What is Active Learning? Perspectives from Five STEM Professors' Teaching Practices in Their Classrooms

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Abstract

This senior thesis investigated what ways, if any, STEM professors incorporated active learning pedagogy in their undergraduate classroom in a small private university in the northeast USA. STEM pedagogy was investigated because of the increasing prominence of active learning methods in the classroom compared to the didactic type of teaching that was prominent in the past (Eichler, 2020). A qualitative case study of five STEM professors was conducted and involved collecting data from biographical questions, a one-hour interview, and the analysis of a document provided by the professor that could have been a lesson plan, an assignment, or an activity they created during the Fall 2022 and Spring 2023 semesters. Four themes emerged from my analysis of data: *(a) considering students' prior knowledge, (b) scaffolding students' learning experiences, (c) imagining and revising instructional sequence to guide student learning, and (d) supporting students' learning through various resources.* These are the active learning strategies that were commonly found in answers from the interview questions. These findings suggest that STEM professors implement active learning strategies in their classrooms. My data also found that none of the professors in this study has completed any formal education in active learning frameworks. This study showcases that STEM professors may be applying active learning in their classrooms because of their experience as teachers rather than a formal education on active learning pedagogy.

1.0 Introduction and Problem Statement

A common notion about postsecondary faculty is that they "teach the way they were taught" because they normally do not receive a formal education on how to teach during graduate school (Oleson and Hora, 2013). The style of teaching most postsecondary faculty is familiar with is known as a traditional style of teaching. A traditional style of teaching involves learning knowledge and skills, similarly, active learning helps students with the practical application of the concept skills and students' attitudes toward the concepts (Bosio and Origo, 2020). Professors that use a traditional style of teaching verbally explain the content through the use of PowerPoints, which teaches the students explicit knowledge (Nonaka and Von Krogh, 2009). With a lecturing style of teaching, there could be minimal participation by the student and the professor may not always be able to gauge the student's knowledge or understanding of the concept (Stanberry and Payne, 2018). Ways that professors combat this in the classroom is by planning whole-class discussions or asking students specific questions throughout the lesson. According to *America's Lab Report*, which was published in 2006, U.S. students' science knowledge has not increased based on the national average of scores of 9, 13, and 17-year-olds (National Research Council, 2006). Science knowledge of students has not increased because of their experience in STEM classrooms. Students can cover more topics in the classroom, but go less in-depth, which leads to a lower understanding of the concepts (Sadler and Tai, 2001). This data creates concern about the science literacy of students who enter college wanting to obtain science or engineering degrees. It was found that many of the students who pursue STEM degrees in college do not complete their degrees, drop out of college, or switch to another field of study (National Research Council, 2006).

When students are given the opportunity to participate in group problem-solving activities and receive feedback simultaneously from professors and peers, there is a positive effect on their learning in the classroom (Conference Board of the Mathematical Sciences, 2016). There is a positive effect on their learning because, even from a young age, students are learning there are different strategies to achieve one result. Different strategies to solve a problem can take less time, be applied to a range of problems, and take less brain power (National Research Council, 2000). These positive effects include students being able to prompt themselves when solving problems without professor help and transferring their skills to different educational settings (National Research Council,2000). When students are allowed to collaborate with their peers, they have the opportunity to learn from each other and discover different strategies they may use to apply their knowledge in the future (LoPresto and Slater, 2016).

The adoption of active learning techniques in undergraduate classrooms remains a challenge, although there is significant literature that supports the efficacy of evidence-based instructional practices in STEM classrooms (Hogan et al., 2016). The most common problems that universities have found in implementing active learning in the classroom include professors' taking the role of "sage on the stage" rather than "guides on the side", as well as lacking evidence-based teaching practices and assessment methods (Elrod and Kezar, 2016). When lesson plans are developed the two different learning processes students should know, the "what" of the concept and the "how" the concept works, may not be integrated. Students could struggle when learning the two processes and if active learning techniques are introduced to the classroom it could help students work towards combining the two processes and expanding their knowledge (Michael, 2006).

1.1 Introduction about active learning

Active learning allows students to be engaged in their own learning through activities or discussions in the classroom instead of passively listening to the professor (Arthurs and Kreager, 2017). Active learning can take many forms in the classroom, polling activities, whole-class discussions, or group activities. When professors use polling activities, they can activate a student's prior knowledge as well as assess the student's understanding of the material they just learned (Lin et al, 2011). Whole-class discussions involve participation from the whole class and can be led by an instructor or a group of students (Middlecamp and Nickel, 2000). These discussions will follow the same general steps, students complete an activity and then students contribute to the whole class discussion through questions and answers (Arthurs and Kreager, 2017). The last form of active learning I will explain briefly is group activities. Group activities can take many different shapes depending on the teacher. There are structured activities such as process-oriented guided inquiry learning (POGIL) which are chemistry-specific activities that allow students to explore the material through application (Hanson, 2006). Another type of group activity can be problem-based learning (PBL). This introduces the concept to students before the lecture through an authentic real-life problem (Amador et al., 2007).

When active learning is implemented in classrooms, students show high engagement with the material and better success in the subject area (Bouwma-Gearhart, 2012). Specifically, when it is implemented in postsecondary classes students have a deeper understanding of the material, and encourages their future commitment to having a deeper understanding of other subjects (Healey, 2005). Students are able to have a deeper understanding of the material because they are given the opportunity to practice the professional skills they may need in industry jobs (Austin, 2011). When students are able to understand the material, this leads to higher retention rates of STEM students (Tomkin et al., 2019). Implementing active learning has shown a change in

power in the classroom, where students are in control of their learning (Bowuma-Gearhart, 2011). Tacit knowledge can be learned through active learning in the classroom when students complete personal hands-on experiences (Nonaka and Von Krogh, 2009).

1.2 Gaps in the literature on active learning

Although there has been new research on active learning in various classroom settings, there has been limited research on the effectiveness of both active and traditional learning on students' achievement in the classroom (Bosio and Orgio, 2020). Students' achievement is not the only thing missing from research, students' attitude and opinion of active learning activities needs to be researched to help professors decide if and how they will implement active learning in their classroom (LoPresto and Slater, 2016). There is also a gap in the literature on what leads professors to decide to implement active learning in their classrooms and how they use published resources to apply it to their classrooms (Arthurs and Kreager, 2017). An important aspect of active learning that is currently missing from research on active learning is how applying active learning strategies in the classroom can impact underrepresented groups in the classroom (Stanberry and Payne, 2018). This means how can teachers bring their authentic selves to their classroom and encourage their students to do the same through active learning strategies.

1.3 What are STEM professors' successes and challenges in implementing active learning?

STEM professors have reported that there is a challenge in implementing active learning in the classroom. One of the biggest challenges is the professor's pedagogical content knowledge and knowledge about scientific inquiry (Fang, 2020). When professors are lacking the knowledge to implement inquiry-based learning in their classrooms, they lack confidence and self-efficacy (Ramnararain, 2016; Naithani, 2008). Professors have misconceptions about what active learning is in the classroom. They mistake active learning for reviewing content taught

previously, rather than engaging students in the material (Joeseph et al., 2021). The challenges of active learning in the classroom are not all on the professors but can also be pointed to a lack of administrative support as well as the lack of instructional materials (Anderson, 2007; Fang, 2020). Unfortunately, professors believe that when they dedicate time in the classroom for engaging activities, they lose time to cover more concepts during the semester (Naithani, 2008; Joseph et al., 2021). The common form of teacher development in higher education is professional development workshops. It has been found that when faculty are exposed to research that showcases classroom issues they are more likely to be motivated to adopt new teaching strategies (Bouwma-Gearhart, 2012).

Successful implementation of active learning in classrooms does not only look like engaging activities but also revising how students are assessed. Tests should not only test if students are able to memorize facts but test their true understanding of the material, allow them to extend their knowledge, and reflect on how the materials impact them (Kinzie, 2005; Weimer, 2003).

2.0 Literature Review

The first laboratory manual was written in 1906 by Rober Millikan, a well-known physicist that believed in the importance of hands-on experience in the classroom to help students learn (Beichner, 2014). A lecture hall in most colleges looks like an amphitheater with hundreds of seats and the professor standing at the front of the room with a chalkboard behind them. Students are confined to their chairs for the duration of the lecture which prevents them from interacting with their peers as well as engaging in activities with the professor. These lecture halls do not only prohibit the students but also restrict the professors from engaging with the students in a one-on-one fashion (Baepler et al., 2016). With the increase of published

evidence that students benefit from the implementation of active learning in the classroom, colleges have begun to transform classrooms into active learning spaces (Smith et al., 2005). An example of a successful implementation of active learning in the classroom is one teacher's blending of arts and science. He has his students create visual advertisements to describe a science idea by combining research and images (Henriksen, 2014).

Active learning is a style of teaching that is a more "learner-centered" approach. It is an additional teaching style that allows students to talk, listen, write, read, and reflect on the contents of an academic subject in a meaningful way (Myers and Jones, 1993). Active learning switches the thought in the classroom to what the teacher is doing in front of the class, to what the students are doing, and how their behaviors determine what is learned (Michael, 2006). When student-centered instruction is properly executed in the classroom, it has been found to increase motivation in students to learn, create a deeper understanding and greater retention of the content, as well as build positive attitudes toward the subject (Michael, 2006). There are many different types of active learning that can be applied in a classroom. These types include interactive lectures, class discussions, case study analysis, role-playing, experiential learning, peer teaching, and flipped lessons (Misseyani et.al, 2018) In interactive lectures, students influence the pace of learning, the content taught, and the activities they complete in the classroom (Michael, 2006). For STEM classrooms active learning can involve problem-based, visual-based, collaborative, project-based, or game-based learning (Misseyani et.al, 2018). The students take a main role in the activity by discovering the problem, drafting solutions to the problem, and then implementing their solutions to test their theories with the support of their teacher and peers. These types of learning are considered active learning because they are student-centered. They involve the students in their own learning and the activities allow the

students to learn independently or in a group with the guidance of the teacher. To implement active learning in the classroom there must be a shift in the teacher's mind from 'how am I comfortable teaching' to 'how do the students learn and how can I enhance their learning' (Naithani, 2008). The President's Council of Advisors on Science and Technology concluded that an implication of more active and engaging classroom environments would achieve improvement in the first 2 years of STEM education (Eichler, 2020). An important part of learning is understanding the language of the concept. To understand the language of the concept students need to have the opportunities to read, speak and write the language (Evens, M. and Michael, J., 2006). Students need to be given the chance to talk to each other in formal and informal situations to test their knowledge of the concepts.

In the changing landscape of education, inquiry has become one of the most important aspects of the goals of teaching and learning (Friesen and Scott, 2013). Inquiry-based learning is a form of active learning where students are given a series of tasks to investigate through their own questions (Ernst et al., 2017). The students are tasked with asking questions about their activity and then allowed to develop ways to find the answers to their questions. In 1996 the National Science Education Standards (NSES) was established by the National Research Council to formally define what inquiry should look like in the classroom. There were three levels of inquiry: low, medium, and high. For the low level of inquiry, the teacher provides the questions for students to answer and the methods that the students will use to answer them (National Research Council, 2000). In the medium level of inquiry, the students create their own questions and are able to answer them after modeling by the teacher (National Research Council, 2000). The last level of inquiry is known as "open inquiry" because it is completely student guided. The students develop their own questions and methods which are most often used to introduce new

concepts in the classroom (National Research Council, 2000). More in-depth and expanded standards were released in 2012 by the National Research Council. This is known as the Next Generation Science Standards (NGSS). These new standards are divided into three categories that have intentional connections across multiple standards. Those categories are Science and Engineering Practice, Disciplinary Core Ideas, and Crosscutting Concepts (National Research Council, 2011). Each of the standards follows the same framework that breaks down the different components into codes that relate to each subject. The codes that are found on the standard, allow educators to plan their lessons with the knowledge they are implementing the NGSS in their classroom.

Even though inquiry-based learning can take many forms in the classroom, there are two main “pillars” that are found to be at its core: deep engagement in rich mathematics, and opportunities to collaborate (Ernst et al., 2017). The first pillar of engagement in mathematics encompasses the students' ability to actively work on challenging mathematical problems. This first pillar is reflective of the medium level of inquiry that was established in NSES that is mentioned above. The students will develop their own mathematical ideas while discovering the answer since many of the students will not know the method to solve the problem (Ernst et al., 2017). In the NGSS this pillar can be seen in some of the codes that can be found within the standards. The M1 code for Math stands for making sense of problems and solving them and the E5 code that relates to math, science, and ELA stands for being able to read, write, and speak using evidence (National Research Council, 2011). The second pillar of collaboration will take many different forms in the classrooms, from group work to students presenting their work to the class, and class-wide collaboration to solve a problem (Ernst et al., 2017). This pillar is grounded in all levels of inquiry established in NSES because an important part of inquiry is the students

having the ability to collaborate with each other and then report their findings. Each of the problems given to the students is meant to introduce a new topic, develop intuition about a concept, synthesize ideas from a few concepts, make a conjecture, prove a theorem, and get practice doing routine or nonroutine problems (Ernst et al., 2017). The codes that this pillar represents from the NGSS are M3 and E4 which states students will be able to construct arguments and critique the reasoning of others (National Research Council, 2011). These codes are common in math, science, and ELA which makes the conclusion that collaboration must be found in all inquiry-based learning classrooms.

The process of inquiry-based learning is capable of being applied to both the sciences and the social sciences, thus allowing principles to be established for most classrooms (Friesen and Scott, 2013). The principles that have been established for a 21st-century education have been labeled as the three E's: engaged thinker, ethical citizen, and entrepreneurial spirit (Friesen and Scott, 2013). An engaged thinker is said to be a student who can think critically, communicate ideas to others, and able to adapt for the future. An ethical citizen is a student who is able to build relationships, demonstrate respect and compassion, as well as use teamwork and collaboration to contribute to society. Lastly, an entrepreneurial spirit is a student who can create opportunities to achieve their goals and has the confidence to take risks and make decisions (Friesen and Scott, 2013). If teachers are able to apply the principles of the three E's to their classrooms, they will be able to encourage students' natural curiosity as well as teach them to be lifelong learners (Friesen and Scott, 2013).

The Herron's Scale for determining the level of inquiry for an activity was established in the late 1960s and was based on the principle "How much is 'given' to the student by the teacher or activity instruction?" (Lederman, 2010). The scale has four levels of inquiry: exploration,

directed, guided, and open-ended (Lederman, 2010). These four levels are reflective of the three levels of inquiry that were established in the NSES in 2000. The only difference between this scale of inquiry and NSES is breaking down the low level of inquiry into two types: exploration and direct. In both the exploration and direct levels of inquiry of the Herron Scale, students are given activities and problems to solve as well as the methods to solve these problems. The difference between these two types of inquiry in the scale is that the exploration level is used for teachers to gain an understanding of their students' prior knowledge of the content (Lederman, 2010). The NGSS that are currently used in classrooms breaks down what inquiry looks like for each of the standards. The NGSS does not limit inquiry to a set number of levels but instead establishes the multitude of ways lessons can be taught and qualify as active learning. The biggest difference between the levels of inquiry that were established and the NGSS is that the NGSS has established codes that relate the commonalities in different subjects. These commonalities allow teachers to bring concepts from different subjects into their classrooms to expand their students' learning. Lessons do not have to contain all levels to be considered inquiry-based learning and the levels do not have to be found in this order. The addition of any aspects of the levels on this scale can be a step in the right direction to adding inquiry-based learning to the classroom.

One of the most common frameworks used in inquiry-based classrooms is the 5Es conceptual framework. The 5Es are Engage, Explore, Explain, Elaborate, and Evaluate. During the engagement stage of the lesson, students will access their prior knowledge to become familiar with the new materials and think about real-world questions (Gao and Hew, 2022). In this stage, students are expected to raise questions, identify problems, and consider answers to their questions. Teachers would also be able to identify misconceptions about the concepts their

students might have (Lederman, 2010). During the “exploration stage”, students will begin to work and understand new knowledge through activities or quizzes that are hands-on experiences (Jogan, 2017). The “exploration stage” of the framework fits all levels of the inquiry scale mentioned above (Lederman, 2010). The “explain section” of the lesson involves the students demonstrating their knowledge of the topic and the teacher demonstrates how to apply the knowledge in further detail (Jogan, 2017; Gao and Hew, 2022). Every level of the inquiry scale asks students to explain their prediction and how they will adapt to changes in the future, which makes the “explanation section” of the 5Es framework one of the most important in a lesson plan (Lederman, 2010). In the “elaboration” of the lesson the students are given the opportunity to apply their new knowledge and skills which allows them to develop a deeper and broader understanding of the concepts (Jogan, 2017). The “elaboration section” of the framework opens the door for open-ended inquiry because it gives students the opportunity to design their own investigations and carry them out (Lederman, 2010). The “evaluation” is the last part of the lesson and this is when the teacher will assess the students and the students are given time to self-reflect (Gao and Hew, 2022). There are formal and informal evaluations that can occur at every level of the inquiry scale (Lederman, 2010). This framework allows teachers to sequence the order of their activities in a way that maximizes student learning.

The 5Es model was developed in 1993 and in 2001, the 7Es Learning Cycle was introduced (Khashan, 2016). The 7Es learning cycle’s goal is to develop expanded scientific concepts and skills by adding two extra sections to the 5E model. The extra sections that are included in the 7E model are “extension” and “exchanging” (Khashan, 2016). In the “extension” section, the teacher helps students connect concepts with other concepts by asking questions that establish the relationship between the two (Khashan, 2016). The “exchanging” section of the

new model involves students participating in activities that help them exchange experiences and knowledge (Khashan, 2016). These two sections can be found within the 5E model as part of the "explain" and "exploration" sections. The 7E model allows teachers to expand on specific concepts in their lessons to make sure all of their students are more active in their learning (Khashan, 2016). The NGSS is the most useful to teachers who want to implement the 5E or 7E model in their classroom. The standards are broken down in ways that allow teachers to make sure they hit the important parts of a specific concept, while also staying student-centered in their approach to teaching. The NSES levels of inquiry can be used to determine how a teacher would like to teach the different parts of their lesson in the 5E or 7E model. The 7E model allows for an expanded lesson plan that can be traced to every level of inquiry from the NSES and broken down to hit most codes of the NGSS.

When students work together in groups in STEM classrooms there is more evidence of learning. In a physics classroom, students that work in groups generate better solutions and unique methods to answer problems, and students in a chemistry classroom have increased retention and higher scores on assessments than students in a conventional classroom (Michael, 2006). One of the most effective active learning techniques in chemistry classrooms that resulted in greater student achievement was student-generated discussions (Niaz et al., 2002). When students are given the opportunity to argue and counter-argue about the concepts it gives them the chance to talk about their misconceptions rather than learn the professor's misconceptions through conventional techniques (Quilez-Pardo and Solaz-Portoles, 1995). Biology is a science that integrates both physics and chemistry, but because of this students can have a hard time understanding biology concepts when they do not fully understand the physics or chemistry topics. When active learning techniques are applied in biology classrooms, they must target the

physics and chemistry misconceptions students have as well as tackle the biology concepts (Michael, 2006). An active learning technique that has worked well in biology courses is concept mapping (Briscoe and LaMaster, 1991). The concept mapping worked well in the classroom because of the ease of biology concepts being put into hierarchical tables of organization (Novak and Gowin, 1984).

2.1 Conceptual Framework

Active learning in the classroom allows teachers to hand responsibility over to the students when it comes to their intellectual development, which means professors will structure the activities in a way where the student's level of involvement affects their level of learning (Naithani, 2008). This does not mean that professors leave the students to their own devices, professors must help the students transition into an active learning mindset and take the time to understand their students' abilities to create activities and assignments that will expand their knowledge (Seeler et al., 1994). Stinson and Milter introduced the two major pillars of an active learning environment to the instructor's development of active learning lessons and the student's ability to transition into an active learning mindset (1996).

Active learning can take many shapes in the classroom. Some examples of active learning models in the classroom include collaborative work, inquiry-based learning, simulation activities, and space interventions. Collaborative work allows students to solve a problem in pairs or groups which can enhance their engagement in class as well as with the material (Barron et al., 1998). When teachers allow students to take part in an activity that allows them to identify a problem, brainstorm solutions for the problem, and then test their solutions, the students are participating in inquiry-based learning (White and Frederickson, 1998). In the classroom, inquiry-based learning can look like case studies, independent projects, and mock trials.

Simulation activities allow students to complete an activity that correlates the material they are learning in class with real-world examples that they would not normally be able to experience in the classroom (Glass and Mackey, 1988). The last type of active learning model that professors could implement in the classroom is space interventions. Space Interventions is an umbrella term that refers to the physical environments as well as the delivery of the material to accommodate active learning in the classroom (National Research Council, 2000). Classrooms with laboratory space, collaboration areas, and moveable furniture are examples of space interventions that make a classroom more accessible for the implementation of active learning (National Research Council, 2000).

3.0 Research Methods

A qualitative study of 5 STEM professors from a private university in the Northeast region of the United States was completed for this paper. A case study was conducted over a period of three months and then the data collected was qualitatively analyzed. In this chapter, the decision to complete a qualitative case study will be discussed as well as the research context of this study. The data instruments collected and the data analysis process will be explained in detail.

3.1 Qualitative Research

In qualitative research, there is an emphasis on interpretive/theoretical frameworks that are used to address the research questions. The data analysis for qualitative research establishes patterns that will contribute to the literature (Denzin and Lincoln, 2011; Creswell, 2013). Qualitative research can be divided into five approaches: narrative, phenomenology, grounded theory, ethnography, and case studies. The choice of approach is rooted in the researcher's

personal interests, which are best suited for the subject area and how the researcher wants to display their findings (Cresswell and Poth, 2018). A case study originates from the human and social sciences disciplines and is rooted in evaluation research (Cresswell and Poth, 2018). When conducting a case study, data collection is completed through interviews, observations, documents, and artifacts, the data analysis is completed through descriptive analysis and defining cross-case themes (Cresswell and Poth, 2018). The qualitative case study design was chosen because of its effectiveness in evaluation research and the purpose of this case study was to discover if current undergraduate STEM professors were applying active learning strategies to their classrooms. This case study includes interviews and artifact collection that were then analyzed for active learning components. My case does not involve classroom observation of the professors. To discover active learning in the professors' teaching strategies, active learning codes were identified and then evaluated to establish themes in the data collected.

3.2 Research Question

The study sought to answer the question: To what extent, if any, do STEM professors use active learning during the planning and teaching of their courses?

3.3 Research Participants and Context

During the Fall 2022 semester, a recruitment period of two weeks was completed to recruit the professors for the study. All associate and tenured professors in STEM departments were sent the recruitment email (Appendix 1: Recruitment Email for Professors) and given two weeks to respond. Once the professor agreed to take part in the study, they were given a consent form that outlined what their participation would involve, how long their participation was needed, and what their data would be used for. After the consent form was signed and returned,

the professor was assigned a number and would be referred to the number from that point forward.

The case study took place at a small private university in the Northeast Region of the United States. The university offers 65 fields of studies, has about 1900 undergraduate students, 1200 graduate students, and employs tenure, adjunct, assistant, and visiting professors. The average class size at the university is 25 students and the largest class is a lecture-style class for Biology with about 60 students. The five professors who volunteered for the study work in the Chemistry and Physics, Biology, and Math departments at the university. As part of their participation in the study, the professors were asked to complete biographical questions before their interview. The professors have PhDs in their respective fields and over 10 years of teaching experience. Two of the five professors have stated they do not have any formal teaching training. The other three professors stated that they took some level of methods of teaching courses in undergraduate and graduate school to prepare them for teaching assistant positions while completing their graduate studies. All of the professors have attended and completed teacher workshops or conferences throughout the years to keep updated on new teaching methods they can implement in their classrooms.

3.4 Research Data and Data Collection

The research study was broken down into three parts. Part 1 involved the completion of biographical questions (Appendix 2: Biographical questions for email) through an email that was sent a week before the sit-down interview. These questions were completed before the interview could take place to establish the academic and professional background of the professor. The questions were created by myself and my research advisor. Part 2 was a one-hour sit-down

interview between me and the professor. The interview was documented through field notes and an audio recording. During the interview, the professor answered questions (Appendix 3: Interview questions for professors) that sought to investigate if they used active learning techniques to create and execute their lesson plans, how they determined student success in their classroom, and how they dealt with student struggles in their classroom. These questions were created by myself and my research advisor and based on interview questions found in published papers on active learning (Byusa et al. 2020 and Rezaei 2020). For the last part of the study, the professors provided me with a lesson plan, activity, or assignment they created for their class. These documents were analyzed for active learning techniques and allowed me to conclude the professor's incorporation of active learning in their classroom. In Table 1 below, you can find how the data was analyzed and which components of the data helped answer my research question.

Table 1: Research Question and Corresponding Data

Research Question	Data	Data Analysis Procedures
To what extent, if any, do STEM professors use active learning during the planning and teaching of their courses?	Interviews	Analyzed answers for active learning components. Categorized codes created. Patterns were identified as themes.
To what extent, if any, do STEM professors use active learning during the planning and teaching of their courses?	Artifacts	Analyzed for active learning components.

3.5 Research Data Analysis

During the interview, the professors were asked 10 questions. I created the questions to gauge the professors' teaching styles without specifically asking them if they use active learning in their classrooms. The first three questions were related to how the professors created their lesson plans, how often they make a lesson plan, and why they would change the lesson plan. The next question allowed the professors to describe their teacher styles through a lesson they have completed in their classroom. To gauge how the professors respond to students not understanding a concept, I asked the professors to give me an example of a lesson that did not work well and asked them to explain why they think it did not work well. The next three questions I asked allowed me to gain an understanding of how the professors determine when students are struggling in the class and what the professors do to help these students. The professors were also asked to describe a specific scenario when a student was struggling in the classroom and what they did to help. I then asked professors to give me examples of how they assess students' learning. My last question to the professors was what advice they would give a new teacher to be a successful instructor in the classroom. The script and questions I used in the interview can be found in Appendix 3.

To analyze the data collected in the interviews, active learning codes were created to discern the patterns between all five professors and their use of active learning in their classrooms. To create these codes I carefully read through each professor's answer and then created a code that best fits the answer. After creating the codes, I look back through them and decided if codes could be combined and settled with 20 active learning codes. The active learning codes that professors use in the planning and executing of lessons are: (1) *considering students' prior knowledge*, (2) *imagining and revising instructional sequence*, (3) *providing resources used in class*, (4) *considering students' educational backgrounds*, (5) *providing*

practice material in class, (6) *implementing group activities*, (7) *scaffolding learnin*g, (8) *having technology issues*, (9) *gauging student reactions through their questions and responses,* (10) *testing students' knowledge*, (11) *continuing to learn and grow*, and (12) *connecting with your students*. It was also found that professors revise their lesson plans for specific reasons: (A) *students are not getting it, reteaching it in a new way*, (B) *revising lessons because I am not happy with it*, (C) *not having enough time to cover materials*, (D) *discovering errors in teaching, correcting it for next year*, and (E) *changing lessons based on students in class*. Three types of teaching styles was coded based on professors answers and these were (L) *lecture*, (P) *providing practice problems*, and (T) *technology enhanced learning*. After analyzing all of the answers and when I began writing this paper, the professors transitioned from participant numbers into pseudonyms. The pseudonyms are generic last names that do not correlate to any professor at the private university. Participant 1 was given the pseudonym Professor Jones. Participant 2 was given the pseudonym Professor Hunter. Participant 3 was given the pseudonym Professor Warner. Participant 4 was given the pseudonym Professor McKenzie. Participant 5 was given the pseudonym Professor Cole.

When Professor Warner was asked to share a lesson to describe their teaching methods, they described using everyday examples to help set the groundwork depending on the concept the students were learning. This is an answer that was coded as (1) *considering students' prior knowledge* because it is an example of how a professor reviews lesson objectives to determine where students' misconceptions will be throughout the lesson and use students' prior knowledge to help understand the concepts. For the active learning code (2) *imagining and revising instructional sequence* I used Professor Jones' method of constantly looking at plans and improving them based on past lessons to help me define the code. This code can be described as

professors paying attention to the instructional sequence they created in their lesson plans and professors may change this instructional sequence during the semester based on how their students are interacting with the concepts. Professor Hunter described to me that they keep a running email of topics they want to add to lessons and new materials or resources they find they want to bring to class. This is an example of professors bringing different resources to their classrooms to enhance their lessons which correlates to active learning code (3) *providing resources used in class.* Similar to considering a students' prior knowledge, professors can (4) *considering students' educational backgrounds* when they look over the lesson objectives and connect real-world examples to the objectives. An example of a professor using this code in their classroom is Professor Jones. When asked how they plan their lesson, they described how they look at the objectives for the course and relate to the student population in their class for the semester.

The fifth active learning code, *providing practice material in class*, was one of the easiest to distinguish in the interview answers. This code can be described as professors creating or finding practice material for students to complete in class to help them review the concepts. Professor McKenzie mentioned that they provide practice material in class to perceive their students' learning barriers and help students articulate their questions. An important model of implementing active learning in the classroom is group activities and this is active learning code (6). Professors implement group activities to help students engage with the material as well as collaborate with their peers. Professor Cole also used group activities in their classroom to identify group leaders and the students who do not put the effort into the activity. Some of the answers to the interview questions did not match any of the active learning codes and therefore codes were created based on specific professor answers. Active learning code (7) *scaffolding*

learning is when professors consciously break down larger concepts into lesson units to help students grasp them. Professor Warner described that when their students are struggling with concepts in the class, they bring back concepts from earlier on to help the students grasp the current topics. When I asked Professor Cole to describe a lesson that did not go as planned they went on to tell me about an exploration lesson they tried on Zoom and unfortunately. it did not work out because students were struggling to collaborate with each other over Zoom. This answer determined active learning code (8) *having technology issues* which describe the technology barriers professor can encounter during remote learning.

When I created the question how do you assess students' learning, I anticipated hearing generic responses such as exams and quizzes but Professor Hunter said their method of assessing students' learning every day in class is by having regular conversations with the students through questions and their responses. This is an example of active learning code (9) *gauging student reactions through their questions and their responses.* The next active learning code (10) *testing students' knowledge* is the other code that came out of the answers to the question of how the professor assesses their students' learning. This code encompasses the low-stake and high-stake assignments professors use in class to assess student learning. Professor McKenzie marks up the in-class activities given to their students and allows the students to rework the problems they got wrong which not only allows the professor to assess the students learning but also allows the students to assess their own learning. The last question I asked the professors was what advice they would give new teachers to be successful in the classroom and two active learning codes were created from the answers. The first code was (11) *continuing to learn and improve* as a professor. This code describes how professors should continue to research new resources to add to their classrooms and seek professional development workshops to learn updated teaching

strategies. When asked this question, Professor Mckenzie told me that professors need to keep an open mind, keep learning new strategies for teaching, and take advantage of the resources out there. An important aspect of active learning is code (12) *connecting with your students.* Professor Warner told me that teachers must put in the effort to get to know their students 1-on-1 and build a meaningful relationship with them. This active learning code allows professors to adapt their lessons and classrooms to benefit their students.

A follow-up question I asked the professors after hearing how they plan their lessons was why would they change a lesson plan. The answers to these questions did not fit into the original 12 codes that were created and each of the professors gave different answers, so I created specific codes for each professor. Professor Hunter recounted times in their classroom when they needed to explain concepts in a different way. They would summarize the content for the students and try to figure out where the students become confused and then try a new approach to reteach the content. This story is an example of the active learning code (A) *students are not getting it, reteaching it in a new way*, where professors observe their students and identify when they need to reteach the material. When professors revise a lesson plan after teaching it because they were unhappy with how it turned out, it is considered active learning code (B) *revising lessons because I am not happy with it.* Professor Hunter expressed this was the most common reason they revise their lesson plans, for both lecture and lab classes. Another active learning code for revising a lesson plan is (C) *not having enough time to cover materials.* Professor Warner discussed changing the pace of their lessons throughout the semester because of running out of time. Many professors reflect on their teaching of lessons and can discover an error that occurred, which is the next active learning code for revising a lesson (D) *discovering errors in teaching, correcting it for next year*. Professor McKenzie described a time when this occurred

for them and they were able to fix the error in their lesson plan for next year. The last active learning code for revising a lesson plan is (E) *changing lessons based on student in class.* This code involves professors changing the activities in a lesson plan at the beginning of the semester because of their student population. Professor Cole told me that if the students in their class are a majority one major, they find specific examples and problems for them to complete that are related to their major to introduce them to why they need to know the concepts and how they can apply their skills in the future.

The last type of active learning code created from the professors' answers came from the interview question, can you share one or two lessons that describe your teaching methods? From the five professor answers three codes were found (L) *lecture,* (P) *providing practice problems,* and (T) *technology enhanced learning.* The lecture code describes a style of teaching that involves the professor explicitly explaining the concepts to the students with questions sprinkled throughout. Professor Jones stated that they have the same approach in all of their classes which looks like 15-20 minutes of lecturing and then some type of activity or review for the students to complete. Practice problems as a style of teaching can take many different forms in the classroom but have the same intent of students practicing the concept and gauging their understanding of the material. Professor Hunter uses case studies in their classroom to add a clinical aspect that prepares students for future careers. The last style of learning is technology enhanced which involves professors using software to build technology activities into their lesson to help students discover and engages with the concepts. Professor Cole takes this approach in all of the classrooms. They use a website for all of their lessons that allow students to follow along and answer questions throughout to test their knowledge as well as inspire curiosity in the material.

After all of the codes were created, the codes were separated into two categories: teacher-centered and student-centered. To be sorted into either of these categories, I considered if the codes allowed the students or professors to be the "main character" while completing or revising a lesson plan. The codes separated into the teacher-centered category will not be considered active learning components but are still essential for professors to implement for a successful classroom. As the interview answers were labeled for active learning components, themes were beginning to emerge. Themes were identified after I noticed patterns in the answers to the interviews and what active learning codes were being used most frequently. The exact descriptions of the active learning codes and more examples can be found in Table 2: Description and Examples of Active Learning Codes. These descriptions encompass the meaning of the codes and explain the examples of the codes that can be found in the research findings section of this paper.

Table 2: Descriptions and Examples of Active Learning Codes

Active Learning Codes	**Category**	**Descriptions**	**Examples**
(1) *Considering students' prior knowledge*	Student-Centered	Professors review the lesson objectives to identify students' misconceptions throughout the lesson. The professor writes their lesson plans with these misconceptions and their students' experiences in mind.	Professor Jones: Look at the material, what do students need to learn Professor Warner: Use everyday examples to help set the groundwork depending on the concept
(2) *Imagining and revising instructional sequence*	Student-Centered	While writing lesson plans and reviewing them throughout the semester, professors pay attention to their instructional sequence. When writing lesson plans for the first time, this looks like paying attention to the flow of concepts. Professors may revise the instructional sequence during the semester because of how the students are interacting with the concepts.	Professor McKenzie: Pay attention to the sequence of topics Professor Jones: When first time teaching constantly looking at plans and improving them based on past lessons
(3) *Providing resources used in*	Student-	Professors bring different resources to their classrooms to enhance their lessons.	Professor Hunter: I keep a running email with topics I want to add to lessons and new

class	Centered	Resources can range from the PowerPoints they use in class, problem sets they create or find, articles they bring in, and exploration technology. Professors are consistently adding new resources to their lessons throughout the semester as new information is released.	material or resources I find I want to bring to class Professor Jones: try to think of resources and styles of teaching to help different levels of learners
(4) *Considering students' educational backgrounds*	Student-Centered	Professors review course objectives and connect them with their students' educational backgrounds. The professors think about the classes their students may have previously taken as well as the reason they would be taking the course.	Professor Hunter: Look at the objectives for the course and relate to the student population Professor Jones: Reorganize lesson over a specific principle or to change the perspective for the students
(5) *Providing practice material in class*	Student-Centered	To help students review the concepts, professors create and find practice material students can complete in class. Depending on the type of course, these practice materials can look like problem sets, case studies, multiple-choice questions, or questions embedded within a PowerPoint. Professors also use the in-class practice material as a low-stakes way to gauge students' understanding of the concepts.	Professor Hunter: Incorporated weekly quizzes to help students stay on top of studying, leave time before exams for in-class reviews Professor McKenzie: Completing activities in class allows me to perceive students' learning barriers. Ask students different questions to get them thinking differently
(6) *Implementing group activities*	Student-Centered	Professors can implement group activities in their classrooms, to help students engage with the material and their peers. Group activities can also be used to gauge students' skills in working in groups.	Professor McKenzie: Implement POGILS, structured group activities that allow students to discover concepts as they complete problems Professor Cole: Ask students to work in groups, identify the group leaders and the students who do not put in any effort, can reshuffle groups to allow collaboration
(7) *Scaffolding learning*	Student-Centered	Professors consciously break down larger concepts into lesson units to help students grasp them. As the class moves on the professor provides less help and allows students to be in control of their own learning.	Professor Warner: add concepts from earlier on if students are struggling to grasp the current concepts
(8) *Having technology issues*	Teacher-Centered	Professors planned activities to be completed by students during remote learning, but students struggled to engage with each other because of technology barriers.	Professor Cole: Tried an exploration lesson on zoom, zoom made it hard for students to collaborate
(9) *Gauging student reactions through their questions and their responses*	Student-Centered	Professors use student questions, responses, and facial expressions to gauge their understanding of the material. This tactic allows professors to decide if the material needs to be retaught or if they may move forward.	Professor Hunter: Talk to students, regular conversations in class, ask questions to determine student understanding

(10) *Testing students' knowledge*	Teacher-Centered	Professors use in-class activities and practice problems to assess students' knowledge of the material. These assignments can be known as low-stakes to help students gauge where there are at in the material or higher stakes, such as exams.	Professor Warner: Stop and assess if everyone is ready to move on after completing a practice problem Professor McKenzie: classroom activities/in-class problems - mark up and allow students to amend
(11) *Continuing to learn and improve*	Teacher-Centered	There are so many resources out there that are being published daily. Professors should continue to add new resources to their lesson plans. They should also seek professional development workshops to continue to grow as a professor and learn new teaching strategies to apply to their classroom.	Professor McKenzie: Keep an open mind, keep learning new strategies for teaching and take advantage of the resources out there
(12) *Connecting with your students*	Teacher-Centered	An important part of being a professor is learning who your students are and connecting with them. This allows professors to adapt their lessons and classrooms to benefit their students and help them learn the material in a meaningful way.	Professor Warner: try to get to know students 1-on-1
(A) *Students are not getting it, reteaching it in a new way*	Teacher-Centered	Professors observe that their students are not understanding the material and decide in the moment to reteach the material. Professors can also decide to reteach material after grading or commenting on completed assignments from students.	Professor Jones: if students are not getting it, reteach lessons Professor Hunter: Ask students if I can explain in a different way, summarize content for the students and try to figure out where the confusion happens, try a new approach to explaining
(B) *Revising lessons because I am not happy with it*	Teacher-Centered	Professors can decide to revise a lesson plan after they have taught the lesson because they were not happy with how it turned out. This revision would be notated and fixed for the next time the lesson is taught.	Professor Hunter:Ask myself what am I not happy with and what can be improved
(C) *Not having enough time to cover materials*	Teacher-Centered	Professors can change the pace of the lesson throughout the week when they have not covered the concepts they wanted in a class period. This can affect the rest of the unit materials and can make the professors revise their plans for a chapter.	Professor Warner: Change the pace of the lesson
(D) *Discovering errors in teaching, correcting it for next year*	Teacher-Centered	After a professor has completed a lesson, they can reflect on their teaching strategy and discover an error. This discovery can allow the professor to fix the error the next time the lesson is taught.	Professor McKenzie: Discover errors in teaching, correct it for next year
(E) *Changing lessons based on*	Student-Centered	Professors will change the activities they give in class based on their student	Professor Cole: Students in my class are majority one major, find examples and

students in class		population. If the majority of students are in one major, the professor will find resources and activities that relate to their major.	problems for them to complete that are related to their major
(L) *Lecture*	Teacher-Centered	A style of teaching that involves the professor explaining the concepts to the students with questions sprinkled throughout. It is a teaching style that lacks student engagement.	Professor Jones: Same approach in all classes, 15-20 minutes of lecturing Professor Cole: Transfer from explorative lessons to lecturing
(P) *Providing practice problems*	Student-Centered	Professors create or find problems to help students practice the content. These practice problems can help the students and the professor gauges the students' understanding of the material.	Professor Hunter: Use case studies to add clinical aspects to prepare students for future careers
(T) *Technology Enhanced Learning*	Student-Centered	Professors discover software and build technology activities into their lessons to help students discover and engage with the concepts. A technology-enhanced lesson can look like guided notes on a website that the students can revisit at their leisure or a specific activity the students need to complete in computer software.	Professor Cole: All of my lessons are on a website and students follow along on the website

3.6 Trustworthiness: Validity and Reliability

The validity of the study was established through the use of the “researcher’s lens” and “reviewer’s lens” (Creswell and Poth, 2018). A “researcher’s lens” refers to how the researcher makes use of different strategies to check for validity in their study (Bazeley, 2013). A “reviewer's lens” refers to the researcher allowing people outside of the study to contribute to the validation strategies used in the study (Merriam and Tisdell, 2015). The strategies of the “researcher’s lens” used in this study include triangulation of multiple sources and reporting data that does not coincide with the patterns established (Yin, 2014). The data instruments were also validated. The questions created for the biographical and interview portion of the data were reviewed by my mentor as well as the Institutional Review Board. Each professor was given

carbon copies of the approved questions. The results of the case study were saved in a folder in a password-protected Google Drive. The last strategy used to validate this study was from a "reviewer's lens" and involved having reviewers not connected to the study examine if the findings concluded were supported by the data as well as having a peer reviewer that was debriefed during various stages of the study (Miles and Huberman, 1994; Creswell and Miller, 2000).

4.0 Research Findings

Findings 1: Multiple codes within one question

When the professors were asked if they were familiar with active learning strategies, all responded that they have heard about them but were not familiar with what they looked like in a classroom and were not sure how to implement them in their classroom. The 10 questions asked during the interview were designed to describe how professors were using active learning in the classroom without directly asking them for the teaching strategies they used in the classroom. The active learning codes that were created from the answers to the professor interviews showcase that the professors are using active learning concepts within their lesson planning and execution of lessons in the classroom. A complete table with all of the interview questions and the active learning codes that were found in the answers can be found in Appendix 4: Complete Breakdown of Interview Questions and Active Learning Codes Associated with the Questions. Of the 20 codes established in the study, each professor can be found multiple times throughout the codes which highlights that each professor uses multiple active learning concepts during the planning and execution of their lessons.

It was also found that there was not only one active learning code that was highlighted in the answers for each question. When the professors were asked the question "Can you please

share one or two lessons that you think describe your teaching methods?", I was able to group code the answers into seven active learning codes. The codes were (1) *considering students' prior knowledge,* (3) *providing resources used in class,* (5) *providing practice material in class,* (6) *implementing group activities,* (L) *lecture,* (P) *providing practice problems,* and (T) *technology enhanced learning.* Many of the codes for this question were also found in multiple professor answers, such as (5) *providing practice material in class.* This code was found in all five professors' answers to this question. Professor Jones stated that in many of their lessons, they provide practice material in class for students to receive feedback on which also allows them to know if the students are understanding the material. Professor Hunter described implementing clinical studies in their classroom as a form of practice material to allow the students to apply their knowledge in a setting similar to future professions in their majors. Professor Warner shared practice problems they hand out to students at the end of every chapter to allow students to practice the material and reflect on what they need to review before an exam. Professor McKenzie and Cole had similar approaches to practice material provided in class. The students are given guided notes to follow along with and practice problems are embedded within the notes for students to complete after learning specific concepts. This allows students to automatically practice and reflect on the material they learned and the professors can note their students' understanding before moving on to their concepts.

Findings 2: Teacher vs Student-Centered Teaching Pedagogies

Following the grouping of professor answers into each of their codes, the codes were categorized into teacher-centered or student-centered. It was found that 60% of the active learning codes created were sorted into the student-centered category and the other 40% of the codes were considered teacher-centered. The codes that were found to be student-centered were

(1) *considering students' prior knowledge,* (2) *imagining and revising instructional sequence,* (3) *providing resources used in class,* (4) *considering students' educational background,* (5) *providing practice material in class,* (6) *implementing group activities,* (7) *scaffolding learning,* (9) *gauging student reactions through their questions and their response,* (12) *connecting with your students,* (E) *changing lessons based on students in class,* (P) *providing practice problems,* and (T) *technology enhanced learning.* I categorized these codes as student-centered because the professors focused on the students' needs in the classroom to better help them.

I considered active learning code (1) as student-centered because Professor Jones told me that they reorganize lessons over a specific principle to help change the perspective of the students. Professor McKenzie pays attention to the sequence of topics in class and asks questions to determine the students' understanding of the material. This was an example of how Professor McKenzie focused on their student responses in relation to active learning code (2) *imagining and revising instructional sequence.* When I asked Professor Jones how they help students that are struggling, they talked about thinking of resources they could bring to their class to help students at different levels of learning. While reading over this answer and deciding what to code to give it, my mind immediately went with (3) *providing resources used in class,* because this answer showcases how professors find resources specifically for their students to help them understand the material. The next active learning code, which was categorized as student-centered was (4) *considering students' educational background.* Similar to active learning code (1), the professor focuses on a student's background to help find resources to help them understand the new material, which is what Professor Warner told me they do when they notice that students are struggling with certain concepts. Active learning code (5) *providing practice material in class,* which is one of the most common active learning models. Professor

McKenzie uses the practice problems they give their students to perceive the students' learning barriers as well as give the students an understanding of their learning. When asked the question, how do you assess students' learning in the classroom, Professor Cole detailed how they use group activities to identify the students who become leaders because they understand the material and the students who do not put in any effort. I chose this specific example to showcase why I chose active learning code (6) *implementing group activities,* was student-centered because I think it was a unique way to use group activities. Students are not only given the opportunity to collaborate with the peers, but the professor uses it to gauge which students may need more support with the material. Active learning code (7) *scaffolding learning* was categorized as student-centered because Professor Warner told me they bring back earlier concepts to help students understand the present complex material. This showcased how a professor thinks about how much help students may need with certain concepts and how the professor implements the help into their lesson. Professor Hunter depicted how they have regular conversations with their students to gauge their understanding of the material. This example correlates to active learning code (9) *gauging student reactions through the questions and their responses,* and this is why it was categorized as student-centered. The most common answer given when I asked the professor what advice they would give a new teacher, was active learning code (12) *connecting with your students*. Professor Warner told me that getting to know your students not only allows them to tailor their lessons to their students while also creating a welcoming classroom. Of the codes created for the answers to the question why professors change their lessons, active learning code (E) *changing lessons based on students in class,* was the only one categorized as student-centered. An example of this code is how Professor Cole changes the practice material they give students based on the students' majors and what would

be relevant to the students. Similar to active learning code (5), code (P) *providing practice problems* is considered student-centered because it allows students to review the material and take command of their learning. Practice can also introduce students to how they can apply the knowledge they are learning in class to what they might do in future careers. This is how Professor Hunter uses practice problems in their classroom. They bring in case studies for their students to review and work through to apply their knowledge. The last active learning code that was categorized as student-centered was (T) *technology enhanced learning,* because Professor Cole writes all of the lessons as an interactive website the students can follow along with. Within the website students are asked questions to test their knowledge.

The other category of active learning codes is teacher-centered. This means the aspect of planning or executing a lesson focuses on the teacher as the "main character" rather than the student. The active learning codes that were teacher-centered were (8) *having technology issues,* (10) *testing students' knowledge,* (11) *continuing to learn and improve,* (A) *students are not getting, reteaching it in a new way,* (B) *revising lessons because I am not happy with it,* (C) *not enough time to cover materials,* (D) *discovering errors in teaching, correcting it for next year,* and (L) *lecture.* Active learning code (8) *having technology issues,* was created because Professor Cole recounted the story of their having to switch up their lesson plan because of a lack of student engagement during remote learning. When professors give exams and assignments, which is one of the ways Professor Jones assesses their students, it was coded as (10) *testing students' knowledge* and considered teacher-centered because this type of testing does not implement active learning. Although the professor may choose to seek professional development to improve for their students, the act of learning new teaching strategies is considered teacher-centered and that is why (11) *continuing to learn and improve* is in this

category. When the professors were asked the question why would you change your lesson plans, four of the five professors' answers were coded and categorized as teacher-centered. The codes were taken word-for-word from the professors' answers. Professor Jones's answer was coded for (A) *students are not getting it, reteaching it in a new way,* Professor Hunter's answer was coded for (B) *revising lessons because I am not happy with it,* Professor Warner's answer was coded for (C) *not enough time to cover materials,* and Professor McKenzie's answer was coded for (D) *discovering errors in teachings, correcting it for next year.* The last active learning code that was categorized as teacher-centered was (L) *lecture.* Professor Jones lectures for about 15-20 minutes in all of their classes and lectures are not considered a student-centered active learning concept. The codes that were sorted into each category and examples highlighting why it was sorted into the category can be found in Table 3. Even though codes were sorted into the teacher-centered category, they are still considered important in the process of planning and executing a lesson in the classroom.

Table 3: Active Learning Codes Categorized and Example Showcasing Why

Category	**Codes**	**Examples from Interviews**
Student-Centered	(1) *Considering students' prior knowledge*	Professor Jones: Reorganize lesson over a specific principle or to change the perspective for the students
	(2) *Imagining and revising instructional sequence*	Professor McKenzie: Pay attention to the sequence of topics in class, ask questions to determine student understanding
	(3) *Providing resources used in class*	Professor Jones: try to think of resources and styles of teaching to help different levels of learners
	(4) *Considering students' educational background*	Professor Warner: Use everyday examples to help set the groundwork depending on the concept
	(5) *Providing practice material in class*	Professor McKenzie: Completing activities in class allows me to perceive students' learning barriers. Ask students different questions to get them thinking differently
	(6) *Implementing group activities*	Professor Cole: Ask students to work in groups, identify the group leaders and the students who do not put in any effort,

		can reshuffle groups to allow collaboration
	(7) *Scaffolding learning*	Professor Warner: add concepts from earlier on if students are struggling to grasp the current concepts
	(9) *Gauging student reactions through their questions and their responses*	Professor Hunter: Talk to students, regular conversations in class, ask questions to determine student understanding
	(12) *Connecting with your students*	Professor Warner: try to get to know students 1-on-1
	(E) *Changing lessons based on students in class*	Professor Cole: Students in my class are majority one major, find examples and problems for them to complete that are related to their major
	(P) *providing practice Problems*	Professor Hunter: Use case studies to add clinical aspects to prepare students for future careers
	(T) *Technology Enhanced Learning*	Professor Cole: All of my lessons are on a website and students follow along on the website
Teacher-Centered	(8) *Having technology Issues*	Professor Cole: Tried an exploration lesson on zoom, zoom made it hard for students to collaborate
	(10) *Testing students' knowledge*	Professor Jones: Exams, lab grade, and assignments
	(11) *Continuing to learn and improve*	Professor McKenzie: Keep an open mind, keep learning new strategies for teaching and take advantage of the resources out there
	(A) *Students are not getting it, reteaching it in a new way*	Professor Jones: reteach lesson as an immediate correction during lesson reveiw
	(B) *Revising lessons because I am not happy with it*	Professor Hunter:Ask myself what am I not happy with and what can be improved
	(C) *Not having enough time to cover materials*	Professor Warner: Change the pace of the lesson
	(D) *Discovering errors in teaching, correcting it for next year*	Professor McKenzie: Discover errors in teaching, correct it for next year
	(L) *Lecture*	Professor Jones: Same approach in all classes, 15-20 minutes of lecturing

Findings 3: Themes

The themes that were established during the analysis of the data collected were (a) *considering students' prior knowledge,* (b) *scaffolding students' learning experiences,* (c)

imagining and revising instructional sequenceto guide students' learning, and (d) *supporting students' learning with various resources.* These themes were discovered while examining the codes found in the answers for each question. These themes were the most frequent and allowed me to group together codes under one specific concept of active learning. Theme (a) encompasses the active learning codes, (1) *considering students' prior knowledge* and (4) *considering students' educational background.* These two active learning codes were grouped under the *prior knowledge* theme because, for active learning code (4), Professor Jones described to me how they take into account the different levels of students' backgrounds when they are overviewing the lesson objectives. Professor Warner likes to use everyday examples in their classroom to help students set the groundwork for complex concepts which is an example of active learning code (1) and puts this code under the theme (a) *considering students' prior knowledge.*

The *scaffolding students' learning experiences* theme highlights the active learning codes, (7) *scaffolding learning, and* (10) *testing students' knowledge.* (5) *providing practice material in class,* and (6) *implementing group activities.* An example of code (7) *scaffolding learning,* is when Professor Warner reintroduces concepts from earlier on to help students apply their knowledge to more complex concepts. Providing support for students to understand the new material is an essential part of scaffolding and why this code was grouped under this theme. When professors used problems during their lectures to test students' knowledge it is a part of *scaffolding* because they are giving students the ability to apply their new knowledge that is low stakes. Professor Warner implements problems within their lecture PowerPoint which demonstrates why code (10) *testing students' knowledge* was grouped under *scaffolding.* Active learning codes (5) *providing practice material in class* and (6)*implementing group activities,*

which have similar reasons for being grouped under *scaffolding.* Professor Hunter and McKenzie use weekly quizzes and POGIL activities, respectfully to gauge if students are able to apply their new knowledge to practice material.

The next theme that was discovered was (c) *imagining and revising instructional sequences to guide student learning,* which showcases when and how professors decided to use active learning concepts in their lessons. The active learning codes that are associated with this theme include (2) *imagining and revising instructional sequence,* (T) *technology enhanced learning,* (5) *providing practice material in class,* and (6) *implementing group activities.* I considered code (2) *imagining and revising instructional sequence* as a part of this theme because Professor Jones told me that they are constantly looking over the lesson objectives and improving their lesson plans based on them. The changing of their lesson plans is an example of them choosing how and when to implement active learning in their classroom. Active learning code (T) *technology enhanced learning* is a type of active learning model and Professor Cole makes a conscious decision to write all of his lessons online to allow students constant access to what they are doing in class and extra practice problems they can complete on their own. Similar to the previous code, codes (5) *providing practice material in class* and (6) *implementing group activities* is a type of active learning model that the professors consciously add to their classrooms to help the students review the material as well as collaborate with their peers.

The last theme that was established was (d) *supporting students' learning through various resources* which demonstrates that the most frequent active learning concepts implemented in the professors' execution of their lessons were (3) *providing resources used in class* and (5) *providing practice material in class.* Providing resources and practice material for students are two active learning models that professors have been implementing for decades.

Professor McKenzie told me that they are always finding new resources to bring to the classroom to align with new learning objectives that are being established. These resources may take many forms from published papers on the concepts to news articles that relate the material to real-world examples. The practice problems that professors bring to class can be planned worksheets they compiled beforehand or problems they create during class time to help students review a specific concept. Professor Warner depicted a scenario to me when they came up with a problem for students to complete which helped them assess if they were ready to move on or if they had to work through more problems. The themes, the active learning codes associated with the theme, and more examples of the codes from the interviews can be found in Table 4.

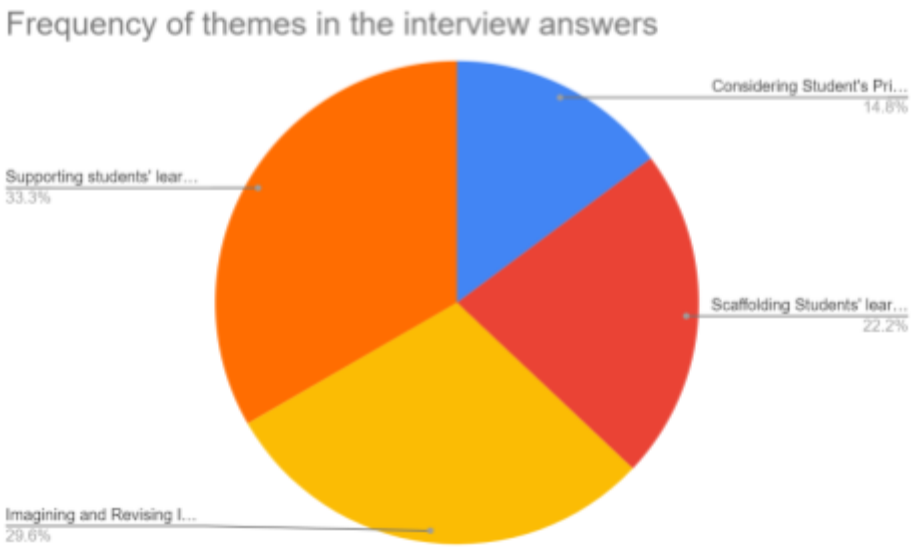
Table 4: Identified Themes and Their Examples from Interviews

Themes	Active learning Codes	Examples from Interviews
Considering Students' Prior knowledge	(1) *Considering students' prior knowledge* (4) *Considering students' educational background*	Professor Warner: Use everyday examples to help set the gound work depending on the concept Professor Jones: When it is students first time taking college courses, there are different levels of student backgrounds Professor Jones: Reorganize lesson over a specific principle or needs to change the perspective for the students
Scaffolding Students' Learning Experiences	(7) *Scaffolding Learning* (10) *Testing students' knowledge* (5) *Providing practice material in class* (6) *Implementing group activities*	Professor Warner: Add concepts from earlier on if students did not grasp the concepts Professor Warner: inserts practice problems within the powerpoint to test student's knowledge Professor Hunter: incorporate weekly quizzes to help students stay on top of studying, leave time before exams for in-class review Professor McKenzie: POGIL: structured group activities that allow students to discover concepts as they complete problems
Imagining and Revising Instructional Sequence to Guide Student Learning	(2) *Imagining and revising instructional sequence* (T) *Technology Enhanced Learning* (5) *providing practice material in class* (6) *Implementing group activities*	Professor Cole: All of my lessons are on a website and students follow along on the website Professor Jones: When first time teaching constantly looking at plans and improving them based on past lessons Professor Hunter: incorporate weekly quizzes to help students stay on top of studying, leave time before exams for in-class review Professor Cole: Ask students to work in groups, identify the group leaders and the students who do not put in any effort, can reshuffle groups to allow for collaboration

Supporting Students' Learning through Various Resources	(3) *Providing resources used in class* (5) *Providing practice material in class*	Professor McKenzie: find new resources to provide students because new learning objectives have been established for the students Professor Warner: ask students if they understand the material and then give them a practice problem to complete to assess if it time to move on

After grouping together the active learning codes into the themes, I went back and found the frequency of the themes in the interview answers. To count the question for the theme, one of the active learning codes that make up a theme had to have been coded for the professor's answers. The codes that make up the theme *prior knowledge* were most frequent in the professor's lesson planning and were found in answers to questions 1, 2, 4, and 5. The theme *scaffolding* and its active learning codes were found in the answers to questions 4, 5, 6, 7, 8, and 9. They are most common in applying active learning concepts in the classroom. The next theme, *purpose of lecture*'s active learning codes were found in the answers to questions 1, 2, 3, 4, 6, 7, 8, and 9. The last theme was *practice material and resources* and the active learning codes that contribute to this theme were found in the answers to nine of the ten questions. The only question it was not an answer to was the last question which asks the professor for advice to new teachers. This demonstrates that finding and bringing practice material and resources to class is essential in the planning and execution of a lesson. The percentages of the themes found in the answers to the interview questions can be found in Figure 1. This figure does not establish the significance of the themes or active learning codes that make up the themes but showcases how often the theme was found in the data collected.

Figure 1: Themes in the Interview Answers



5.0 Discussion, Implications of Study

The research completed in this study was guided by the research question: To what extent, if any, do STEM professors use active learning during the planning and teaching of their courses? Findings suggest that STEM professors use active learning concepts and frameworks during the planning and implementation of their lessons. This was indicated by the themes that were found in the last stage of the analysis of the data collected.

Considering Students' Prior Knowledge

Based on the codes I created from my data the professors are using active learning in their classrooms. The active learning the professors are implementing in their classrooms allows their students to take ownership of their learning and engage with the material. The first active learning component the professors are using is prior knowledge. Prior knowledge is an essential part of active learning because it has been found that "all learning involves transfer from previous experiences" (National Academy of Sciences, 2000). At the beginning of a lesson,

professors can ask specific questions that allow students to recall information they have already learned to transition into the new material they are going to learn. When students are able to establish links between their prior knowledge and new experiences within multiple STEM disciplines, students can understand the relationships between the different disciplines (Sen et al., 2018). These relationships allow students to interconnect the STEM discipline rather than think they are disjointed concepts. Merrill (2002) stated that new knowledge and skills can only be established after prior knowledge has been activated in students. To activate prior knowledge, professors can use metaphors or general review strategies. Metaphors allow professors to relate complex concepts to similar concepts previously learned (Smith and Ragan, 2005). This connects to findings 2, the active learning codes that were categorized for this theme are student-centered. Multiple professors bring in everyday examples to their classrooms to help connect the material in the classroom to experiences the students understand. When professors can allow learners to explicitly retrieve prior information or experiences this can foster a higher learner performance (Morrison and Anglin, 2005). Activating prior knowledge can also allow professors to incorporate new knowledge into existing schemata (Glisczinski, 2011).

Scaffolding Students' Learning Experiences

When active learning is implemented in the classroom, it allows students to take control of their learning, but this control does not mean they do not need guidance and support from the professor to apply their knowledge (Koc and Demirbilek, 2018). When discussing students' ability to apply knowledge in the classroom, there are two types of transfer: near transfer and far transfer (Martinez, 2010). Near transfer refers to students' ability to apply their knowledge from one concept to a similar one, and far transfer allows students to apply their knowledge to a completely different concept (Smith and Ragan, 2005). Professors must make the decision of the type of transfer they want the students to complete when they are bringing activities to the

classroom. Students should practice applying new concepts or skills in a timely manner, as well as in a way that the knowledge can be applied beyond the classroom (Merrill 2002). Providing practice at a time when students can reflect and receive feedback from the professor is important in fostering long-term learning (Stetson-Tiligadas, 2018). Different scaffolding techniques that can be implemented in the classroom include providing templates and worked examples. These are most beneficial to novice learners that need to apply their knowledge in an immediate application (Sweller, 1994; Kirschner et al., 2006). An important factor when applying scaffolding is its gradual removal to allow students to take control of their learning (Merrill 2002).

Imagining and Revising Instructional Sequence to Guide Student Learning

An important factor when deciding to implement active learning in a classroom is how and when it will be done. If professors give the students an overload of information at one time, it can place a heavy burden on the student's cognitive load and will be ineffective (van Merrienboer and Ayres, 2005). When professors are handing out problems to students, they must decide when to increase the difficulty of the problems. If the difficulty of the problems increases too rapidly, it will hinder the student's ability to solve the problems and the student's output will decrease (Kuruganti et al., 2012). Many different sequences can be used to introduce practice problems to students, such as general-to-specific, specific-to-general, and simple-to-complex (Kuruganti et al., 2012; Kalyuga et al., 2010). There is not one correct way to implement practice problems; it depends on the content and the learner's level. It is part of a professor's responsibility to decide what process they want to use based on their students (Stetson-Tiligadas, 2018). Another responsibility of a professor when they implement active learning in their classroom is to incorporate multiple representations of the concepts (Stetson-Tiligadas, 2018).

The multiple representations allow students to develop cognitive flexibility as well as problem-solving skills.

Supporting Students' Learning through Various Resources

The importance of providing practice material in the classroom is it allows students to apply their new knowledge (Merrill, 2002). Stetson-Tiligadas (2018) stated that the practice material given to students is one of the most commonly applied strategies of active learning in the classroom. The practice material is well supported in the research literature as an effective instructional strategy to promote learning (Demetriou et al., 2011). The practice material provided by the professors in this case study falls under the category of problem-based learning or problem-centered learning (Stetson-Tiligadas, 2018). Problem-based learning focuses on the learner and the active role the learner plays in building knowledge (Savery, 2009). Students are given complete control of the learning process and must find resources to reach the solution to the problem (Barrows, 2002). This type of problem-based learning is ineffective if students are given minimal guidance or direction (Merrill and Gilbert, 2008). Problem-centered learning describes an environment where students can use their knowledge and skills to solve problems and are provided support and scaffolding when necessary (Stetson-Tiligadas, 2018). Problems can either be well-structured or ill-structured and choosing the appropriate problems to implement in the classroom is essential to using active learning in the classroom (Jonassen, 2011). With the information collected from the professors, there is not enough to distinguish between the two types of problems given.

New resources, such as papers, simulation software, and laboratory procedures, about STEM disciplines are published daily. Professors have to take the time to research these new resources to bring to the classroom and help students discover complex solutions to STEM problems (Ah-Namand and Osman, 2018). The new knowledge students must learn needs to be

demonstrated to them rather than told to them (Stetson-Tiligadas, 2018). When students are provided with resources that they can relate to their own experiences, it can increase their motivation as well as their long-term learning (Merrill, 2002). These resources are essential to demonstrating various approaches to solving a problem and will strengthen the students' thinking skills. (Stetson-Tiligadas, 2018).

6.0 Conclusion and Limitations of Study

Findings from my analysis created four themes within the active learning codes: (a) *considering students' prior knowledge,* (b) *scaffolding students' learning experiences,* (c) *imagining and revising instructional sequence to guide students' learning, and* (d) *supporting students' learning with various resources.* These are the active learning strategies that were the most commonly found in the answers to the interview questions. These findings suggest that STEM professors are implementing active learning strategies in their classrooms. After analysis of the data collected from the biographical questions, it has been found that none of the professors in this study has completed any formal training in active learning frameworks. This data showcases that STEM professors may be applying active learning in their classrooms because of their experience as teachers in the classroom rather than a formal adoption of active learning. All of the professors who participated in this study have over 10 years of experience in the classroom, and that experience has led them to implement active learning in their classrooms even though they do not have formal training in it. The implementation of active learning in their classrooms tells us that more research is needed to discover how and when professors, who have no formal training in active learning, begin to implement it in their classrooms. Active learning is becoming more common in early and secondary education classrooms, and more frameworks need to be developed to help STEM professors implement it in their classrooms.

There are limitations to this study. We were limited to the knowledge of the professors' classrooms that were discussed during the interviews and therefore direct conclusions about how the active learning strategies were implemented in the classroom cannot be made. Classroom observations were not conducted as a part of this study and should be considered as further research to gain more insight into the active learning environment of STEM professors' classrooms.

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8.0 Appendices

Appendix 1: Recruitment Email for Professors

Dear (professor),

My name is Iliana Correa, a senior Chemistry major at Arcadia. I am currently completing my senior thesis which involves collecting information with regards to your teaching practice in **(mention name of course)** at Arcadia. Specifically, my research question is, To what extent, if any, do STEM professors use active learning pedagogies during planning and teaching their course?

I am sending an email to ask for your participation in my study. There are three parts to this study. The first part will happen over email, the second and third part will happen on campus.

In Part 1, I will send you biographical questions through an email for you to answer which should take between 15 and 20 minutes to answer. These questions will help to establish your background as a STEM professor. These questions will be sent a week before our sit-down interview and must be completed a day before the interview.

For Part 2, you will be invited for a 1 hour sit down interview with me. In this audio recorded interview we will discuss a lesson you have prepared for the interview and your teaching practices.

For Part 3, I will ask for you to give me a lesson plan, activity, or assignment you have prepared for a class at the end of the interview. I will analyze what is given to me for areas of active learning.

From start to finish your participation in the study can take up to a week or longer depending on how our schedule aligns to sit down for an interview. All parts of the study will be completed in the fall 2022 semester.

You do not have to participate in the study, but if you do, a consent form with your signature will be required before any parts of the study are started. You can withdraw from the study at any point before the interview takes place by emailing myself. Once the interview takes place you will be given a randomized number that you will be referred to in my study.

If you would like to be a participant in my study, please respond before **(date 2 weeks after I send out this email).** I look forward to hearing from you soon about your

participation. If you have any questions about the study or what would be going on before you consent do not hesitate to respond to this email.

Thank you in advance,

Iliana Correa

Appendix 2: Biographical Questions for Email

1. Can you please describe your general subject expertise?
2. Can you tell me about your teaching experiences? How many years have you been teaching?
3. Have you taken any methods of teaching courses while in school?
    a. Have you taken any workshops to help you teach?

Appendix 3: Interview Questions

Script before interview

Hi, I want to thank you again for participating in my study. I am interviewing you and other professors in the STEM department at Arcadia to collect information with regards to your teaching practices in undergraduate **<mention name of course>** course . As indicated on the consent form, I will be collecting audio-recording during this interview so I can go back and listen to it as well as take field notes while we are talking. Do you have any questions before we start?

1. How do you plan your lessons?
    a. How often do you plan your lessons?
    b. Do you change your lessons? Why?
2. Can you please share one or two lessons that you think describe your teaching methods?

3. Can you give an example of a lesson that did not work well? Why do you think it did not work well?
4. How do you determine if and how your students are struggling in **(mention a course)**?
5. What do you do to help your students learn (mention from their example)?
6. Can you please provide a specific scenario when students or a student had difficulty on a concept during instruction? What did you do?
7. Can you give examples of how you assess students' learning?
8. What advice would you give a new teacher like me to be a successful instructor in the classroom?

Appendix 4: Complete breakdown of Interview Questions and Active Learning Codes Associated with the Questions

Interview Questions	Codes	Examples from Interviews
How do you plan your lessons?	1. Considering Prior knowledge	Professor Jones: Look at material, what do students need to learn
	2. Imagining and revising instructional sequence	Professor McKenzie: Pay attention to the sequence of topics
	3. Providing resources used in class	Professor Cole: I have lessons already written, I go over the plans to add new resources or examples
	4. Considering students' educational background	Professor Hunter: Look at objectives for course and relate to student population
How often do you plan your lessons?	2. Imagining and revising instructional sequence	Professor Jones: When first time teaching constantly looking at plans and improving them based on past lessons
	4. Considering students' educational background	Professor Jones: Reorganize lesson over a specific principle or needs to change the perspective for the students

	3. Providing resources used in class	Professor Hunter: I keep a running email with topics I want to add to lessons and new material or resources I find I want to bring to class
Do you change your lessons? Why?	2. Imagining and revising instructional sequence	Professor Hunter: Change plans all the time based on what happens in class
	A. Students are not getting it, reteaching in a new way	Professor Jones: if students are not getting it, reteach lessons
	3. Providing resources used in class	Professor Warner: add more examples to help students
	B. Revising lesson because I am not happy with it	Professor Hunter: Ask myself what am I not happy with and what can be improved
	C. Not having enought time to cover materials	Professor Warner: Change the pace of the lesson
	D. Discovering errors in teaching, correcting it for next year	Professor McKenzie
	E. Changing lessons based on students in class	Professor Cole: Students in my class are majority one major, find examples and problems for them to complete that are related to their major
Can you please share one or two lessons that you think describe your teaching methods?	5. Providing practice material in class	Professor Jones: Complete review questions and exercises in class to get feedback from students
	3. Providing resources used in class	Professor Cole: Students use an exploration software to help understand a concept
	1. Considering students' prior knowledge	Professor Warner: Use everyday examples to help set the gound work depending on the concept
	6. Implementing group activities	Professor McKenzie: POGIL: structured group activities that allow students to discover concepts as they complete problems
	L. Lecture	Professor Jones: Same approach in all classes, 15-20 minutes of lecturing
	P. Providing practice Problems	Professor Hunter: Use case studies to add clinical aspects to prepare students for future careers

	T. Technology Enhanced Learning	Professor Cole: All of my lessons are on a website and students follow along on the website
Can you give an example of a lesson that did not work well? Why do you think it did not work well?	1. Considering students' prior knowledge	Professor McKenzie: Tried to use POGILS in an introductory course but students did not understand how to complete the problems and felt exposed for not knowing
	4. Considering students' educational background	Professor Jones: When it is students first time taking college courses, there are different levels of student backgrounds
	3. Providing resources used in class	Professor Jones: Try to think of resources and styles of teaching to help different levels of learners
	D. Discovering errors in teaching, correcting it for next year	Professor Hunter: tried a new experiment and I did not provide enough background foundation and students did not understand why they were performing the experiment or how to analyze the data
	7. Scaffolding Learning	Professor Warner: Add concepts from earlier on if students did not grasp the concepts
	8. Having technology issues	Professor Cole: Tried an exploration lesson on zoom, zoom made it hard for students to collaborate
How do you determine if and how your students are struggling in your classes	5. Providing practice material in class	Professor Jones: Review activities throughout the lesson in class and student responses from practice quizzes
	9. Gauging student reactions through their questions and their response	Professor Hunter: Talk to students, regular conversations in class, ask questions to determine students understanding
What do you do to help your students learn difficult content?	A. Students are not getting it, reteaching in a new way	Professor Jones
	5. Providing practice material in class	Professor Hunter: incorporate weekly quizzes to help students stay on top of studying, leave time before exams for in-class review
	3. Providing resources used in class	Professor Warner: use online materials, and find demos that are short and to the point

	L. Lecture	Professor Cole: Transfer from explorative lessons to lecturing
Can you please provide a specific scenario when students or a student had difficulty on a concept during instruction? What did you do?	5. Providing practice material in class	Professor McKenzie: Completing activities in class allows me to perceive students' learning barriers. Ask students different questions to get them thinking differently
	A. Students are not getting it, reteaching it in a new way	Professor Hunter: Ask students if I can explain in a different way. summarize content for the students and try to figure out where the confusion happens, try a new approach to explaining
	10. Testing students' knowledge	Professor Warner: Stop and assess if everyone is ready to move on after completing a practice problem
Can you give examples of how you assess students' learning?	5. Providing practice material in class	Professor Jones: not for credit activities, weekly quizzes that are low impact
	6. Implementing group activities	Professor Cole: Ask students to work in groups, identify the group leaders and the students who do not put in any effort, can reshuffle groups to allow for collaboration
	10. Testing students' knowledge	Professor McKenzie: classroom activities/in class problems - mark up and allow students to amend
What advice would you give a new teacher like me to be a successful instructor in the classroom?	11. Continuing to learning and improving	Professor McKenzie: Keep an open mind, keep learning new strategies for teaching and take advantage of the resources out there
	12. Connecting with your students	Professor Warner: try to get to know students 1-on-1