & Sams, A. (2009). Remixing Chemistry Class: Two Colorado Teachers Make Vodcasts of Their Lectures to Free Up Class Time for Hands-On Activities. *Learning & Leading with Technology*, 36(4), 22-27.

Betihavas, V., Bridgman, H., Kornhaber, R., & Cross, M. (2016). The evidence for 'flipping out': A systematic review of the flipped classroom in nursing education. *Nurse Education Today*, 38, 15-21. doi: 10.1016/j.nedt.2015.12.010

Birch, S., & Ladd, G. (1997). The teacher-child relationship and children's early school adjustment. *Journal of School Psychology*, 35, 61-7

Bishop, Y. M., Fienberg, S. E., & Holland, P. W. (2007). *Discrete multivariate analysis: theory and practice*: Springer Science & Business Media.

Bjork, R. A. (1994). Memory and metamemory considerations in the training of human beings. In J. M. A. P. Shimamura (Ed.), *Metacognition: Knowing about knowing* (pp. 185-205). Cambridge, MA, US: The MIT Press.

Black, A. E., & Deci, E. L. (2000). The effects of instructors' autonomy support and students' autonomous motivation on learning organic chemistry: A self-determination theory perspective. *Science Education*, 84(6), 740-756. doi: 10.1002/1098-237X(200011)84:6<740::AID-SCE4>3.0.CO;2-3

Bland, M., Saunders, G., & Frisch, J. K. (2007). In defense of the lecture. *Journal of College Science Teaching*, 37(2), 10.

Blasco-Arcas, L., Buil, I., Hernández-Ortega, B., & Sese, F. J. (2013). Using clickers in class. The role of interactivity, active collaborative learning and engagement in learning performance. *Computers & Education*, 62, 102-110. doi: http://dx.doi.org/10.1016/j.compedu.2012.10.019

Blatchford, P., Bassett, P., Brown, P., & Webster, R. (2009). The effect of support staff on pupil engagement and individual attention. *British Educational Research Journal*, 35(5), 661-686.

Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palincsar, A. (1991). Motivating Project-Based Learning: Sustaining the Doing, Supporting the Learning. *Educational Psychologist*, 26(3-4), 369-398. doi:10.1080/00461520.1991.9653139

Bonwell, C. C., & Eison, J. A. (1991). Active Learning: Creating Excitement in the Classroom. 1991 *ASHE-ERIC Higher Education Reports*: Association for the Study of Higher Education.

Bower, G. H. (1992). How might emotions affect learning. In S.-A. Christianson (Ed.), The handbook of emotion and memory: *Research and theory* (Vol. 3, pp. 31). Mahwah, NJ: Erlbaum.

Brewer, C. A., & Smith, D. (2011). *Vision and change in undergraduate biology education: a call to action*. American Association for the Advancement of Science, Washington, DC.

Bristol, T. (2014). Flipping the Classroom. *Teaching and Learning in Nursing*, 9(1), 43-46. doi: 10.1016/j.teln.2013.11.002

Bruner, J. S. (1960). *The process of education*. Oxford, England: Harvard University Press.

Burns, R. A. (1985). Information Impact and Factors Affecting Recall. Paper presented at the *7th Annual National Conference on Teaching Excellence and Conference of Administrators*, Austin, TX.

Butler, M. S. R., and K. C. Dee. 2013. "Active Learning Requires Learning–Not Just Activity." *Annual Meeting of the American Society for Engineering Education*, Atlanta, GA, June 23–26.

Butz, N. T., & Stupnisky, R. H. (2016). A mixed methods study of graduate students' self-determined motivation in synchronous hybrid learning environments. *The Internet and Higher Education*, 28, 85-95. doi: 10.1016/j.iheduc.2015.10.003

Caldwell, J. E. (2007). Clickers in the large classroom: Current research and best-practice tips. *CBE- Life Sciences Education*, 6(1), 9–20.

Calder, K. (1953). *Statistical inference*: New York: Holt.

Campbell, C., & Monk, S. (2015). Introducing a learner response system to pre-service education students: Increasing student engagement. *Active Learning in Higher Education*, 16(1), 25-36. doi: 10.1177/1469787414558981

Carini, R. M., Kuh, G. D., & Klein, S. P. (2006). Student engagement and student learning: Testing the linkages*. *Research in Higher Education*, 47(1), 1-32.

Cavanagh AJ, Aragón OR, Chen X, Couch B, Durham M, Bobrownicki A, Hanauer DI, Graham MJ (2016). Student buy-in to active learning in a college science course. *CBE-Life Science Education* 15, ar76.

Chemers, M. M., Zurbriggen, E. L., Syed, M., Goza, B. K., & Bearman, S. (2011). The role of efficacy and identity in science career commitment among underrepresented minority students. *Journal of Social Issues*, 67(3), 469-491.

Chen, P.-S. D., Lambert, A. D., & Guidry, K. R. (2010). Engaging online learners: The impact of Web-based learning technology on college student engagement. *Computers & Education*, 54(4), 1222-1232. doi: http://dx.doi.org/10.1016/j.compedu.2009.11.008

Chi, M. T. H., & Wylie, R. (2014). The ICAP Framework: Linking Cognitive Engagement to Active Learning Outcomes. *Educational Psychologist*, 49(4), 219-243. doi: 10.1080/00461520.2014.965823

Ciani, K. D., Middleton, M. J., Summers, J. J., & Sheldon, K. M. (2010). Buffering against performance classroom goal structures: The importance of autonomy support and classroom community. *Contemporary Educational Psychology*, 35(1), 88-99. doi: 10.1016/j.cedpsych.2009.11.001

Coates, H. (2007). A model of online and general campus-based student engagement. *Assessment & Evaluation in Higher Education*, 32(2), 121-141. doi: 10.1080/02602930600801878

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, N.J.: L. Erlbaum Associates.

Corno, L., & Mandinach, E. B. (1983). The role of cognitive engagement in classroom learning and motivation. *Educational Psychologist*, 18(2), 88-108. doi: 10.1080/00461528309529266

Council, N. R. (2000). *How People Learn: Brain, Mind, Experience, and School*: Expanded Edition. Washington, DC: The National Academies Press.

Council, N. R. (2003). *BIO2010: Transforming Undergraduate Education for Future Research Biologists*. Washington, DC: The National Academies Press.

Council, N. R. (2009). *A New Biology for the 21st Century*. (978-0-309-14488-9). Washington, DC: The National Academies Press Retrieved from /catalog/12764/a-new-biology-for-the-21st-century.

Crews, T., & Butterfield, J. B. (2014). Data for Flipped Classroom Design: Using Student Feedback to Identify the Best Components from Online and Face-to-Face Classes. *Higher Education Studies*, 4(3). doi: 10.5539/hes.v4n3p38

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika*, 16(3), 297-334. doi: 10.1007/bf02310555

Deci, E. L. (1980). *The psychology of self-determination*. Lexington, Mass.: Lexington Books.

Deci, E. L., Eghrari, H., Patrick, B. C., & Leone, D. R. (1994). Facilitating internalization: the self-determination theory perspective. *Journal of Personality*, 62(1), 119-142.

Deci, E. L. (1975). *Intrinsic Motivation*. Plenum Press, New York

Deci, E. L., & Ryan, R. M. (1985a). The general causality orientations scale: Self-determination in personality. *Journal of Research in Personality*, 19(2), 109-134. doi: http://dx.doi.org/10.1016/0092-6566(85)90023-6

Deci, E. L., & Ryan, R. M. (1985b). Intrinsic motivation and self-determination in human behavior. New York: Plenum.

Dixson, M. D. (2010). Creating Effective Student Engagement in Online Courses: What Do Students Find Engaging? *Journal of Scholarship of Teaching and Learning*, 10(2), 1-13.

Dolan, E. L. (2015). Biology Education Research 2.0. *CBE-Life Sciences Education*, 14(4). doi: 10.1187/cbe.15-11-0229

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education*, 84(3), 287-312.

Euzent, P., Martin, T., Moskal, P., & Moskal, P. (2011). Assessing student performance and perceptions in lecture capture vs. face to face course delivery. *Journal of Information Technology Education*, 10, 295–307.

Finn, J. D., Pannozzo, G. M., & Voelkl, K. E. (1995). Disruptive and inattentive-withdrawn behavior and achievement among fourth graders. *Elementary School Journal*, 95, 421-454

Frederickson, N., Reed, P., & Clifford, V. (2005). Evaluating Web-Supported Learning versus Lecture-Based Teaching: Quantitative and Qualitative Perspectives. *Higher Education*, 50(4), 645-664.

Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School Engagement: Potential of the Concept, State of the Evidence. *Review of Educational Research*, 74(1), 59-109.

Freeman, M. K., Schrimsher, R. H., & Kendrach, M. G. (2006). Student Perceptions of Online Lectures and WebCT in an Introductory Drug Information Course. *American Journal of Pharmaceutical Education*, 70(6), 126. doi: 10.5688/aj7006126

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, 111(23), 8410-8415. doi: 10.1073/pnas.1319030111

Freeman, S., O'Connor, E., Parks, J. W., Cunningham, M., Hurley, D., Haak, D., Dirks, C., and Wenderoth, M. P. (2007). Prescribed active learning increases performance in introductory biology. *CBE-Life Sciences Education* 6, 132–139.

Freeman, T. M., Anderman, L. H., & Jensen, J. M. (2007). Sense of Belonging in College Freshmen at the Classroom and Campus Levels. *The Journal of Experimental Education*, 75(3), 203-220. doi: 10.3200/JEXE.75.3.203-220

Gingerich, A. C., & Lineweaver, T. T. (2013). OMG! Texting in Class = U Fail :( Empirical Evidence That Text Messaging During Class Disrupts Comprehension. *Teaching of Psychology*, 41(1), 44-51. doi: 10.1177/0098628313514177

González-Cutre, D., Sierra, A. C., Beltrán-Carrillo, V. J., Peláez-Pérez, M., & Cervelló, E. (2016). A school-based motivational intervention to promote physical activity from a self-determination theory perspective. *The Journal of Educational Research*, 1-11. doi: 10.1080/00220671.2016.1255871

Gorsuch, R. (1983). *Factor analysis*. 2nd. Hillsdale, NJ: LEA.

Guo, P. J., Kim, J., & Rubin, R. (2014). How video production affects student engagement: an empirical study of MOOC videos. Paper presented at the *Proceedings of the first ACM conference on Learning @ scale conference*, Atlanta, Georgia, USA.

Haak, D. C., HilleRisLambers, J., Pitre, E., & Freeman, S. (2011). Increased structure and active learning reduce the achievement gap in introductory biology. *Science*, 332(6034), 1213e1216. http://dx.doi.org/10.1126/science.1204820.

Hall, N. C., Hladkyj, S., Perry, R. P., & Ruthig, J. C. (2004). The Role of Attributional Retraining and Elaborative Learning in College Students' Academic Development. *The Journal of Social Psychology*, 144(6), 591-612. doi: 10.3200/SOCP.144.6.591-612

Hall, N. C., Perry, R. P., Goetz, T., Ruthig, J. C., Stupnisky, R. H., & Newall, N. E. (2007). Attributional retraining and elaborative learning: Improving academic development through writing-based interventions. *Learning and Individual Differences*, 17(3), 280-290. doi: http://dx.doi.org/10.1016/j.lindif.2007.04.002

Hallgren, K. A. (2012). Computing Inter-Rater Reliability for Observational Data: An Overview and Tutorial. *Tutorials in quantitative methods for psychology*, 8(1), 23-34.

Hampden-Thompson, G., & Bennett, J. (2013). Science Teaching and Learning Activities and Students' Engagement in Science. *International Journal of Science Education*, 35(8), 1325-1343. doi: 10.1080/09500693.2011.608093

Hanson, J. (2016). Surveying the experiences and perceptions of undergraduate nursing students of a flipped classroom approach to increase understanding of drug science and its application to clinical practice. *Nurse Education in Practice*, 16(1), 79-85. doi:10.1016/j.nepr.2015.09.001

Hao, Y. (2016). Exploring undergraduates' perspectives and flipped learning readiness in their flipped classrooms. *Computers in Human Behavior*, 59, 82-92. doi:10.1016/j.chb.2016.01.032

Hayter, J. K., & Rochelle, C. F. (2014). Clickers: Performanceand attitudes in principles of microeconomics. *Journal of Economics and Finance Education*, 13, 33–44.

Henningsen, M., & Stein, M. K. (1997). Mathematical Tasks and Student Cognition: Classroom-Based Factors That Support and Inhibit High-Level Mathematical Thinking and Reasoning. *Journal for Research in Mathematics Education*, 28(5), 524-549. doi: 10.2307/749690

Hindelang, M. J., Hirschi, T., & Weis, J. G. (1979). Correlates of Delinquency: The Illusion of Discrepancy between Self-Report and Official Measures. *American Sociological Review*, 44(6), 995-1014. doi: 10.2307/2094722

Hora, M. T., Oleson, A., & Ferrare, J. J. (2013). *Teaching Dimensions Observation Protocol (TDOP) User's Manual*. Madison: Wisconsin Center for Education Research.

Hotle, S. L., & Garrow, L. A. (2016). Effects of the Traditional and Flipped Classrooms on Undergraduate Student Opinions and Success. Jou*rnal of Professional Issues in Engineering Education and Practice*, 142(1), 05015005. doi: 10.1061/(asce)ei.1943-5541.0000259

James, J. E., & Hardardottir, D. (2002). Influence of attention focus and trait anxiety on tolerance of acute pain. *British journal of health psychology*, 7(2), 149-162.

Jang, H., Reeve, J., & Deci, E. L. (2010). Engaging students in learning activities: It is not autonomy support or structure but autonomy support and structure. *Journal of Educational Psychology*, 102(3), 588-600. doi: 10.1037/a0019682

Johnstone, A. H., & Percival, F. (1976). Attention breaks in lectures. *Education in chemistry*, 13(2), 49-50.

Kanat-Maymon, Y., Benjamin, M., Stavsky, A., Shoshani, A., & Roth, G. (2015). The role of basic need fulfillment in academic dishonesty: A self-determination theory perspective. *Contemporary Educational Psychology*, 43, 1-9. doi: http://dx.doi.org/10.1016/j.cedpsych.2015.08.002

Karpicke, J. D., & Blunt, J. R. (2011). Retrieval Practice Produces More Learning than Elaborative Studying with Concept Mapping. *Science*, 331(6018), 772-775. doi: 10.1126/science.1199327

Karpicke, J. D., & Roediger, H. L. (2008). The Critical Importance of Retrieval for Learning. *Science*, 319(5865), 966-968. doi: 10.1126/science.1152408

Kay, R. H. (2012). Exploring the use of video podcasts in education: A comprehensive review of the literature. *Computers in Human Behavior*, 28(3), 820-831. doi: http://dx.doi.org/10.1016/j.chb.2012.01.011

Knight, J. K., Wise, S. B., Rentsch, J., & Furtak, E. M. (2015). Cues Matter: Learning Assistants Influence Introductory Biology Student Interactions during Clicker-Question Discussions. *CBE-Life Sciences Education*, 14(4). doi: 10.1187/cbe.15-04-0093

Knight, J. K., Wise, S. B., & Sieke, S. (2016). Group Random Call Can Positively Affect Student In-Class Clicker Discussions. *CBE-Life Sciences Education*, 15(4). doi: 10.1187/cbe.16-02-0109

Koch, I. (2014). *Analysis of multivariate and high-dimensional data*. Cambridge: Cambridge University Press.

Kohn, A. (2011). The Case Against GRADES. *Educational Leadership*, 69(3), 28-33.

Kornell N, Bjork RA (2008) Learning concepts and categories: is spacing the “enemy of induction”? *Psychological Science* 19:585–592.

Kothiyal, A., Majumdar, R., Murthy, S., & Iyer, S. (2013). Effect of think-pair-share in a large CS1 class: 83% sustained engagement. Paper presented at the *Proceedings of the ninth annual international ACM conference on International computing education research*, San Diego, San California, USA.

Kuh, G. D., Cruce, T. M., Shoup, R., Kinzie, J., & Gonyea, R. M. (2008). Unmasking the Effects of Student Engagement on First-Year College Grades and Persistence. *The Journal of Higher Education*, 79(5), 540-563. doi: 10.1080/00221546.2008.11772116

Kuh, G. D., Kinzie, J., Cruce, T., Shoup, R., & Gonyea, R. (2007). *Connecting the dots: Multifaceted analyses of the relationships between student engagement results from the NSSE, and the institutional practices and conditions that foster student success*. Indianapolis, IN: Lumina Foundation for Education.

Kuznekoff, J. H., Munz, S., & Titsworth, S. (2015). Mobile Phones in the Classroom: Examining the Effects of Texting, Twitter, and Message Content on Student Learning. *Communication Education*, 64(3), 344-365. doi: 10.1080/03634523.2015.1038727

Lam, S., Wong, B., Yang, H., & Liu, Y. (2012). Understanding student engagement with a contextual model. In S. L. Christenson, A. L. Reschly, & C. Wylie (Eds.), *Handbook of research on student engagement* (pp. 403^420). New York, NY: Springer

Landis, J. R., & Koch, G. G. (1977). The Measurement of Observer Agreement for Categorical Data. *Biometrics*, 33(1), 159-174. doi: 10.2307/2529310

Lane, E. S., & Harris, S. E. (2015). A New Tool for Measuring Student Behavioral Engagement in Large University Classes. *Journal of College Science Teaching*, 44(6), 83-91.

Lavigne, G. L., Vallerand, R. J., & Miquelon, P. (2007). A motivational model of persistence in science education: A self-determination theory approach. *European Journal of Psychology of Education*, 22(3), 351-369. doi: 10.1007/bf03173432

Lewin, J. D., Vinson, E. L., Stetzer, M. R., & Smith, M. K. (2016). A Campus-Wide Investigation of Clicker Implementation: The Status of Peer Discussion in STEM Classes. *CBE-Life Sciences Education*, 15(1). doi: 10.1187/cbe.15-10-0224

Lewis, R. A. (1995). Video introductions to laboratory: Students positive, grades unchanged. *American Journal of Physics*, 63(5), 468-470. doi: 10.1119/1.17914

Lindenberger, U., & Potter, U. (1998). The complex nature of unique and shared effects in hierarchical linear regression: Implications for developmental psychology. *Psychological Methods*, 3, 218–230.

Linnenbrink, E. A., & Pintrich, P. R. (2003). THE ROLE OF SELF-EFFICACY BELIEFS INSTUDENT ENGAGEMENT AND LEARNING INTHECLASSROOM. *Reading & Writing Quarterly*, 19(2), 119-137. doi: 10.1080/10573560308223

Lohse, K. R., & Sherwood, D. E. (2011). Defining the Focus of Attention: Effects of Attention on Perceived Exertion and Fatigue. *Frontiers in Psychology*, 2, 332. doi: 10.3389/fpsyg.2011.00332

Lyman, F. T. (1981). The responsive classroom discussion: The inclusion of all students. *Mainstreaming digest*, 109-113.

Lyman, F. T. (1987). Think-pair-share: An expanding teaching technique. *MAA-CIE Cooperative News*, 1(1), 1-2.

Lyman, F. T. (1992). Think-pair-share, thinktrix, thinklinks, and weird facts: An interactive system for cooperative thinking. *Enhancing thinking through cooperative learning*, 169-181.

Malik, M., & Parveen, N. (2015). Intrinsic Motivation of the High and Low Academic Achievers. *American Journal of Educational Research*, 3(11), 1481-1483.

Marks, H. M. (2000). Student engagement in instructional activity: Patterns in the elementary, middle, and high school years. *American Educational Research Journal*, 37(1), 153-184.

Martin, P., Bateson, P. P. G., & Bateson, P. (1993). *Measuring behavior: an introductory guide*: Cambridge University Press.

Mazur, E. (1997). *Peer Instruction, A User's Manual*, Upper Saddle River, NJ: Prentice-Hall.

McAuley, E., Duncan, T., & Tammen, V. V. (1989). Psychometric properties of the Intrinsic Motivation Inventory in a competitive sport setting: A confirmatory factor analysis. *Research quarterly for exercise and sport*, 60(1), 48-58.

McAuley, E., Wraith, S., & Duncan, T. E. (1991). Self-Efficacy, Perceptions of Success, and Intrinsic Motivation for Exercise1. *Journal of Applied Social Psychology*, 21(2), 139-155.

McDonough, K., & Foote, J. A. (2015). The impact of individual and shared clicker use on students' collaborative learning. *Computers & Education*, 86, 236-249. doi: http://dx.doi.org/10.1016/j.compedu.2015.08.009

McKeachie, W. J. (1951). Anxiety in the college classroom. *The Journal of Educational Research*, 45(2), 153-160.

McLeod, J., Fisher, J., & Hoover, G. (2003). *The key elements of classroom management: Managing time and space, student behavior, and instructional strategies*: ASCD.

Menard, S. W. (2002). *Applied logistic regression analysis* (2nd ed.). Thousand Oaks, Calif.: Sage Publications.

Mitchell, R. C., & Carson, R. T. (1989). Using surveys to value public goods : the contingent valuation method. Washington, D.C. Baltimore: *Resources for the Future*; Distributed worldwide by the Johns Hopkins University Press.

Molenaar, I., van Boxtel, C. A. M., & Sleegers, P. J. C. (2010). The effects of scaffolding metacognitive activities in small groups. *Computers in Human Behavior*, 26(6), 1727-1738. doi: http://dx.doi.org/10.1016/j.chb.2010.06.022

Morrison, R. W., Caughran, J. A., & Sauers, A. L. (2014). Classroom Response Systems for Implementing Interactive Inquiry in Large Organic Chemistry Classes. *Journal of Chemical Education*, 91(11), 1838-1844. doi: 10.1021/ed300688d

O'Bannon, B. W., & Thomas, K. (2014). Teacher perceptions of using mobile phones in the classroom: Age matters! *Computers & Education*, 74, 15-25. doi: http://dx.doi.org/10.1016/j.compedu.2014.01.006

O'Flaherty, J., & Phillips, C. (2015). The use of flipped classrooms in higher education: A scoping review. *The Internet and Higher Education*, 25, 85-95. doi: 10.1016/j.iheduc.2015.02.002

Orsini, C., Binnie, V. I., & Wilson, S. L. (2016). Determinants and outcomes of motivation in health professions education: a systematic review based on self-determination theory. *Journal of Educational Evaluation for Health Professions*, 13, 19. doi: 10.3352/jeehp.2016.13.19

Pakdel, B. (2013). The Historical Context of Motivation and Analysis Theories Individual Motivation. *International Journal of Humanities and Social Science*, 3, 13.

Paolicelli, R.C., Bolasco, G., Pagani, F., Maggi, L., Scianni, M., Panzanelli, P., Giustetto, M., Ferreira, T.A., Guiducci, E., Dumas, L., et al. (2011). Synaptic pruning by microglia is necessary for normal brain development. *Science* 333, 1456–1458.

Patrick, H., Ryan, A. M., & Pintrich, P. R. (1999). The differential impact of extrinsic and mastery goal orientations on males' and females' self-regulated learning. *Learning and Individual Differences*, 11(2), 153-171. doi: http://dx.doi.org/10.1016/S1041-6080(00)80003-5

Paulson, D. R. (1999). Active learning and cooperative learning in the organic chemistry lecture class. *Journal of Chemical Education*, 76(8), 1136-1140.

Pedhazur, E. J. (1997). *Multiple regression in behavioral research: explanation and prediction* (3rd ed.). Forth Worth: Harcourt Brace College Publishers.

Phillips, D. C. (1995). The good, the bad, and the ugly: The many faces of constructivism. *Educational researcher*, 24(7), 5-12.

Pintrich, P. R., Smith, D. A. F., Garcia, T., & McKeachie, W. J. (1991). *A manual for the use of the Motivated Strategies for Learning Questionnaire (MSLQ)*. Ann Arbor, MI: National

Porter, S. R., Whitcomb, M. E., & Weitzer, W. H. (2004). Multiple surveys of students and survey fatigue. *New Directions for Institutional Research*, 2004(121), 63-73. doi: 10.1002/ir.101

Prather, E. E., & Brissenden, G. (2009). Clickers as Data Gathering Tools and Students' Attitudes, Motivations, and Beliefs on Their Use in This Application. *Astronomy Education Review*, 8(1), 10103.

Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education*, 93(3), 223-231.

Renninger, K. A. (2000). Individual interest and its implications for understanding intrinsic motivation. In C. Sansone & J. M. Harackiewicz (Eds.), *Intrinsic and extrinsic motivation: The search for optimal motivation and performance* (pp. 375–407). New York: Academic.

Repp, A. C., Nieminen, G. S., Olinger, E., & Brusca, R. (1988). Direct observation: Factors affecting the accuracy of observers. *Exceptional Children*, 55(1), 29-36.

Rice, W. R. (1989). Analyzing Tables of Statistical Tests. *Evolution*, 43(1), 223-225. doi: 10.2307/2409177

Richtel, M. (2010, August 15). *Outdoors and Out of Reach, Studying the Brain*. New York Times, p. 16.

Risko, E. F., Anderson, N., Sarwal, A., Engelhardt, M., & Kingstone, A. (2012). Everyday Attention: Variation in Mind Wandering and Memory in a Lecture. *Applied Cognitive Psychology*, 26(2), 234-242. doi: 10.1002/acp.1814

Risko, E. F., Buchanan, D., Medimorec, S., & Kingstone, A. (2013). Everyday attention: Mind wandering and computer use during lectures. *Computers & Education*, 68, 275-283. doi:http://doi.org/10.1016/j.compedu.2013.05.001

Robinson, C. C., & Hullinger, H. (2008). New Benchmarks in Higher Education: Student Engagement in Online Learning. *Journal of Education for Business*, 84(2), 101-109. doi: 10.3200/JOEB.84.2.101-109

Rohrer, D., Dedrick, R. F., & Burgess, K. (2014). The benefit of interleaved mathematics practice is not limited to superficially similar kinds of problems. *Psychonomic Bulletin & Review*, 21(5), 1323-1330. doi: 10.3758/s13423-014-0588-3

Romanov, K., & Nevgi, A. (2007). Do medical students watch video clips in eLearning and do these facilitate learning? *Medical Teacher*, 29(5), 490-494. doi: 10.1080/01421590701542119

Rubin, B., Fernandes, R., Avgerinou, M. D., & Moore, J. (2010). The effect of learning management systems on student and faculty outcomes. *The Internet and Higher Education*, 13(1–2), 82-83. doi: http://doi.org/10.1016/j.iheduc.2009.10.008

Ruiz-Primo, M. A., Briggs, D., Iverson, H., Talbot, R., & Shepard, L. A. (2011). Impact of Undergraduate Science Course Innovations on Learning. *Science*, 331(6022), 1269-1270. doi: 10.1126/science.1198976

Russell, C. P., & French, D. P. (2001). Using a Newton Personal Data Assistant To Assess Student Participation in Biology Laboratories – A Technique Borrowed From Ethology. *The American Biology Teacher*, 63(7), 491-497. doi: 10.1662/0002-7685(2001)063[0491:UANPDA]2.0.CO;2

Ryan, M. P., & Martens, G. G. (1989). *Planning a College Course; A Guidebook for the Graduate Teaching Assistant*. Ann Arbor, Mich.: National Center for Research to Improve Postsecondary Teaching and Learning.

Ryan, R. M., & Deci, E. L. (2000). Intrinsic and Extrinsic Motivations: Classic Definitions and New Directions. *Contemporary Educational Psychology*, 25(1), 54-67. doi: http://dx.doi.org/10.1006/ceps.1999.1020

Ryan, R. M., Koestner, R., & Deci, E. L. (1991). Ego-involved persistence: When free-choice behavior is not intrinsically motivated. *Motivation and Emotion*, 15(3), 185-205. doi: 10.1007/bf00995170

Sawada, D., Piburn, M. D., Judson, E., Turley, J., Falconer, K., Benford, R., & Bloom, I. (2002). Measuring Reform Practices in Science and Mathematics Classrooms: The Reformed Teaching Observation Protocol. *School Science and Mathematics*, 102(6), 245-253. doi: 10.1111/j.1949-8594.2002.tb17883.x

Schreiber, B. E., Fukuta, J., & Gordon, F. (2010). Live lecture versus video podcast in undergraduate medical education: A randomisedrandomized controlled trial. *BMC Medical Education*, 10(1), 68. doi: 10.1186/1472-6920-10-68

Schumm, M. F., & Bogner, F. X. (2016). Measuring adolescent science motivation. *International Journal of Science Education*, 38(3), 434-449. doi: 10.1080/09500693.2016.1147659

Schunk, D. H. (2012). *Learning theories: an educational perspective* (6th ed.. ed.). Boston: Boston : Pearson.

Schunk, D. H., Meece, J. L., & Pintrich, P. R. (2014). *Motivation in education: theory, research, and applications*. Boston: Pearson.

Sinatra, G. M., Heddy, B. C., & Lombardi, D. (2015). The Challenges of Defining and Measuring Student Engagement in Science. *Educational Psychologist*, 50(1), 1-13. doi: 10.1080/00461520.2014.1002924

Singh, T., & Kashyap, N. (2015). Does Doodling Effect Performance: Comparison Across Retrieval Strategies. *Psychological Studies*, 60(1), 7-11. doi:10.1007/s12646-014-0293-3

Skinner, E. A., & Belmont, M. J. (1993). Motivation in the classroom: Reciprocal effects of teacher behavior and student engagement across the school year. *Journal of Educational Psychology*, 85(4), 571.

Slavin, R. E. (1990). *Cooperative learning: Theory, research, and practice*: Englewood Cliffs, NJ: Prentice-Hall.

Smith, M. K., Jones, F. H. M., Gilbert, S. L., & Wieman, C. E. (2013). The Classroom Observation Protocol for Undergraduate STEM (COPUS): A New Instrument to Characterize University STEM Classroom Practices. *CBE-Life Sciences Education*, 12(4), 618-627. doi: 10.1187/cbe.13-08-0154

Snowman. J. (1984). Learning tactics and strategies. In G. D. Phye & T. Andre (Eds.), *Cognitive classroom learning: Understanding, thinking and problem solving* (pp. 243-276). New York: Academic Press.

Standage, M., Duda, J. L., & Ntoumanis, N. (2005). A test of self-determination theory in school physical education. *British Journal of Educational Psychology*, 75(3), 411-433. doi: 10.1348/000709904X22359

Steffe, L. P., & Gale, J. E. (1995). *Constructivism in education*: Lawrence Erlbaum Hillsdale, NJ.

Stowell, J. R., Oldham, T., & Bennett, D. (2010). Using Student Response Systems (“Clickers”) to Combat Conformity and Shyness. *Teaching of Psychology*, 37(2), 135-140. doi: 10.1080/00986281003626631

Stuart, J., & Rutherford, R. J. D. (1978). MEDICAL STUDENT CONCENTRATION DURING LECTURES. *The lancet*, 312(8088), 514-516. doi: http://dx.doi.org/10.1016/S0140-6736(78)92233-X

Sweller, J. (1991). Cognitive Load Theory and the Format of Instruction. *Cognition & Instruction*, 8(4), 40p.

Tabachnick, B. G., & Fidell, L. S. (2007). *Using multivariate statistics*, 5th ed. Boston, MA: Allyn & Bacon/Pearson Education.

Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International Journal of Medical Education*, 2, 53-55. doi: 10.5116/ijme.4dfb.8dfd

Taylor, G., Jungert, T., Mageau, G. A., Schattke, K., Dedic, H., Rosenfield, S., & Koestner, R. (2014). A self-determination theory approach to predicting school achievement over time: the unique role of intrinsic motivation. *Contemporary Educational Psychology*, 39(4), 342-358. doi: http://dx.doi.org/10.1016/j.cedpsych.2014.08.002

Taylor, K., & Rohrer, D. (2010). The effects of interleaved practice. *Applied Cognitive Psychology*, 24(6), 837-848. doi: 10.1002/acp.1598

Templeton, G. F. (2011). A two-step approach for transforming continuous variables to normal: implications and recommendations for IS research. *Communications of the Association for Information Systems*, 28(4), 41-58.

Tessier, J. (2013). Student Impressions of Academic Cell Phone Use in the Classroom. *Journal of College Science Teaching*, 43(1), 25-29.

Thorndike, E. L. (1913). *The psychology of learning* (Vol. 2): Teachers College, Columbia University.

Tindell, D. R., & Bohlander, R. W. (2012). The Use and Abuse of Cell Phones and Text Messaging in the Classroom: A Survey of College Students. *College Teaching*, 60(1), 1-9. doi: 10.1080/87567555.2011.604802

Ting, Y.-L. (2015). Tapping into students' digital literacy and designing negotiated learning to promote learner autonomy. *The Internet and Higher Education*, 26, 25-32. doi: 10.1016/j.iheduc.2015.04.004

Tinto, V. (1997). Classrooms as Communities: Exploring the Educational Character of Student Persistence. *The Journal of Higher Education*, 68(6), 599-623. doi: 10.2307/2959965

Tobias, S. (1994). Interest, prior knowledge, and learning. *Review of Educational Research*, 64, 37–54.

Trees, A. R., & Jackson, M. H. (2007). The learning environment in clicker classrooms: Student processes of learning and involvement in large university courses using student response systems. *Learning, Media and Technology*, 32(1), 21–40.

Tsigilis, N., & Theodosiou, A. (2003). Temporal stability of the intrinsic motivation inventory. *Perceptual and Motor Skills*, 97(1), 271-280.

Vallerand, R. J., Fortier, M. S., & Guay, F. (1997). Self-determination and persistence in a real-life setting: Toward a motivational model of high school dropout. *Journal of Personality and Social Psychology*, 72(5), 1161-1176. doi: 10.1037/0022-3514.72.5.1161

Van Gorp, M. J., & Grissom, S. (2001). An Empirical Evaluation of Using Constructive Classroom Activities to Teach Introductory Programming. *Computer Science Education*, 11(3), 247-260. doi: 10.1076/csed.11.3.247.3837

van Vliet, E. A., Winnips, J. C., & Brouwer, N. (2015). Flipped-Class Pedagogy Enhances Student Metacognition and Collaborative-Learning Strategies in Higher Education But Effect Does Not Persist. *CBE-Life Sciences Education*, 14(3). doi:10.1187/cbe.14-09-0141

Vlachopoulos, S. P., Asci, F. H., Cid, L., Ersoz, G., González-Cutre, D., Moreno-Murcia, J. A., & Moutão, J. (2013). Cross-cultural invariance of the basic psychological needs in exercise scale and need satisfaction latent mean differences among Greek, Spanish, Portuguese and Turkish samples. *Psychology of Sport and Exercise*, 14(5), 622-631. doi:https://doi.org/10.1016/j.psychsport.2013.03.002

Vygotsky, L. S. (1980). *Mind in society: The development of higher psychological processes*: Harvard university press.

Wallace, R. M. (2003). Online Learning in Higher Education: a review of research on interactions among teachers and students. *Education, Communication & Information*, 3(2), 241.

Waschull, S. B. (2001). The Online Delivery of Psychology Courses: Attrition, Performance, and Evaluation. *Teaching of Psychology*, 28(2), 143-147. doi: doi:10.1207/S15328023TOP2802_15

Watkins, M. W., & Pacheco, M. (2000). Interobserver Agreement in Behavioral Research: Importance and Calculation. *Journal of Behavioral Education*, 10(4), 205-212. doi: 10.1023/a:1012295615144

Weiner, B. (2001). Intrapersonal and Interpersonal Theories of Motivation from an Attribution Perspective. In F. Salili, C. Y. Chiu & Y. Y. Hong (Eds.), *Student Motivation: The Culture and Context of Learning* (pp. 17-30). Boston, MA: Springer US.

Wieling, M. B., & Hofman, W. H. A. (2010). The impact of online video lecture recordings and automated feedback on student performance. *Computers & Education*, 54(4), 992-998. doi: http://dx.doi.org/10.1016/j.compedu.2009.10.002

Williams, G. C., & Deci, E. L. (1996). Internalization of biopsychosocial values by medical students: A test of self-determination theory. *Journal of Personality and Social Psychology*, 70(4), 767-779. doi: 10.1037/0022-3514.70.4.767

Williams, G. C., Saizow, R., Ross, L., & Deci, E. L. (1997). Motivation underlying career choice for internal medicine and surgery. *Social Science & Medicine*, 45(11), 1705-1713.

Williams, G. C., Wiener, M. W., Markakis, K. M., Reeve, J., & Deci, E. L. (1994). Medical students' motivation for internal medicine. *Journal of General Internal Medicine*, 9(6), 327-333. doi: 10.1007/bf02599180

Wilson, K., & Korn, J. H. (2007). Attention during lectures: Beyond ten minutes. *Teaching of Psychology*, 34(2), 85-89.

APPENDIX I.1

Data collection sheet for the research on Assessing the Effect of Active Learning on Student Engagement Behavior.

Observations for (Date): ____/_____/_______ Observations made by (Name): ____________________________ Transect Observed: ______________

Time Observations Started: ______________ AM PM Number of Students in Transect: ___________ Number of students in the class: ____________

| Behavior | Course Relatedness | Observational Intervals (minutes) 5 ☐ | 10 ☐ | 15 ☐ | 20 ☐ | 25 ☐ | 30 ☐ | 35 ☐ | 40 ☐ | 45 ☐ | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Computer | Related | | | | | | | | | | |
| | Not Related | | | | | | | | | | |
| | Undecided | | | | | | | | | | |
| Listening | Related | | | | | | | | | | |
| | Not Related | | | | | | | | | | |
| | Undecided | | | | | | | | | | |
| Phone | Related | | | | | | | | | | |
| | Not Related | | | | | | | | | | |
| | Undecided | | | | | | | | | | |
| Taking Notes | Related | | | | | | | | | | |
| | Not Related | | | | | | | | | | |
| | Undecided | | | | | | | | | | |
| Talking to Other Students | Related | | | | | | | | | | |
| | Not Related | | | | | | | | | | |
| | Undecided | | | | | | | | | | |
| Interacting with Instructor | Related | | | | | | | | | | |
| | Not Related | | | | | | | | | | |
| | Undecided | | | | | | | | | | |
| Other | Related | | | | | | | | | | |
| | Not Related | | | | | | | | | | |
| | Undecided | | | | | | | | | | |

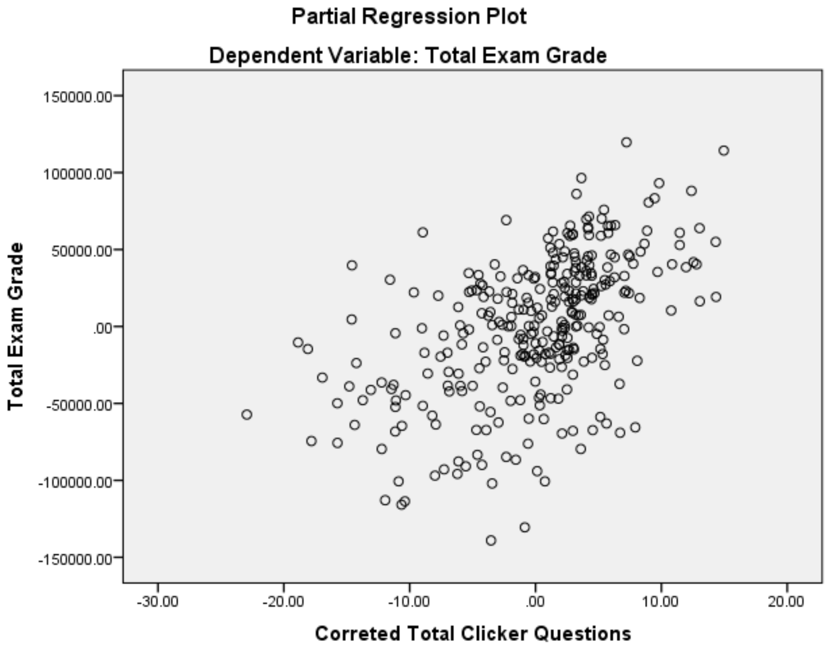
**NOTES:**

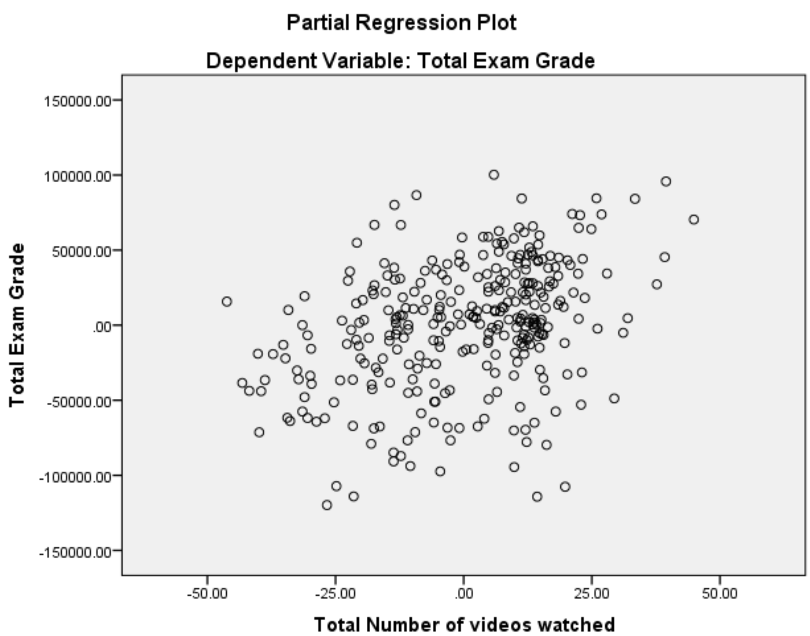
_______________________________________________________________________________________

_______________________________________________________________________________________

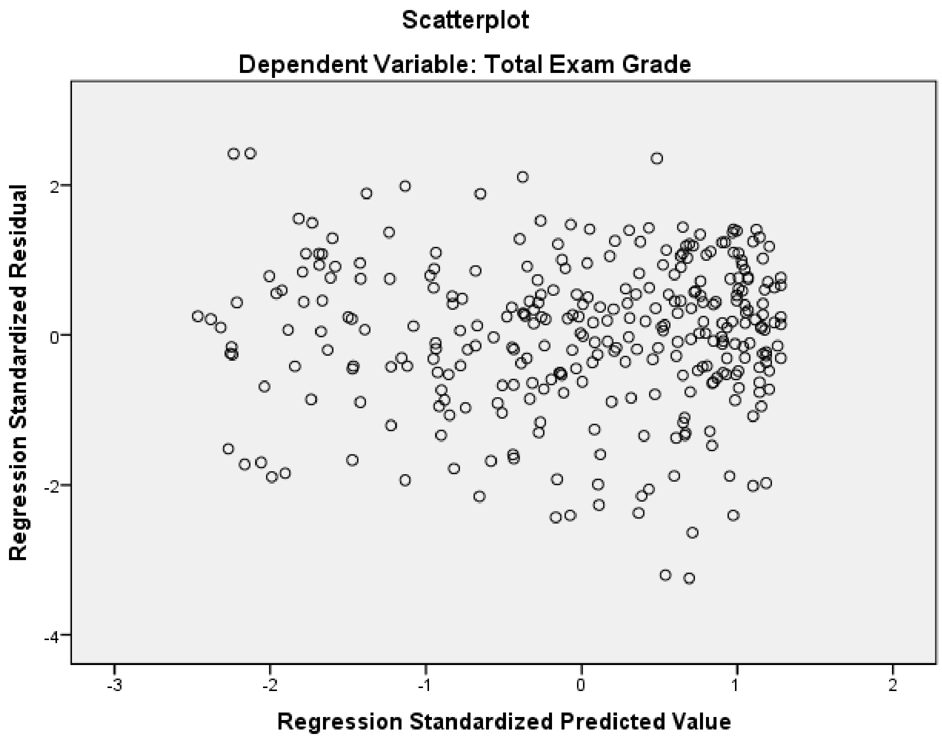
# APPENDIX II.1

## REGRESSION ASSUMPTION TESTS

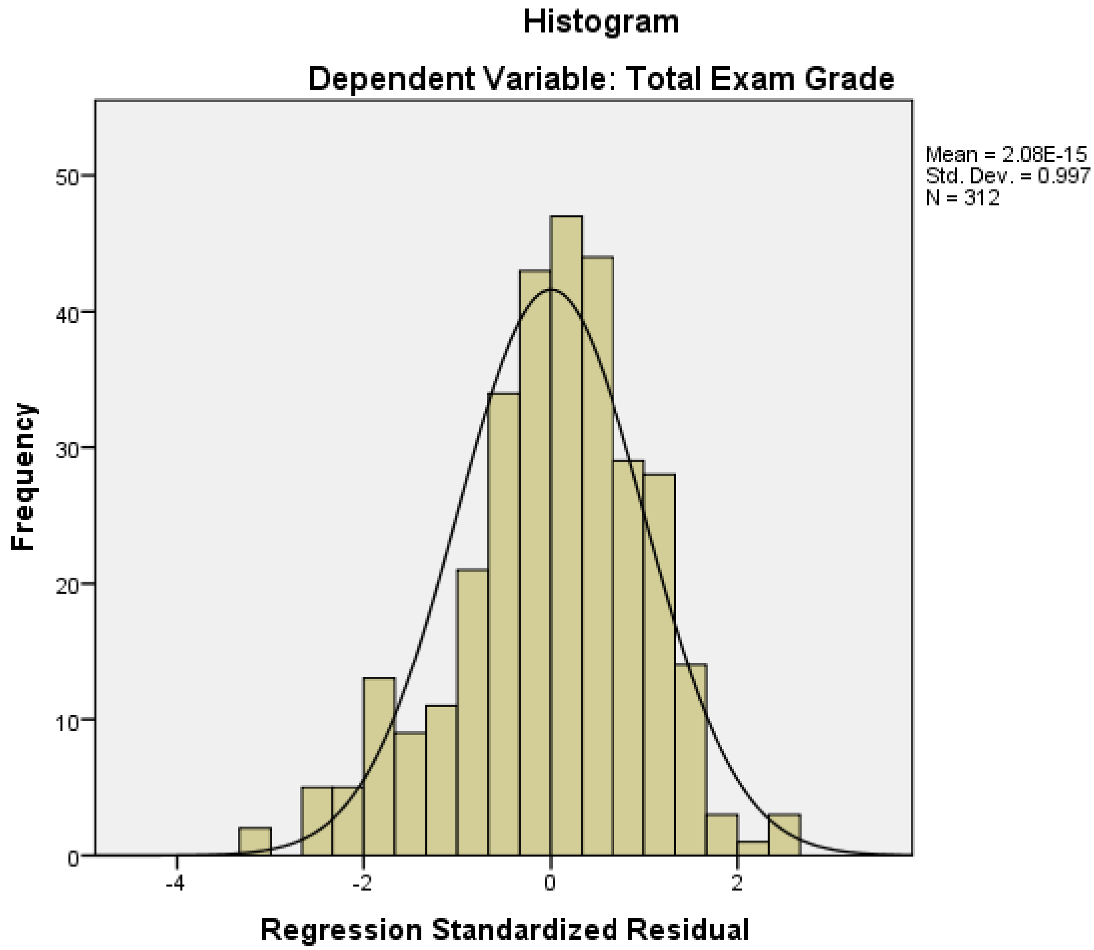



The first step in meeting the regression assumptions is to check for bivariate normality. The top figure represents the correlation between the adjusted number of clicker participations and exam score. The bottom figure represents the correlation between videos watched at total exam score. Since I have clouds of points and no emerging shapes to the data, I can say that the assumption of bivariate normality is met.




The next regression assumptions testing step is to check the assumption of homogeneity of variances. For this test, we examine the homoscedasticity of residuals. AsIdo not see any weird patters emerging and instead a cloud of data,Ican assume that the residuals are homoscedastic. There formyassumtions are met for regression.




The final regression assumptions testing step in meeting the assumptions for regression is checking the normality of the residuals, which we can see here. From an examination of the residuals we say that they are normally distributed therefore meeting my assumption.

APPENDIX II.2

| Model Summary | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| A | | | | | Change Statistics | | | | |
| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate | R Square Change | F Change | df1 | df2 | Sig. F Change |
| Video Watching | 0.597[a] | 0.357 | 0.355 | 66.77490 | 0.357 | 172.041 | 1 | 310 | 0.000 |
| Clicking | 0.731[b] | 0.534 | 0.531 | 56.90586 | 0.178 | 117.849 | 1 | 309 | 0.000 |

a. Predictors: (Constant), Total Number of videos watched

b. Predictors: (Constant), Total Number of videos watched, Correted Total Clicker Questions

| Model Summary | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| B | | | | | Change Statistics | | | | |
| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate | R Square Change | F Change | df1 | df2 | Sig. F Change |
| Clicking | 0.688[a] | 0.473 | 0.471 | 60.43977 | 0.473 | 278.389 | 1 | 310 | 0.000 |
| Video Watching | 0.731[b] | 0.534 | 0.531 | 56.90586 | 0.061 | 40.698 | 1 | 309 | 0.000 |

a. Predictors: (Constant), Correted Total Clicker Questions

b. Predictors: (Constant), Correted Total Clicker Questions, Total Number of videos watched

Hierarchical regression models showing that clickers are stronger predictors of performance as represented through the change in $R^2$ and F change values. Model A adds video watching first ($R^2$ change = 0.357, F change = 172.041) and clicking second ($R^2$ change = 0.178, F change = 117.849). Model B adds clicking first ($R^2$ change = 0.473, F change = 278.389) and video watching second ($R^2$ change = 0.061, F change = 40.689).

# APPENDIX III.1

The Self-Determination continuum (Ryan & Deci, 2000).

| | | | | | | |
|---|---|---|---|---|---|---|
| | Not self-determined | | | | | Self-determined |
| | Amotivation | Extrinsic Motivation | | | | Intrinsic Motivation |
| Locus of control: | Impersonal | External | Somewhat External | Somewhat Internal | Internal | Internal |
| Motivational regulators: | No intention Lack of control | Compliance External rewards or punishments | Ego-involvement | Valuing an activity | Choices prioritized by goals | Interest Enjoyment Inherent satisfaction |

# APPENDIX III.2

# INTRINSIC MOTIVATION INVENTORY

| INTRINSIC MOTIVATION INVENTORY | | | |
|---|---|---|---|
| **Intrinsic Motivation Subscale** | **Question Prompt** | **1 = Used in First Study<br>2 = Used in Second Study** | **Reverse Code** |
| Interest/Enjoyment | I enjoyed doing this activity very much | | |
| | This activity was fun to do. | | |
| | I thought this was a boring activity. | | R |
| | This activity did not hold my attention at all. | | R |
| | I would describe this activity as very interesting. | | |
| | I thought this activity was quite enjoyable. | | |
| | While I was doing this activity, I was thinking about how much I enjoyed it. | | |
| | | | |
| Perceived Competence | I think I am pretty good at this activity. | 1, 2 | |
| | I think I did pretty well at this activity, compared to other students. | 1, 2 | |
| | After working at this activity for awhile, I felt pretty competent. | 1 | |
| | I am satisfied with my performance at this task. | 1, 2 | |
| | I was pretty skilled at this activity. | 1, 2 | |
| | This was an activity that I couldnt do very well. | 1, 2 | R |
| | | | |
| Effort/Importance | I put a lot of effort into this. | | |
| | I didnt try very hard to do well at this activity. | | R |
| | I tried very hard on this activity. | | |
| | It was important to me to do well at this task. | | |
| | I didnt put much energy into this. | | R |
| | | | |
| Pressure/Tension | I did not feel nervous at all while doing this. | | R |
| | I felt very tense while doing this activity. | | |
| | I was very relaxed in doing these. | | R |
| | I was anxious while working on this task. | | |
| | I felt pressured while doing these. | | |
| | | | |
| Perceived Choice | I believe I had some choice about doing this activity. | 1, 2 | |
| | I felt like it was not my own choice to do this task. | 1, 2 | R |
| | I didnt really have a choice about doing this task. | 1, 2 | R |
| | I felt like I had to do this. | 1 | R |
| | I did this activity because I had no choice. | 1, 2 | R |
| | I did this activity because I wanted to. | 1 | |
| | I did this activity because I had to. | 1 | R |
| | | | |
| Value/Usefulness | I believe this activity could be of some value to me. | | |
| | I think that doing this activity is useful for ______________________ | | |
| | I think this is important to do because it can ______________________ | | |
| | I would be willing to do this again because it has some value to me. | | |
| | I think doing this activity could help me to ____________________ | | |
| | I believe doing this activity could be beneficial to me. | | |
| | I think this is an important activity. | | |
| | | | |
| Relatedness | I felt really distant to this person. | 1, 2 | R |
| | I really doubt that this person and I would ever be friends. | | R |
| | I felt like I could really trust this person. | 1, 2 | |
| | Id like a chance to interact with this person more often. | 1, 2 | |
| | I'd really prefer not to interact with this person in the future. | 1, 2 | R |
| | I don't feel like I could really trust this person. | 1 | R |
| | It is likely that this person and I could become friends if we interacted a lot. | | |
| | I feel close to this person. | 1,2 | |

APPENDIX III.3

List of Intrinsic Motivation Survey (IMI) survey questions listed by Self-Determination theory (SDT) component. *= Question in both first and second surveys.

| SDT Component | IMI Question Prompt |
|---|---|
| **Perceived Activity Competency** | While studying biology in this course, I think I am pretty good at this activity. * |
| | While studying biology in this course, I think I did pretty well at this activity, compared to other students. * |
| | While studying biology in this course, After working at this activity for a while, I felt pretty competent. |
| | While studying biology in this course, I am satisfied with my performance at this task. * |
| | While studying biology in this course, I was skilled at this activity. * |
| | While studying biology in this course, This was an activity that I couldn't do very well. * |
| **Perceived Activity Autonomy** | While studying biology in this course, I believe I had some choice about doing this activity. * |
| | While studying biology in this course, I felt like it was not my own choice to do this task. * |
| | While studying biology in this course, I didn't really have a choice about doing this task. * |
| | While studying biology in this course, I felt like I had to do this. |
| | While studying biology in this course, I did this activity because I had no choice. * |
| | While studying biology in this course, I did this activity because I wanted to. |
| | While studying biology in this course, I did this activity because I had to. |
| **Perceived Activity Relatedness** | While studying biology in this course, I feel close to others when I do this activity. * |
| | While studying biology in this course, I felt like I could trust others to do this activity with me. * |
| | While studying biology in this course, I feel really distant from others when I do this activity. * |
| | While studying biology in this course, I felt like I couldn't trust others to do this activity with me. |
| | While studying biology in this course, I'd like a chance to interact with people more often while doing this activity. * |
| | While studying biology in this course, I'd really prefer not to interact with people while doing this activity in the future. * |

# APPENDIX III.4

## SPRING 2015 FINAL REFLECTION

**Flipped Classroom – Final Reflection & Survey**

Your comments will not be read until AFTER grades are due, so you should feel comfortable commenting freely.

Please help me understand how you think about the class better by commenting on the following:

The questions in the following table examine the specific activities within your flipped biology course. The table includes: You Writing and Answering Verso Questions, Lance Answering Verso questions, Clickers, Group Activities, In-Class Discussion, and Exams 1-3. For each of the following statements please type the number which best reflects your experience for this course in the box that corresponds with each activity and indicator. Please note that if your course does not contain a particular activity then you should respond with an "NA" for not applicable

1=strongly agree, 2=agree, 3=somewhat agree, 4=somewhat disagree, 5=disagree, 6=strongly disagree, NA=not applicable

| | Course Activities | | | | | |
|---|---|---|---|---|---|---|
| **Indicator Statements** | Writing and Answering Verso Questions | Video Lectures | Clickers | Group Activity (Worksheets, diagrams, etc.) | In-Class Discussion | Exams 1-3 |
| I believe I had some choice about doing this activity. | | | | | | |
| I was pretty skilled at this activity. | | | | | | |
| I did this activity because I wanted to. | | | | | | |
| I did this activity because I had to. | | | | | | |
| I felt like I couldn't trust information from other for this activity | | | | | | |
| I am satisfied with my performance at this task. | | | | | | |
| I think I did pretty well at this activity, compared to other students. | | | | | | |
| I didn't really have a choice about doing this task. | | | | | | |
| I felt like I had to do this. | | | | | | |

1=strongly agree, 2=agree, 3=somewhat agree, 4=somewhat disagree, 5=disagree, 6=strongly disagree, NA=not applicable

| | Course Activities | | | | | |
|---|---|---|---|---|---|---|
| **Indicator Statements** | Writing and Answering Verso Questions | Video Lectures | Clickers | Group Activity (Worksheets, diagrams, etc.) | In-Class Discussion | Exams 1-3 |
| I feel close to others when I do this activity | | | | | | |
| This was an activity that I could not do very well. | | | | | | |
| After working at this activity for a while, I felt competent. | | | | | | |
| I'd like a chance to interact with people more often while doing this activity | | | | | | |
| I felt like I could trust information from other for this activity | | | | | | |
| I felt like it was not my own choice to do this task. | | | | | | |
| I feel really distant from others when I do this activity | | | | | | |
| I think I am pretty good at this activity. | | | | | | |
| I'd really prefer not to interact with people while doing this activity in the future | | | | | | |
| I did this activity because I had no choice. | | | | | | |

**Were you always prepared to participate? Was everyone else prepared to participate? On what evidence do you base these answers?**

**For the next several questions please select the answer that most represents your viewpoint. We highly value your input.**

**Group activities (such as worksheets and diagramming):**

**I think that the group activities were: A) Too difficult, B) Too easy, or C) Just right**

**Could you please explain using an example from class?**

**I think that the length of time Lance allowed for these activities was: A) Too long, B) Too short, or C) Just right**

**Please explain your reasoning for your choice.**

**In-class structure:**

**Class time was divided up (usually) into 4 different parts: Verso, Group Activity, Class Discussion, and Clickers. Please rank the 4 parts in order of your preference for them with 4 = MOST preferred and 1 = LEAST preferred**

**Verso: 1 2 3 4 Group Activity: 1 2 3 4 Class Discussion: 1 2 3 4 Clickers: 1 2 3 4**

**Out of class activities,**
**What else did you do outside class to study/prepare for class? What resources did you find helpful?**

**Attendance**

**Why did you choose to attend classes? If/When you did not, why did you think it was not worth attending?**

**Feel free to add any other comments**

**Flipped Classroom – Final Reflection & Survey (10 pts)**

Your comments will not be read until AFTER grades are submitted, so you should feel comfortable commenting freely.

Please help me understand how you think about the class by commenting on the following statements. When you read these statements please have the following phrase in mind, **"While studying biology in this course…"**

The questions in the following table examine the specific activities within this course. For each of the following statements please type the number which best reflects your experience for this course in the box that corresponds with each activity and indicator (See example below). If you perceive that the statement does not apply to a particular activity then you should respond with an "NA" for not applicable.

***SAMPLE ANSWERS***- 1=strongly agree, 2=agree, 3=somewhat agree, 4=somewhat disagree, 5=disagree, 6=strongly disagree, NA=not applicable

| | Course Activities | | | | | |
|---|---|---|---|---|---|---|
| **"While studying biology in this course…"** | Writing and Answering Verso Questions | Video Lectures | Clickers | Group Activity (Worksheets, diagrams, etc.) | In-Class Discussion | Exams 1-3 |
| I believe I had some choice about doing this activity. | 2 | 2 | 4 | 6 | 1 | NA |

1=strongly agree, 2=agree, 3=somewhat agree, 4=somewhat disagree, 5=disagree, 6=strongly disagree, NA=not applicable

| | Course Activities | | | | | |
|---|---|---|---|---|---|---|
| **"While studying biology in this course…"** | Writing and Answering Verso Questions | Video Lectures | Clickers | Group Activity (Worksheets, diagrams, etc.) | In-Class Discussion | Exams 1-3 |
| I believe I had some choice about doing this activity. | | | | | | |
| I was pretty skilled at this activity. | | | | | | |
| I did this activity because I wanted to. | | | | | | |
| I did this activity because I had to. | | | | | | |
| I felt like I couldn't trust information from other for this activity | | | | | | |

| **"While studying biology in this course…"** | Writing and Answering Verso Questions | Video Lectures | Clickers | Group Activity (Worksheets, diagrams, etc.) | In-Class Discussion | Exams 1-3 |
|---|---|---|---|---|---|---|
| I am satisfied with my performance at this task. | | | | | | |
| I think I did pretty well at this activity, compared to other students. | | | | | | |
| I didn't really have a choice about doing this task. | | | | | | |
| I felt like I had to do this. | | | | | | |
| I feel close to others when I do this activity | | | | | | |
| This was an activity that I couldn't do very well. | | | | | | |
| After working at this activity for a while, I felt pretty competent. | | | | | | |
| I'd like a chance to interact with people more often while doing this activity | | | | | | |
| I felt like I could trust information from other for this activity | | | | | | |
| I felt like it was not my own choice to do this task. | | | | | | |
| I feel really distant from others when I do this activity | | | | | | |
| I think I am pretty good at this activity. | | | | | | |
| I'd really prefer not to interact with people while doing this activity in the future | | | | | | |
| I did this activity because I had no choice. | | | | | | |

**How often were you prepared to participate?**

- **a) always or almost always**
- **b) most of the time**
- **c) more than half the time**
- **d) less than half the time**
- **e) some of the time**
- **f) never**

**How would you describe the preparation the preparation of the other members of your group?**

- **a) one other member was prepared**
- **b) most were prepared**
- **c) all were prepared**
- **d) none were prepared**

**Would you consider your role in your group in class to be**

- **a) the person who explains the concept most of the time**
- **b) a person who explains often but listens most of the time**
- **c) a person who explains rarely but listens most of the time**
- **d) a person who listens**
- **e) a person who does not choose to participate**

| **Please Rank order the following activities** | Writing and Answering Verso Questions | Video Lectures | Clickers | Group Activity (Worksheets, diagrams, etc.) | In-Class Discussion | Exams 1-3 | Textbook Reading | Video Packets | Learning to Draw processes |
|---|---|---|---|---|---|---|---|---|---|
| 1 = LEAST preferred<br>8 = MOST preferred | | | | | | | | | |
| 1 = Contributed LEAST to my learning<br>8 = Contributed MOST to my learning | | | | | | | | | |
| 1 = Encouraged class attendance LEAST<br>8 = Encouraged class attendance MOST | | | | | | | | | |

**What would you like to tell me about any of the activities in the table above?**

**We used Verso and Cards to collect questions from the class. Which (if any) do you prefer and why?**

**We are considering inserting multiple-choice questions and textbook reading assignments between shorter segments of video-lecture to help students assess their understanding of concepts. To access the next video would require answering the questions and those questions would count for credit (replacing reflections). What do you think?**

**Feel free to add any other comments**

# SPRING 2016 FINAL REFLECTION

**Flipped Classroom – Final Reflection & Survey (10 pts)**

Your comments will not be read until AFTER grades are submitted, so you should feel comfortable commenting freely.

Please help me understand how you think about the class by commenting on the following statements. When you read these statements please have the following phrase in mind, **"While studying biology in this course…"**

The questions in the following table examine the specific activities within this course. For each of the following statements please type the number which best reflects your experience for this course in the box that corresponds with each activity and indicator (See example below). If you perceive that the statement does not apply to a particular activity then you should respond with an "NA" for not applicable.

***SAMPLE ANSWERS***- 1=strongly agree, 2=agree, 3=somewhat agree, 4=somewhat disagree, 5=disagree, 6=strongly disagree, NA=not applicable

| | Course Activities | | | | | |
|---|---|---|---|---|---|---|
| **"While studying biology in this course…"** | Writing and Answering Verso Questions | Video Lectures | Clickers | Group Activity (Worksheets, diagrams, etc.) | In-Class Discussion | Exams 1-3 |
| I believe I had some choice about doing this activity. | 2 | 2 | 4 | 6 | 1 | NA |

1=strongly agree, 2=agree, 3=somewhat agree, 4=somewhat disagree, 5=disagree, 6=strongly disagree, NA=not applicable

| | Course Activities | | | | | |
|---|---|---|---|---|---|---|
| **"While studying biology in this course…"** | Writing and Answering Verso Questions | Video Lectures | Clickers | Group Activity (Worksheets, diagrams, etc.) | In-Class Discussion | Exams 1-3 |
| I believe I had some choice about doing this activity. | | | | | | |
| I was pretty skilled at this activity. | | | | | | |
| I did this activity because I wanted to. | | | | | | |
| I did this activity because I had to. | | | | | | |
| I felt like I couldn't trust information from other for this activity | | | | | | |

| **"While studying biology in this course…"** | Writing and Answering Verso Questions | Video Lectures | Clickers | Group Activity (Worksheets, diagrams, etc.) | In-Class Discussion | Exams 1-3 |
|---|---|---|---|---|---|---|
| I am satisfied with my performance at this task. | | | | | | |
| I think I did pretty well at this activity, compared to other students. | | | | | | |
| I didn't really have a choice about doing this task. | | | | | | |
| I felt like I had to do this. | | | | | | |
| I feel close to others when I do this activity | | | | | | |
| This was an activity that I couldn't do very well. | | | | | | |
| After working at this activity for a while, I felt pretty competent. | | | | | | |
| I'd like a chance to interact with people more often while doing this activity | | | | | | |
| I felt like I could trust information from other for this activity | | | | | | |
| I felt like it was not my own choice to do this task. | | | | | | |
| I feel really distant from others when I do this activity | | | | | | |
| I think I am pretty good at this activity. | | | | | | |
| I'd really prefer not to interact with people while doing this activity in the future | | | | | | |
| I did this activity because I had no choice. | | | | | | |

**How often were you prepared to participate?**

a) always or almost always
b) most of the time
c) more than half the time
d) less than half the time
e) some of the time
f) never

**How would you describe the preparation the preparation of the other members of your group?**

a) one other member was prepared
b) most were prepared
c) all were prepared
d) none were prepared

**Would you consider your role in your group in class to be**

a) the person who explains the concept most of the time
b) a person who explains often but listens most of the time
c) a person who explains rarely but listens most of the time
d) a person who listens
e) a person who does not choose to participate

| Please Rank order the following activities | Writing and Answering Verso Questions | Video Lectures | Clickers | Group Activity (Worksheets, diagrams, etc.) | In-Class Discussion | Exams 1-3 | Textbook Reading | Video Packets | Learning to Draw processes |
|---|---|---|---|---|---|---|---|---|---|
| 1 = LEAST preferred<br>8 = MOST preferred | | | | | | | | | |
| 1 = Contributed LEAST to my learning<br>8 = Contributed MOST to my learning | | | | | | | | | |
| 1 = Encouraged class attendance LEAST<br>8 = Encouraged class attendance MOST | | | | | | | | | |

**What would you like to tell me about any of the activities in the table above?**

**For the next set of questions, please indicate to what extent you either agree to disagree with the following statements:**

1) I derive great personal satisfaction from working on a team that is doing important research.
   Strongly Agree Agree Somewhat Agree Somewhat Disagree Disagree Strongly Disagree
2) The daily work of a scientist is appealing to me.
   Strongly Agree Agree Somewhat Agree Somewhat Disagree Disagree Strongly Disagree
3) My science major/science-related track is a waste of my time.
   Strongly Agree Agree Somewhat Agree Somewhat Disagree Disagree Strongly Disagree
4) I am enjoying my science major/science-related track very much this semester.
   Strongly Agree Agree Somewhat Agree Somewhat Disagree Disagree Strongly Disagree
5) I have a strong sense of belonging to the community of scientists.
   Strongly Agree Agree Somewhat Agree Somewhat Disagree Disagree Strongly Disagree
6) I feel like I belong in the field of science.
   Strongly Agree Agree Somewhat Agree Somewhat Disagree Disagree Strongly Disagree
7) I think my science major/science-related track is very interesting.
   Strongly Agree Agree Somewhat Agree Somewhat Disagree Disagree Strongly Disagree
8) I have come to think of myself as a 'scientist'.
   Strongly Agree Agree Somewhat Agree Somewhat Disagree Disagree Strongly Disagree
9) I'm glad I'm in a science major/science-related track this semester.
   Strongly Agree Agree Somewhat Agree Somewhat Disagree Disagree Strongly Disagree
10) I would recommend my science major/science
   Strongly Agree Agree Somewhat Agree Somewhat Disagree Disagree Strongly Disagree

**What grade do you expect to get in this course?**

**Feel free to add any other comments**

**Flipped Classroom – Final Reflection & Survey (10 pts)**

Your comments will not be read until AFTER grades are submitted, so you should feel comfortable commenting freely.

Please help me understand how you think about the class by commenting on the following statements. When you read these statements please have the followir phrase in mind, **"While studying biology in this course…"**

The questions in the following table examine the specific activities within this course. For each of the following statements please type the number which best reflects your experience for this course in the box that corresponds with each activity and indicator (See example below). If you perceive that the statement does not apply to a particular activity then you should respond with an "NA" for not applicable.

***SAMPLE ANSWERS***- 1=strongly agree, 2=agree, 3=somewhat agree, 4=somewhat disagree, 5=disagree, 6=strongly disagree, NA=not applicable

| | Course Activities | | | | | |
|---|---|---|---|---|---|---|
| **"While studying biology in this course…"** | Writing and Answering Verso Questions | Video Lectures | Clickers | Group Activity (Worksheets, diagrams, etc.) | In-Class Discussion | Exams 1-3 |
| I believe I had some choice about doing this activity. | 2 | 2 | 4 | 6 | 1 | NA |

1=strongly agree, 2=agree, 3=somewhat agree, 4=somewhat disagree, 5=disagree, 6=strongly disagree, NA=not applicable

| | Course Activities | | | | | |
|---|---|---|---|---|---|---|
| **"While studying biology in this course…"** | Writing and Answering Verso Questions | Video Lectures | Clickers | Group Activity (Worksheets, diagrams, etc.) | In-Class Discussion | Exams 1-3 |
| I believe I had some choice about doing this activity. | | | | | | |
| I was pretty skilled at this activity. | | | | | | |
| I am satisfied with my performance at this task. | | | | | | |
| I think I did pretty well at this activity, compared to other students. | | | | | | |
| I didn't really have a choice about doing this task. | | | | | | |
| I feel close to others when I do this activity | | | | | | |
| This was an activity that I couldn't do very well. | | | | | | |

| **"While studying biology in this course…"** | Writing and Answering Verso Questions | Video Lectures | Clickers | Group Activity (Worksheets, diagrams, etc.) | In-Class Discussion | Exams 1-3 |
|---|---|---|---|---|---|---|
| I'd like a chance to interact with people more often while doing this activity | | | | | | |
| I felt like I could trust information from other for this activity | | | | | | |
| I felt like it was not my own choice to do this task. | | | | | | |
| I feel really distant from others when I do this activity | | | | | | |
| I think I am pretty good at this activity. | | | | | | |
| I'd really prefer not to interact with people while doing this activity in the future | | | | | | |
| I did this activity because I had no choice. | | | | | | |

**How often were you prepared to participate?**

**a) always or almost always**
**b) most of the time**
**c) more than half the time**
**d) less than half the time**
**e) some of the time**
**f) never**

**How would you describe the preparation the preparation of the other members of your group?**

**a) one other member was prepared**
**b) most were prepared**
**c) all were prepared**
**d) none were prepared**

**Would you consider your role in your group in class to be**

**a) the person who explains the concept most of the time**
**b) a person who explains often but listens most of the time**
**c) a person who explains rarely but listens most of the time**
**d) a person who listens**
**e) a person who does not choose to participate**

| **Please Rank order the following activities** | Writing and Answering Verso Questions | Video Lectures | Clickers | Group Activity (Worksheets, diagrams, etc.) | In-Class Discussion | Exams 1-3 | Textbook Reading | Video Packets | Learning to Draw processes |
|---|---|---|---|---|---|---|---|---|---|
| 1 = LEAST preferred<br>9 = MOST preferred | | | | | | | | | |
| 1 = Contributed LEAST to my learning<br>9 = Contributed MOST to my learning | | | | | | | | | |
| 1 = Encouraged class attendance LEAST<br>9 = Encouraged class attendance MOST | | | | | | | | | |

**What would you like to tell me about any of the activities in the table above?**

**For the next set of questions, please indicate to what extent you either agree to disagree with the following statements:**

1) I derive great personal satisfaction from working on a team that is doing important research.
   Strongly Agree   Agree   Somewhat Agree   Somewhat Disagree   Disagree   Strongly Disagree
2) The daily work of a scientist is appealing to me.
   Strongly Agree   Agree   Somewhat Agree   Somewhat Disagree   Disagree   Strongly Disagree
3) My science major/science-related track is a waste of my time.
   Strongly Agree   Agree   Somewhat Agree   Somewhat Disagree   Disagree   Strongly Disagree
4) I am enjoying my science major/science-related track very much this semester.
   Strongly Agree   Agree   Somewhat Agree   Somewhat Disagree   Disagree   Strongly Disagree
5) I have a strong sense of belonging to the community of scientists.
   Strongly Agree   Agree   Somewhat Agree   Somewhat Disagree   Disagree   Strongly Disagree
6) I feel like I belong in the field of science.
   Strongly Agree   Agree   Somewhat Agree   Somewhat Disagree   Disagree   Strongly Disagree

7) I think my science major/science-related track is very interesting.
Strongly Agree Agree Somewhat Agree Somewhat Disagree Disagree Strongly Disagree
8) I have come to think of myself as a 'scientist'.
Strongly Agree Agree Somewhat Agree Somewhat Disagree Disagree Strongly Disagree
9) I'm glad I'm in a science major/science-related track this semester.
Strongly Agree Agree Somewhat Agree Somewhat Disagree Disagree Strongly Disagree
10) I would recommend my science major/science
Strongly Agree Agree Somewhat Agree Somewhat Disagree Disagree Strongly Disagree

**What grade are you expecting in this course?**

**A B C D F**

**Do the pre-class lecture videos help you learn biology? Why? How?**

**Is there anything else you would like to tell us about the videos you watched for this class?**

**Do you have any other suggestions for how the course could be improved to help you learn better?**

APPENDIX III.5

Factor loadings from the first iteration of the motivation survey. Lecture and clicker questions never converged and were therefore left out of the factorial analysis.

**VERSO Pattern Matrix[a,b]**

| | Factor | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Autonomy 4: I did this activity because I wanted to. | -.668 | | | | | |
| Autonomy 8: I didn't really have a choice about doing this task. | .802 | | | | | |
| Autonomy 9: I felt like I had to do this. | .722 | | | | | |
| Autonomy 15: I felt like it was not my own choice to do this task. | .549 | | | | | |
| Autonomy 19: I did this activity because I had to. | .720 | | | | | |
| Competency 11: This was an activity that I couldn't do very well. | .321 | | -.321 | | | |
| Competency 6: I am satisfied with my performance at this task. | | .720 | | | | |
| Competency 7: I think I did pretty well at this activity, compared to other students. | | .979 | | | | |
| Competency 17: I think I am pretty good at this activity. | | .694 | | | | |
| Relatedness 13: I'd like a chance to interact with people more often while doing this activity | | | .524 | | | |
| Relatedness 14: I felt like I could trust others to do this activity with me | | | .507 | | | |
| Relatedness 5: I felt like I couldn't trust others to do this activity with me | | | .342 | | | |
| Relatedness 18: I'd really prefer not to interact with people while doing this activity in the future | | | .579 | | | |
| Competency 2: I was pretty skilled at this activity. | | | | .869 | | |
| Autonomy 3: I did this activity because I had no choice. | | | | -.420 | | |
| Relatedness 16: I feel really distant from others when I do this activity | | | | | .933 | |
| Competency 12: After working at this activity for a while, I felt pretty competent. | | | | | | .554 |
| Autonomy 1: I believe I had some choice about doing this activity. | | | | | | |
| Relatedness 10: I feel close to others when I do this activity | | | | | | |

Extraction Method: Principal Axis Factoring.
Rotation Method: Oblimin with Kaiser Normalization.
a. Course = OSU Honors
b. Rotation converged in 8 iterations.

**Clicker Pattern Matrix[a]**

| | Factor | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| Autonomy 1: I believe I had some choice about doing this activity. | | .534 | | | |
| Autonomy 3: I did this activity because I had no choice. | | | | .352 | |
| Autonomy 4: I did this activity because I wanted to. | | | | | -.587 |
| Autonomy 8: I didn't really have a choice about doing this task. | | .818 | | | |
| Autonomy 9: I felt like I had to do this. | | .733 | | | |
| Autonomy 15: I felt like it was not my own choice to do this task. | | .583 | | | |
| Autonomy 19: I did this activity because I had to. | | .691 | | | |
| Competency 2: I was pretty skilled at this activity. | .471 | | | | .458 |
| Competency 6: I am satisfied with my performance at this task. | .874 | | | | |
| Competency 7: I think I did pretty well at this activity, compared to other students. | .773 | | | | |
| Competency 11: This was an activity that I couldn't do very well. | .687 | | | | |
| Competency 12: After working at this activity for a while, I felt pretty competent. | .529 | | | | |
| Competency 17: I think I am pretty good at this activity. | .812 | | | | |
| Relatedness 5: I felt like I couldn't trust others to do this activity with me | | | -.742 | | |
| Relatedness 10: I feel close to others when I do this activity | | | | .496 | |
| Relatedness 13: I'd like a chance to interact with people more often while doing this activity | | | | .489 | |
| Relatedness 14: I felt like I could trust others to do this activity with me | | | -.641 | | |
| Relatedness 16: I feel really distant from others when I do this activity | | | | | -.343 |
| Relatedness 18: I'd really prefer not to interact with people while doing this activity in the future | | | -.701 | | |

Extraction Method: Principal Axis Factoring.
Rotation Method: Oblimin with Kaiser Normalization.
a. Rotation converged in 9 iterations.

**Group Activity Pattern Matrix[a,b]**

| | Factor 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Competency 2: I was pretty skilled at this activity. | .815 | | | | |
| Competency 6: I am satisfied with my performance at this task. | .774 | | | | |
| Competency 7: I think I did pretty well at this activity, compared to other students. | .864 | | | | |
| Competency 11: This was an activity that I couldn't do very well. | .452 | | -.416 | | |
| Competency 12: After working at this activity for a while, I felt pretty competent. | .524 | | | | |
| Competency 17: I think I am pretty good at this activity. | .789 | | | | |
| Autonomy 8: I didn't really have a choice about doing this task. | | .714 | | | |
| Autonomy 9: I felt like I had to do this. | | .441 | | | |
| Autonomy 15: I felt like it was not my own choice to do this task. | | .682 | | | |
| Autonomy 19: I did this activity because I had to. | | .712 | | | |
| Relatedness 16: I feel really distant from others when I do this activity | | | -.819 | | |
| Relatedness 18: I'd really prefer not to interact with people while doing this activity in the future | | | -.630 | | |
| Relatedness 13: I'd like a chance to interact with people more often while doing this activity | | | | .641 | |
| Relatedness 5: I felt like I couldn't trust others to do this activity with me | | | | | -.649 |
| Relatedness 14: I felt like I could trust others to do this activity with me | | | | | -.684 |
| Autonomy 1: I believe I had some choice about doing this activity. | | | | | |
| Autonomy 3: I did this activity because I had no choice. | | | | | |
| Autonomy 4: I did this activity because I wanted to. | | | | | |
| Relatedness 10: I feel close to others when I do this activity | | | | | |

Extraction Method: Principal Axis Factoring.
Rotation Method: Oblimin with Kaiser Normalization.
a. Course = OSU Honors
b. Rotation converged in 18 iterations.

**Whole Class Discussion Pattern Matrix[a]**

| | Factor 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Autonomy 1: I believe I had some choice about doing this activity. | | | | | |
| Autonomy 3: I did this activity because I had no choice. | | | | .687 | |
| Autonomy 4: I did this activity because I wanted to. | | | | .326 | |
| Autonomy 8: I didn't really have a choice about doing this task. | | .778 | | | |
| Autonomy 9: I felt like I had to do this. | | .855 | | | |
| Autonomy 15: I felt like it was not my own choice to do this task. | | .591 | | | |
| Autonomy 19: I did this activity because I had to. | | .499 | | | |
| Competency 2: I was pretty skilled at this activity. | .818 | | | | |
| Competency 6: I am satisfied with my performance at this task. | .866 | | | | |
| Competency 7: I think I did pretty well at this activity, compared to other students. | .819 | | | | |
| Competency 11: This was an activity that I couldn't do very well. | .364 | | | | .368 |
| Competency 12: After working at this activity for a while, I felt pretty competent. | .603 | | | | |
| Competency 17: I think I am pretty good at this activity. | .852 | | | | |
| Relatedness 5: I felt like I couldn't trust others to do this activity with me | | | -.629 | | |
| Relatedness 10: I feel close to others when I do this activity | .482 | | | | |
| Relatedness 14: I felt like I could trust others to do this activity with me | | | -.597 | | |
| Relatedness 18: I'd really prefer not to interact with people while doing this activity in the future | | | -.400 | | .536 |
| Relatedness 16: I feel really distant from others when I do this activity | | | | | .802 |
| Relatedness 13: I'd like a chance to interact with people more often while doing this activity | | | | | |

Extraction Method: Principal Axis Factoring.
Rotation Method: Oblimin with Kaiser Normalization.
a. Rotation converged in 17 iterations.

**Video Pattern Matrix[a,b]**

| | Factor | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Competency 2: I was pretty skilled at this activity. | .613 | | | |
| Competency 6: I am satisfied with my performance at this task. | .869 | | | |
| Competency 7: I think I did pretty well at this activity, compared to other students. | .782 | | | |
| Competency 11: This was an activity that I couldn't do very well. | .596 | | | |
| Competency 12: After working at this activity for a while, I felt pretty competent. | .632 | | | |
| Competency 17: I think I am pretty good at this activity. | .715 | | | |
| Autonomy 1: I believe I had some choice about doing this activity. | | .320 | | |
| Autonomy 8: I didn't really have a choice about doing this task. | | .784 | | |
| Autonomy 9: I felt like I had to do this. | | .544 | | |
| Autonomy 15: I felt like it was not my own choice to do this task. | | .661 | | |
| Relatedness 16: I feel really distant from others when I do this activity | | .449 | | |
| Autonomy 19: I did this activity because I had to. | | .792 | | |
| Relatedness 13: I'd like a chance to interact with people more often while doing this activity | | | .559 | |
| Relatedness 14: I felt like I could trust others to do this activity with me | | | .403 | |
| Relatedness 18: I'd really prefer not to interact with people while doing this activity in the future | | | .705 | |
| Autonomy 3: I did this activity because I had no choice. | | | | .375 |
| Relatedness 5: I felt like I couldn't trust others to do this activity with me | | | | .438 |
| Relatedness 10: I feel close to others when I do this activity | | | | -.729 |
| Autonomy 4: I did this activity because I wanted to. | | | | |

Extraction Method: Principal Axis Factoring.
Rotation Method: Oblimin with Kaiser Normalization.
a. Course = OSU Honors
b. Rotation converged in 9 iterations.

**Exams Pattern Matrix[a,b]**

| | Factor | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Competency 2: I was pretty skilled at this activity. | .779 | | | | | |
| Competency 6: I am satisfied with my performance at this task. | .896 | | | | | |
| Competency 7: I think I did pretty well at this activity, compared to other students. | .845 | | | | | |
| Competency 11: This was an activity that I couldn't do very well. | .660 | | | | | |
| Competency 12: After working at this activity for a while, I felt pretty competent. | .824 | | | | | |
| Competency 17: I think I am pretty good at this activity. | .872 | | | | | |
| Autonomy 8: I didn't really have a choice about doing this task. | | .720 | | | | |
| Autonomy 9: I felt like I had to do this. | | .766 | | | | |
| Autonomy 15: I felt like it was not my own choice to do this task. | | .583 | | | | -.351 |
| Relatedness 16: I feel really distant from others when I do this activity | | .350 | | | | |
| Autonomy 19: I did this activity because I had to. | | .651 | | | | |
| Relatedness 13: I'd like a chance to interact with people more often while doing this activity | | | .506 | | | |
| Relatedness 18: I'd really prefer not to interact with people while doing this activity in the future | | | .692 | | | |
| Autonomy 1: I believe I had some choice about doing this activity. | | | | -.570 | | |
| Autonomy 3: I did this activity because I had no choice. | | | | .406 | | |
| Relatedness 10: I feel close to others when I do this activity | | | | | -.903 | |
| Relatedness 5: I felt like I couldn't trust others to do this activity with me | | | | | | -.505 |
| Autonomy 4: I did this activity because I wanted to. | | | | | | |
| Relatedness 14: I felt like I could trust others to do this activity with me | | | | | | |

Extraction Method: Principal Axis Factoring.
Rotation Method: Oblimin with Kaiser Normalization.
a. Course = OSU Honors
b. Rotation converged in 20 iterations.

APPENDIX III.6

MANOVA RESULTS TABLE

Comparison of measures of psychological needs support at the FAL and TAL institutions. Instructional activities under investigation are clickers, group activity (group), whole class discussion (class), lecture, and exams. * = significant difference.

| **Dependent Variable** | ***df*** | ***df* error** | ***f*** | **Course** | **Means** | **99.9% Confidence Interval** | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound |
| Clicker Needs Support | 1 | 179 | .000 | FAL | 4.216 | 4.108 | 4.324 |
| | | | | TAL | 4.216 | 4.104 | 4.328 |
| Group Needs Support | 1 | 179 | 3.286 | FAL | 4.122 | 4.016 | 4.228 |
| | | | | TAL | 4.263 | 4.153 | 4.373 |
| Class Needs Support | 1 | 179 | .194 | FAL | 4.196 | 4.089 | 4.304 |
| | | | | TAL | 4.162 | 4.050 | 4.273 |
| Lecture Needs Support | 1 | 179 | 6.333 | FAL | 3.827 * | 3.708 | 3.946 |
| | | | | TAL | 4.046 * | 3.922 | 4.169 |
| Exam Needs Support | 1 | 179 | 6.372 | FAL | 3.290 * | 3.147 | 3.433 |
| | | | | TAL | 3.553 * | 3.405 | 3.702 |

APPENDIX III.7

Pairwise comparison of TAL and FAL instruction psychological needs satisfaction scores. Post-hoc test run using a Bonferroni correction. * = significant difference.

| TAL Pairwise Comparisons | | | | | | |
|---|---|---|---|---|---|---|
| Motivation Comparisons | | Mean Difference | Standard Error | Sig. | 95% Confidence Interval for Difference | |
| | | | | | Lower Bound | Upper Bound |
| Clickers | Group Activity | -.047 | .029 | 1.000 | -.129 | .035 |
| | Whole Class Discussion | .054 | .038 | 1.000 | -.055 | .163 |
| | Lecture | .170* | .047 | .005 | .034 | .307 |
| | Exams | .663* | .074 | .000 | .449 | .876 |
| Group Activity | Clickers | .047 | .029 | 1.000 | -.035 | .129 |
| | Whole Class Discussion | .101 | .039 | .107 | -.010 | .213 |
| | Lecture | .217* | .048 | .000 | .080 | .355 |
| | Exams | .710* | .077 | .000 | .488 | .931 |
| Whole Class Discussion | Clickers | -.054 | .038 | 1.000 | -.163 | .055 |
| | Group Activity | -.101 | .039 | .107 | -.213 | .010 |
| | Lecture | .116 | .051 | .251 | -.031 | .263 |
| | Exams | .609* | .074 | .000 | .395 | .822 |
| Lecture | Clickers | -.170* | .047 | .005 | -.307 | -.034 |
| | Group Activity | -.217* | .048 | .000 | -.355 | -.080 |
| | Whole Class Discussion | -.116 | .051 | .251 | -.263 | .031 |
| | Exams | .492* | .063 | .000 | .312 | .673 |
| Exams | Clickers | -.663* | .074 | .000 | -.876 | -.449 |
| | Group Activity | -.710* | .077 | .000 | -.931 | -.488 |
| | Whole Class Discussion | -.609* | .074 | .000 | -.822 | -.395 |
| | Lecture | -.492* | .063 | .000 | -.673 | -.312 |

| FAL Pairwise Comparisons | | | | | | |
|---|---|---|---|---|---|---|
| Motivation Comparisons | | Mean Difference | Standard Error | Sig. | 95% Confidence Interval for Difference | |
| | | | | | Lower Bound | Upper Bound |
| Clickers | Group Activities | .093 | .046 | .453 | -.039 | .226 |
| | Whole Class Discussion | .019 | .049 | 1.000 | -.120 | .159 |
| | Lecture | .389* | .062 | .000 | .211 | .567 |
| | Exams | .926* | .077 | .000 | .706 | 1.146 |
| Group Activities | Clickers | -.093 | .046 | .453 | -.226 | .039 |
| | Whole Class Discussion | -.074 | .044 | .982 | -.202 | .053 |
| | Lecture | .296* | .056 | .000 | .134 | .458 |
| | Exams | .833* | .078 | .000 | .609 | 1.056 |
| Whole Class Discussion | Clickers | -.019 | .049 | 1.000 | -.159 | .120 |
| | Group Activities | .074 | .044 | .982 | -.053 | .202 |
| | Lecture | .370* | .063 | .000 | .190 | .550 |
| | Exams | .907* | .075 | .000 | .690 | 1.124 |
| Lecture | Clickers | -.389* | .062 | .000 | -.567 | -.211 |
| | Group Activities | -.296* | .056 | .000 | -.458 | -.134 |
| | Whole Class Discussion | -.370* | .063 | .000 | -.550 | -.190 |
| | Exams | .537* | .075 | .000 | .323 | .752 |
| Exams | Clickers | -.926* | .077 | .000 | -1.146 | -.706 |
| | Group Activities | -.833* | .078 | .000 | -1.056 | -.609 |
| | Whole Class Discussion | -.907* | .075 | .000 | -1.124 | -.690 |
| | Lecture | -.537* | .075 | .000 | -.752 | -.323 |

# APPENDIX III.8

Correlating engagement behaviors and students' perceptions of needs support.

**Correlations**

| | | Total Number of videos watched | Total Number of clicker sessions participated in | Mean Clicker Autonomy | Mean Clicker Competency | Mean Clicker Relatedness | Mean Lecture Autonomy | Mean Lecture Copetency | Mean Lecture Relatedness | Mean Clicker Needs Score | Mean Lecture Needs Score |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Number of videos watched | Pearson Correlation | 1 | 0.557** | -0.021 | -0.034 | -0.028 | -0.096 | 0.351** | -0.095 | -0.057 | 0.123* |
| | Sig. (2-tailed) | | 0.000 | 0.723 | 0.571 | 0.644 | 0.111 | 0.000 | 0.112 | 0.344 | 0.040 |
| | N | 312 | 312 | 275 | 275 | 275 | 280 | 280 | 280 | 274 | 279 |
| Total Number of clicker sessions participated in | Pearson Correlation | 0.557** | 1 | -0.137* | 0.217** | 0.155* | -0.082 | 0.187** | -0.097 | 0.096 | 0.021 |
| | Sig. (2-tailed) | 0.000 | | 0.023 | 0.000 | 0.010 | 0.172 | 0.002 | 0.104 | 0.112 | 0.723 |
| | N | 312 | 312 | 275 | 275 | 275 | 280 | 280 | 280 | 274 | 279 |
| Mean Clicker Autonomy | Pearson Correlation | -0.021 | -0.137* | 1 | 0.175** | 0.000 | 0.600** | 0.141* | 0.231** | 0.608** | 0.479** |
| | Sig. (2-tailed) | 0.723 | 0.023 | | 0.004 | 0.001 | 0.000 | 0.020 | 0.000 | 0.000 | 0.000 |
| | N | 275 | 275 | 275 | 275 | 275 | 275 | 275 | 275 | 274 | 274 |
| Mean Clicker Competency | Pearson Correlation | -0.034 | 0.217** | 0.175** | 1 | 0.559** | 0.173** | 0.473** | 0.183** | 0.794** | 0.411** |
| | Sig. (2-tailed) | 0.571 | 0.000 | 0.004 | | 0.000 | 0.004 | 0.000 | 0.002 | 0.000 | 0.000 |
| | N | 275 | 275 | 275 | 275 | 275 | 275 | 275 | 275 | 274 | 274 |
| Mean Clicker Relatedness | Pearson Correlation | -0.028 | 0.155* | 0.204** | 0.559** | 1 | 0.142* | 0.268** | 0.430** | 0.772** | 0.390** |
| | Sig. (2-tailed) | 0.644 | 0.010 | 0.001 | 0.000 | | 0.018 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 275 | 275 | 275 | 275 | 275 | 275 | 275 | 275 | 274 | 274 |
| Mean Lecture Autonomy | Pearson Correlation | -0.096 | -0.082 | 0.600** | 0.173** | 0.142* | 1 | 0.074 | 0.227** | 0.402** | 0.646** |
| | Sig. (2-tailed) | 0.111 | 0.172 | 0.000 | 0.004 | 0.018 | | 0.218 | 0.000 | 0.000 | 0.000 |
| | N | 280 | 280 | 275 | 275 | 275 | 280 | 280 | 280 | 274 | 279 |
| Mean Lecture Copetency | Pearson Correlation | .351** | .187** | 0.141* | 0.473** | 0.268** | 0.074 | 1 | 0.090 | 0.394** | 0.648** |
| | Sig. (2-tailed) | 0.000 | 0.002 | 0.020 | 0.000 | 0.000 | 0.218 | | 0.134 | 0.000 | 0.000 |
| | N | 280 | 280 | 275 | 275 | 275 | 280 | 280 | 280 | 274 | 279 |
| Mean Lecture Relatedness | Pearson Correlation | -0.095 | -0.097 | 0.231** | 0.183** | 0.430** | 0.227** | 0.090 | 1 | 0.356** | 0.589** |
| | Sig. (2-tailed) | 0.112 | 0.104 | 0.000 | 0.002 | 0.000 | 0.000 | 0.134 | | 0.000 | 0.000 |
| | N | 280 | 280 | 275 | 275 | 275 | 280 | 280 | 280 | 274 | 279 |
| Mean Clicker Needs Score | Pearson Correlation | -0.057 | 0.096 | 0.608** | 0.794** | 0.772** | 0.402** | 0.394** | 0.356** | 1 | 0.588** |
| | Sig. (2-tailed) | 0.344 | 0.112 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 |
| | N | 274 | 274 | 274 | 274 | 274 | 274 | 274 | 274 | 274 | 274 |
| Mean Lecture Needs Score | Pearson Correlation | .123* | 0.021 | 0.479** | 0.411** | 0.390** | 0.646** | 0.648** | 0.589** | 0.588** | 1 |
| | Sig. (2-tailed) | 0.040 | 0.723 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | |
| | N | 279 | 279 | 274 | 274 | 274 | 279 | 279 | 279 | 274 | 279 |

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

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

# APPENDIX III.9

## Factor analysis from the new version, shorter version of the survey.

**Verso Pattern Matrix[a]**

| | Factor | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| Autonomy 3: I did this activity because I had no choice. | .898 | | | | |
| Relatedness 10: I feel close to others when I do this activity | .583 | | -.346 | | |
| Competency 2: I was pretty skilled at this activity. | -.341 | .814 | | | |
| Competency 6: I am satisfied with my performance at this task. | -.334 | .548 | | | |
| Relatedness 16: I feel really distant from others when I do this activity | .729 | | | | |
| Autonomy 8: I didn't really have a choice about doing this task. | | .561 | | | |
| Autonomy 1: I believe I had some choice about doing this activity. | | | .549 | | |
| Competency 7: I think I did pretty well at this activity, compared to other students. | | | -.587 | | |
| Relatedness 14: I felt like I could trust others to do this activity with me | | | -.720 | | |
| Relatedness 18: I'd really prefer not to interact with people while doing this activity in | | | .534 | | |
| Autonomy 15: I felt like it was not my own choice to do this task. | | | | -.970 | |
| Relatedness 13: I'd like a chance to interact with people more often while doing this | | | | | -.651 |
| Competency 11: This was an activity that I couldn't do very well. | | | | | |
| Competency 17:I think I am pretty good at this activity. | | | | | |

**Video Pattern Matrix[a]**

| | Factor | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| Competency 2: I was pretty skilled at this activity. | .836 | | | | |
| Autonomy 3: I did this activity because I had no choice. | -.844 | | | | |
| Competency 6: I am satisfied with my performance at this task. | .830 | | | | |
| Relatedness 10: I feel close to others when I do this activity | -.783 | | | | |
| Autonomy 1: I believe I had some choice about doing this activity. | | -.920 | | | |
| Competency 7: I think I did pretty well at this activity, compared to other students. | | .796 | | | |
| Relatedness 18: I'd really prefer not to interact with people while doing this activity in | | .386 | .745 | -.371 | |
| Relatedness 14: I felt like I could trust others to do this activity with me | | | -.870 | | |
| Relatedness 16: I feel really distant from others when I do this activity | | | -.477 | | |
| Autonomy 8: I didn't really have a choice about doing this task. | | | | .400 | |
| Competency 11: This was an activity that I couldn't do very well. | | | | .522 | |
| Relatedness 13: I'd like a chance to interact with people more often while doing this | | | | -.357 | |
| Autonomy 15: I felt like it was not my own choice to do this task. | | | | | .607 |
| Competency 17:I think I am pretty good at this activity. | | | | | .419 |

Extraction Method: Principal Axis Factoring.
Rotation Method: Oblimin with Kaiser Normalization.
a. Rotation converged in 7 iterations.

**Clicker Pattern Matrix[a]**

| | Factor | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| Autonomy 3: I did this activity because I had no choice. | .754 | | | | |
| Relatedness 10: I feel close to others when I do this activity | .834 | | | | |
| Relatedness 16: I feel really distant from others when I do this activity | .821 | | | | |
| Autonomy 1: I believe I had some choice about doing this activity. | | -.714 | | | |
| Competency 7: I think I did pretty well at this activity, compared to other students. | | .750 | .358 | | |
| Relatedness 14: I felt like I could trust others to do this activity with me | | .538 | .335 | | |
| Relatedness 18: I'd really prefer not to interact with people while doing this activity in | | -.512 | | | -.394 |
| Competency 2: I was pretty skilled at this activity. | | | .895 | | |
| Competency 6: I am satisfied with my performance at this task. | | | .559 | | |
| Relatedness 13: I'd like a chance to interact with people more often while doing this | | | .530 | | |
| Autonomy 15: I felt like it was not my own choice to do this task. | | | .502 | | -.441 |
| Autonomy 8: I didn't really have a choice about doing this task. | | | | .402 | |
| Competency 11: This was an activity that I couldn't do very well. | | | | .801 | |
| Competency 17:I think I am pretty good at this activity. | | | | | .682 |

Extraction Method: Principal Axis Factoring.
Rotation Method: Oblimin with Kaiser Normalization.
a. Rotation converged in 22 iterations.

**Group Activity Pattern Matrix[a]**

| | Factor | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Autonomy 3: I did this activity because I had no choice. | -.832 | | | |
| Competency 2: I was pretty skilled at this activity. | .626 | | .449 | |
| Competency 6: I am satisfied with my performance at this task. | .600 | | .505 | |
| Relatedness 10: I feel close to others when I do this activity | -.748 | | | |
| Relatedness 16: I feel really distant from others when I do this activity | -.776 | | | |
| Autonomy 1: I believe I had some choice about doing this activity. | | -.373 | | |
| Competency 7: I think I did pretty well at this activity, compared to other students. | | .856 | .351 | |
| Relatedness 14: I felt like I could trust others to do this activity with me | | .753 | | |
| Relatedness 18: I'd really prefer not to interact with people while doing this activity in | | -.597 | .394 | |
| Relatedness 13: I'd like a chance to interact with people more often while doing this | | | .674 | |
| Autonomy 15: I felt like it was not my own choice to do this task. | | | .700 | |
| Autonomy 8: I didn't really have a choice about doing this task. | | | | .850 |
| Competency 17:I think I am pretty good at this activity. | | | | .611 |
| Competency 11: This was an activity that I couldn't do very well. | | | | |

Extraction Method: Principal Axis Factoring.
Rotation Method: Oblimin with Kaiser Normalization.
a. Rotation converged in 13 iterations.

**Exam Pattern Matrix[a]**

| | Factor | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Competency 2: I was pretty skilled at this activity. | .865 | | .324 | |
| Autonomy 3: I did this activity because I had no choice. | -.877 | | | |
| Competency 6: I am satisfied with my performance at this task. | .821 | | | |
| Relatedness 10: I feel close to others when I do this activity | -.636 | | | |
| Relatedness 16: I feel really distant from others when I do this activity | -.860 | | | |
| Competency 11: This was an activity that I couldn't do very well. | | .785 | | |
| Autonomy 15: I felt like it was not my own choice to do this task. | | .730 | | |
| Competency 17:I think I am pretty good at this activity. | | .522 | | |
| Relatedness 18: I'd really prefer not to interact with people while doing this activity in | | .686 | | |
| Competency 7: I think I did pretty well at this activity, compared to other students. | | | .533 | |
| Relatedness 13: I'd like a chance to interact with people more often while doing this | | | .356 | |
| Relatedness 14: I felt like I could trust others to do this activity with me | | | .850 | |
| Autonomy 1: I believe I had some choice about doing this activity. | | | | .399 |
| Autonomy 8: I didn't really have a choice about doing this task. | | j | | .347 |

Extraction Method: Principal Axis Factoring.
Rotation Method: Oblimin with Kaiser Normalization.
a. Rotation converged in 7 iterations.

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Doctor of Philosophy

Thesis: ASSESSING STUDENT BEHAVIORS AND MOTIVATION FOR ACTIVELY LEARNING BIOLOGY

Major Field: Integrative Biology

Biographical:

Education:

Completed the requirements for the Doctor of Philosophy in Integrative Biology at Oklahoma State University, Stillwater, Oklahoma in May, 2017.

Completed the requirements for the Master of Science in Biology at Ball State University, Muncie, Indiana in 2013.

Completed the requirements for the Bachelor of Arts in Biology at Taylor University, Upland, Indiana in 2005.

Experience:

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| 2014- | Graduate Research Assistant on HHMI Undergraduate Introductory Course Reform Grant; Oklahoma State University; Stillwater, OK |
| 2013-2014 | Graduate Teaching Assistant; Oklahoma State University; Stillwater, OK |
| 2012-2013 | Graduate Teaching Assistant; Ball State University; Muncie, IN |
| 2007-2013 | Starbucks Coffee Company; Chicago, IL |

Professional Memberships:

Association of Biology Laboratory Educators
Environments and Metrics in Biology Education and Research
National Association of Biology Teachers
National Science Teachers Association
Society for the Advancement of Biology Education Research