THE EXAMINATION OF FEMALE STUDENTS' EXPERIENCES IN SOCIOSCIENTIFIC ISSUE-BASED SCIENCE CLASSROOMS

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ABSTRACT

Most educational studies highlight the gender gap in Science, Technology, Engineering, and Mathematics (STEM). Female students' interest and success in STEM are behind their male peers, especially in chemistry and physics classes. Females are less likely to pursue a STEM field in college. In addition, few women want to be scientists and engineers. The gender gap in STEM may be a result of traditional science teaching methods. Female students' expectations are not met, and as a result, their science interest decreases in these classrooms, as well as not pursuing STEM careers in specific chemistry, engineering, and physics.

There is an increase in research and curriculum reform movements containing socioscientific issues (SSI) extending worldwide. SSI provides an opportunity to engage students in critical thinking. SSI-based science classrooms are based on real-world problems like climate change, genetic modification, and vaccination. Integrating SSI into science classrooms as a revolutionary method might renew the practices of our traditional science classrooms. However, few SSI-based educational research studies have focused on the gender gap issue.

This dissertation investigated 216 middle and high school students' experiences in SSI-based classrooms with a mixed-methods approach. I investigated Model-Evidence Link diagram's effectiveness on the shiftiest in students' plausibility toward scientific model and scientific knowledge gaining in the quantitative part. I examined their experiences in SSI-based classrooms with the open-ended question survey in the qualitative part. SSI-based science activities provided gender equity conditions in science classrooms. Both genders evaluated the scientific model as more plausible by eliminating

the alternative model as less plausible, and they gained scientific knowledge about Climate Change and Wetlands. The MEL diagram seemed more effective for the students' positive plausibility shifts toward the scientifically accepted model.
Also, both genders had positive experiences in SSI-based classrooms in general. However, female students did not want to continue a STEM career except biomedical sciences. MEL design can be renewed by adding some initial and interval short activities and using some SSI topic-related posters and objects to prepare students for critical thinking and keep them more engaged during the activities. Also, adding student interviews and live recording the student discussions might give an understanding of the collaboration and student experiences in the SSI-based classrooms.

DEDICATION

To my daughter and all girls…

I hope, one day, every child comes to the world with fairer economic and environmental conditions and a mom's unconditional love…

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CHAPTER 1

INTRODUCTION

Socioscientific issues (SSI) are complicated, open-ended, and controversial social problems, such as animal testing, climate change, genetic engineering, and nuclear power (Zeidler & Nichols, 2009). Many SSI generate an atmosphere of debate. Because of their characteristics, integrating SSI into science classrooms can engage students in critical discourse, which in turn potentially promotes deeper learning (Genel & Topcu, 2016). The students may reflect on their ideas and thoughts with SSI during their discussion. SSI-based classroom activities may also facilitate collaboration among students by allowing them to have active roles in discussions and resulting in more critical evaluations about scientific claims. This facilitation is particularly crucial to learning.

SSI into science classrooms as a revolutionary method might refresh the implementations of our traditional science classrooms. Most students are interested in global and personally relevant topics in science classrooms instead of complex scientific issues and laws, such as thermodynamics (Zeidler & Nichols, 2009). Individual learning differences and speeds are not taken into account in these classrooms. Also, traditional science classrooms are based mainly on teachers having an active role. The students try to learn while listening to their teachers, and they focus on memorization without an effort to understand the topic’s meaning (Prince & Felder, 2006). Therefore, they encounter some trouble creating new ideas and connections between science lessons and their daily lives. These traditional approaches might decrease students’ engagement and achievement in science education, especially female students' engagement, and achievement.

The Research Problem

Less engaging instructional methods might not properly motivate students who tend to show a lower level of interest and academic achievement in STEM, especially female students. As a result, traditional teaching approach might not create the gender equity in science classrooms. The gender gap is a critical issue in science education (Barmby et al., 2008; Khishfe et al., 2017; Wu & Tsai, 2007). Male students are outperforming female students in primary and secondary science classrooms concerning interest in the subject as well as academic performance and standardized exams in mathematics and science (Archer et al., 2013; UNESCO, 2019). With the potential of engaging students in scientific discourses, SSI-based science instruction may increase female students' learning who traditionally underperform relative to male students in primary and secondary science classrooms (Halpern et al., 2007).

Purpose

Understanding learners' experiences in science classroom settings is essential because their experiences can form their motivation to decide on science careers, participate in science learning, and maintain their interest and curiosity in science (Bonnette et al., 2019). I aim to explore female students' experiences in SSI-based science classrooms. Also, I propose to examine the effectiveness of Model-Evidence Link (MEL) diagrams in facilitating students' scientific discourse in SSI-based science classrooms (Lombardi et al., 2013). More specifically, I explore whether or not there is any gender difference regarding scientific knowledge and plausibility in SSI-based instructions.

Research Questions

In this dissertation, I investigated four research questions:

1. How does Model Evidence Link (MEL) diagram affect students' plausibility of scientific and alternative models about socioscientific topics? Are there any gender gaps?
2. How does Model Evidence Link (MEL) diagram affect students' scientific knowledge of socioscientific topics? Are there any gender gaps?
3. What are the female students' experiences in SSI-based instructional activity compared to male students?
4. What is the effect of SSI-based science instruction on female students' experiences for pursuing science related career plans compared to male students?

Significance of the Study

This study is essential to understand females' perspectives and thoughts about science education. For this reason, very little qualitative research investigated the educational experiences of female s. Also, a few studies about SSI-based science learning analyzed their research results by gender. However, they do not investigate gender differences as the primary research aim. This mixed-methods design will focus on whether students gain scientific knowledge and improve their critical thinking skills. The students can reflect on their inner voice and experiences from their sides, and these reflections will enrich the study's results. We can redesign more efficient SSI-based science teaching instructions for considering female and male students' experiences.

Thus, this study is significant to use SSI-based learning not only to gain scientific knowledge with a critical lens but also to create gender equity in science classrooms.

Definition of Terms

I list below key terms and their definitions used throughout the dissertation:

- *Model Evidence Link (MEL) diagram*-as an instructional scaffold to help the students understanding of the connections between models and lines of evidence (Chinn & Buckland, 2012)

- *Plausibility*- as a tentative judgment on the potential truthfulness of a scientific explanation or model (Lombardi et al., 2016).

- *Socioscientific Issues*- controversial real-world problems with conceptual and procedural connections to science (Sadler, 2009).

Organization of Dissertation

This chapter submits an overview of the research problem, aim and significance of the research, research questions, and definitions of key terms used throughout the dissertation.

In Chapter 2, I will review the literature regarding traditional science teaching, socioscientific issues, student discourse, student engagement, the role of teachers in SSI-based classrooms, gender gap in science education. The theoretical framework will consist of scientific literacy, social development theory, and expectancy-value theory. I will discuss the effectiveness of SSI--based science instructions for the gender gap issue. Finally, I identify the research questions and develop hypotheses regarding these questions.

In Chapter 3, I will describe the research sample, research context, data collection procedures, research instruments to investigate research questions.

In Chapter 4, I will analyze each research question. I will employ statistical analyzes using SPSS version 27 to investigate research questions 1 and 2. I will conduct the practices in repeated measures to understand time change and univariate analyses to understand the gender gap and the effectiveness of the MEL diagram. Next, I will analyze the students' open-ended survey answers to explore research questions 3 and 4. Finally, I will present a summary of the major results.

In Chapter 5, I review and discuss the findings for each research question. I then discuss the research limitations, and I will conclude the dissertation with future implications for research and teaching.

CHAPTER 2

LITERATURE REVIEW

Science Teaching Methods

Traditional science teaching practices focus on scientific facts, vocabulary, definitions, algorithms, and necessary skills (Prince & Felder, 2006). Traditionally, students learn science deductively. Teachers present a scientific subject and demonstrate this subject's similar derivations. The learners follow a firm procedure throughout science learning process without any discussion (Prince & Felder, 2006). Besides, they focus on correct answers, creating an asymmetrical conversation with the teacher at the center (Heaysman & Tubin, 2018). The students practice these presentations for their assignments. Finally, the teachers evaluate their skills when expecting to do almost the same kinds of exam questions.

Traditional science teaching methods involve activities that are less student-centered. In these classrooms, learners are there to receive knowledge, whereas the teacher is the experience provider. Learners do not investigate the scientific phenomena by asking questions such as why and how. However, science's development process includes justifying and discovering knowledge. Justifying knowledge refers to "what people know," while discovering knowledge focuses on "how people know" (Yang, 2004). Traditional classrooms are mainly based on what people know. In other words, scientific knowledge is more important than the discovery process of scientific knowledge. The students in the receiver role do not use their cognitive skills. They do not test the knowledge's correctness nor try to find other possibilities toward this solid knowledge. They might accept the knowledge directly without testing, but this knowledge might be incorrect. This statement may create some significant consequences for the future of science and society.

Also, traditional classrooms do not provide enough opportunities for students to make connections with the real world. Many science teachers tend to explain scientific knowledge, especially physics and chemistry teachers (Lee & Yang, 2017). However, science teaching should include personal and societal issues that are relevant to students to motivate and engage them in learning science and apply their understanding to their personal and social lives (National Research Council, 2012).. Due to the lack of realizing the relatedness of science with daily life, traditional science learning might be accepted as unrelated to their everyday life by some students. They, particularly female students, assume that science is hard and irrelevant for them (Archer et al., 2013). Wu and Tsai (2007) found that the students did not have sufficient skills to connect what they had learned in a science classroom and what they faced in the real world. Teaching science with possible real-life context examples is more useful for the students as they make the connections between global issues and themselves (Wu & Tsai, 2007).

Another issue is that there is little peer collaboration in traditional science teaching (Darling-Hammond et al., 2019). However, collaborative learning provides several science learning opportunities, such as developing critical thinking skills, creating an effective learning environment, and generating unique ideas (Gilley & Clarkston, 2014). Every different perspective can offer unique ideas for the knowledge construction process. Furthermore, the participants might cooperatively engage their peers in the science learning process. Thus, collaboration should take place in our science classroom.

Aspects of traditional teaching methods, such as only passively taking in knowledge and not making real-world connections and having less collaboration in science learning, create some learning challenges, less science interest, and the gender gap. Learners criticize regular science teaching content and methods (Archer et al., 2013). Even though the traditional classrooms focus on "what we know," we need "how we know" and "how we construct new knowledge" in our age. Thus, we should design our science classroom settings considering learners' active participation and real-life context relatedness (Lombardi et al., 2021).

Constructivism as a philosophy focuses on this dynamic and social process in learning. Learners construct new ideas and concepts based on their past and current social environment experiences (Bruner, 1990). Constructivist teaching approaches encourage students to actively construct on prior knowledge (Cakir, 2008). Thus, constructivist classrooms are based on group discussions, explorations, explanations, trying out solutions for open-ended problems, and using different kinds of lesson materials (Cakir, 2008). These diverse teaching methods are helpful for the students' learning process. For several reasons, the students might learn differently. One teaching technique, such as discussion, might be more efficient for one student, whereas another student prefers online learning (Zeidler et al., 2019). Several studies show that constructive learning approaches help the students create a more engaging and enjoyable classroom environment (Day & Bryce, 2013). For example, Day and Bryce (2013) explored that the students expressed their engagement positively with climate change and global warming. The teacher encourages the students' active participation, supports knowledge construction, and tries to increase their motivation in science classrooms. As a consequence, constructivist science instructions provide several opportunities for learners to construct new unique concepts.

Student Discourse in Science Classrooms

Discourse is a process between a group's participants and aims to enable students to talk to each other in science classes (Marton et al., 2004). It is more than classroom conversation because it reflects students' inner voices. Most researchers conceptualize that discourse practices are based on the teacher and the student centered within the dialogue (Rees & Roth, 2019). Researchers have highlighted the importance of student discourse in science education because several classroom-based studies show improvements in conceptual learning when engaging in argumentation (Osborne, 2010). Chin and Osboner (2010) found that encouraging students to ask questions within discussion can extend students' arguments because they make argumentative actions such as challenges, refutations, justifications, and concessions. Also, they can collaboratively construct new meanings. However, students often encounter challenges constructing arguments for their own questions (Bravo-Torija & Jiménez-Aleixandre, 2011; Chin & Osborne, 2010). Thus, researchers agree that clear instructions should be submitted to the students to lower the learning barrier.

Educational researchers have generally investigated student discourse regarding how the students justify and present their pieces of evidence (Bravo-Torija & Jiménez-Aleixandre, 2011; Erduran et al., 2004; Wu & Tsai, 2007). However, student discourse has methodological challenges in determining what influences learning progression and how the students generate knowledge and claims. One of the trends in determining the learners' argumentative process has been using pre- and post-tests with teaching practice based on socioscientific issues (SSI) (Lieshout & Dawson, 2016). Other methods for obtaining data are individual interviews and small group studies (Sadler et al., 2004). An open-ended questionnaire for collecting individuals' arguments is another method (Wu & Tsai, 2007). Some researchers analyze students' written texts to understand their statements. Schools may not have similar argumentation processes or practices. However, the research patterns help raise significant issues connected with argumentation in schools (Arvola & Lundegård, 2011). Therefore, each study provides a good understanding of students' argumentation skills.

Developing argumentation involves a complicated process. Students mostly have weak arguments in science education (Sadler, 2004). Thus, they fail to advance their argumentation abilities. This skill's development is a problematic educational aim. In this arduous process, more practice and more time are necessary. Some studies show that students' argumentation skills develop due to both the teachers and students gaining experiences. Ottander and Ekborg (2012) found that nearly all students declared that they learned how to argue and analyze information during the SSI-based classroom activity. Lieshout and Dawson (2016) examined male high school students' argumentation skills using records on students' biotechnological applications. They found that the majority of students had a reasonable understanding of biotechnology.

Discourse is vital for SSI-based science learning activities because it allows the learners to think about authentic problems (Zeidler et al., 2019). Discourse in the learning environment triggers the conceptualization of the students' scientific claims instead of them just having short answers. During learning activities, they think, evaluate, and debate their scientific claims critically. Peer-to-peer interactions support and expand small and large group discussions. These interactions might generate very creative arguments. The discourse practices in SSI-based classrooms contribute to the improvement of learners' critical thinking abilities because learners have an active role and peer support.

Student Engagement

There is little agreement about the definition, effectiveness, and successful measurement of student engagement (Sinatra et al., 2015). Educational researchers have used engagement to explore several educational phenomena, such as learning context design; student academic performance and success; students' self-perception; students' enactment of cognitive, motivational, affective, metacognitive, and social processes; their interaction with materials, peers, and teachers; and teachers' activities (Azevedo, 2015). Due to the widespread use of this term, student engagement seems more a metaphor for quality learning and teaching because it is accepted as the combination of attempts, involvement, concentration, action initiation, power, persistence, enjoyment, interest, and satisfaction in the social and physical ambiances (Skinner et al., 2008; Zepke, 2017). These characteristics are central to the understanding and development of students' learning (Ryu & Lombardi, 2015). Moreover, engagement predicts students' education success, grades, test scores, and learning in the short run, as well as their education progression, retention, graduation levels and achievements, and academic careers in the long term (Skinner et al., 2008).

Fredricks et al. (2004) suggest that engagement consists of three forms: behavioral, emotional, and cognitive engagement. Behavioral engagement refers to students actively taking part in learning practices; emotional engagement refers to learners having positive senses, attitudes, interest, and values about learning practices; and cognitive engagement refers to students having the willingness to spend the effort necessary to understand complex thoughts and complicated skills and so comprises motivational goals and self-regulated learning.

Several studies show that engagement is related to positive learning results (Fredricks et al., 2004). Sinatra et al. (2015) state several benefits, such as increased motivation, learning, and class participation, when learners are engaged. Interestingly, most educational research studies found a decrease in students' active engagement in science learning, interest, motivation, eagerness, and future science career choices from kindergarten to high school (Osborne & Dillon, 2008). Unfortunately, there is a specific decline in student engagement between middle school and high school in science classrooms. This engagement decline can be seen as more explicit for female students, racial minorities, and groups with a low socioeconomic status.

Socioscientific Issues

Socioscientific issues (SSI) are controversial real-world problems, such as animal testing, climate change, freshwater resources, genetic engineering, and vaccination (Grace & Ratcliffe, 2002; Sadler, 2004). People encounter SSI in their daily lives. In recent years, the internet and social media have made available an unprecedented amount of information about SSI that affects people personally or globally. The huge information drive brings advantages but also some challenges affecting the world. For example, some claims on the internet about COVID-19 that are not based on scientific evidence have influenced people's decisions about getting vaccinated. SSI has taken place in our lives, but the necessity of critical thinking skills is increasing daily.

Critical thinking plays a crucial key in scientific knowledge construction, but this construction, which is a complex process (Muis et al., 2021). Traditional science teaching methods cause some issues in facilitating students' critical thinking skills during this complex process. SSI describes social dilemmas containing political, ethical, moral, and scientific factors within a scientific context (Ratcliffe & Grace, 2003; Sadler, 2004). These factors may be challenging to dissociate due to the link between science and its social consequences. However, SSI with these factors' debatable natures engages students in dialogue and discussion in the classrooms (Sadler, 2004; Sadler & Donnelly, 2006). Using SSI in science teaching promotes cognitive skills using student-driven discussions (Uitto et al., 2011). Also, these activities improve scientific content knowledge and scientific literacy (Sadler, 2010; Sadler & Zeidler, 2009), increase the level of understanding of scientific content (Klosterman & Sadler, 2010), and encourage students to have a positive attitude toward science (Sadler, 2009).

There has been an increasing trend in educational research on using SSI for science teaching over the last two decades (Zeidler et al., 2019). SSI-based activities may facilitate collaboration between group participants, with students assuming active roles in science classrooms, which results in more critical evaluations about scientific claims instead of giving only short answers. Therefore, SSI might improve students' active discussion practices and skills, helping them realize evidence and data's truthfulness. SSI offers learners the chance to inspect issues from multiple perspectives and exhibit doubt toward information (Zeidler & Kahn, 2014). Also, Ke et al. (2020) explored that students had positive attitudes and experiences toward SSI-based learning. They describe SSI as relevant, interesting, and useful in science learning. In this context, using SSI in science classrooms is significant in science education (Sadler & Dawson, 2012).

The Role of the Teacher in SSI-Based Science Classrooms

Teachers try to create positive learning environments, but they might face some challenges during teaching practices. Several studies highlight that science teachers' SSI teaching in science classrooms seems troublesome and complicated due to a new teaching approach and the lack of SSI-based teaching experiences (Dawson & Carson, 2017; Genel & Topçu, 2016; Sadler, 2009). In particular, they face challenges in evaluating and managing their students' performance, teaching time, and lack of pedagogical and content knowledge (Arvola & Lundegård, 2011; Christenson & Chang Rundgren, 2015; Dawson & Carson, 2017; Genel & Topcu, 2016; Saunders & Rennie, 2011; Tidemand & Nielsen, 2017).

To reduce the complexity of grading SSI argumentation, researchers may develop a new framework. For instance, Christenson and Chang Rundgren (2015) created a framework to evaluate the SSI argumentation of secondary-school-level students. This framework helps the teachers by supplying a foundational grading tool serving each teaching context. It is feasible for teachers to use while assessing student SSI argumentation because of a low degree of complexity and high school practice adaptability. Gustafsson and Öhman (2013) designed a tool as a facilitator to improve group members' understanding. The researcher believed that this tool helps both educational researchers and teachers understand how students communicate and what they select to emphasize in their debate. For a reason, it serves as a thinking tool, supporting useful knowledge when evaluating, implementing, improving, and planning SSI-based discussions.

One of the critical issues is that teachers might choose to reduce their active roles in these classrooms without influencing their students' decisions about SSI. Foong and Daniel (2013) found that the teacher neither promoted nor refuted genetically modified foods. Many students gave logical reasons when facing different SSIs, yet few students constructed a refutation in their arguments. However, the teacher's active role is crucial to SSI-based learning. The students create good discussions with the teacher's engagement and support.

Another challenge is that standardized tests might affect the teachers' performance and thoughts because of the state and national standards. They might face some issues while planning their lessons for SSI-based learning activities. To reduce this pressure, educational policymakers should provide excellent opportunities for using SSI-based teaching in science classrooms. Although they realize the importance of these learning activities, this realization may not be reflected in the curriculum. Thus, the curriculum makers should support teachers in real-time, not just express the importance of these learning activities.

Also, teachers' comprehensive knowledge and skills are necessary for SSI-based learning assessment (Tideman & Nielsen, 2017). Genel and Topcu (2016) examined the SSI-based teaching practices of pre-service science teachers (PSTs) in science classrooms. Unfortunately, their arguments are generally maintained at the basic level. A more interdisciplinary, well-designed cooperation between language teachers and science teachers, and even social science teachers, would help understand and evaluate student argumentation skills within the SSI context. Language teachers have more experience working on creating high-quality argumentation, and they have a long history of teaching and assessing argumentation (Christenson et al., 2017). Also, Christenson et al. (2017) found that the language teachers' assessment correlated more with previous research about the quality of socioscientific argumentation. Hence, cooperation between language and science teachers would help enhance the quality of the evaluation.

Several SSI-based teaching techniques can be seen in the literature, including simulations, group studies, whole-class discussions, visual documents, data, and pieces of evidence (Sadler, 2004). Settelmaier (2003) used a dilemma technique to address SSI, whereas some researchers preferred theory and evidence in evaluating SSI (Yang, 2004; Lombardi & Sinatra, 2012). These papers show that there is no single way to teach SSI. This broad scope gives the teachers some alternatives to arrange their teaching strategies based on their students' SSI (Sadler, 2004). Hence, both pre-service and in-service teacher education programs should be modified to assist teachers in integrating SSI into their course content, supporting them regarding scientific plausibility, and evaluating student arguments (Christenson et al., 2017; Sadler, 2004).

Gender Gap in Science Education

Today, the gender gap is one of the crucial issues in science education, particularly in the physical sciences and engineering (Archer et al., 2013; Wu & Tsai, 2007). Although science and technology-related jobs have become more prevalent in the twenty-first century, few female students pursue science-related careers or are interested in science. Men are disproportionately represented in science, engineering, and technology (Khishfe & Boujaoude, 2014). They outperform female students in primary and secondary science classrooms in terms of interest in the subject and academic performance and standardized exams in math and science (Halpern et al., 2007). Based on Weinburgh's (1995) meta-analysis, male students have a more positive attitude toward science than female students in all types of science. Men are also overrepresented in science-related jobs (National Science Board, 2015).

Some researchers found that female students express enjoyment of science in primary and secondary schools (Baker & Leary, 1995). However, they avoid pursuing science careers even if they have a potential capacity in their science classroom. Besides, science-related career options seem unattractive and undesirable goals. Another interesting finding is that some male students have negative views of women in science (Stake, 2006). Even children mostly associate science with men. These statements are not related to biological factors but are the result of social considerations (Archer et al., 2013).

Young children tend to start feeling driven in science, regardless of gender, ethnicity, or even educational achievement (Patrick et al., 2008). Many factors, such as negotiating biological transitions and relationships with their friends and parents, can shape their motivation in science practices (Bonette et al, 2019). Another potential issue is that parents support their sons more in science learning compared to their daughters. The parents' association of science with masculinity deters girls from the idea of succeeding in science lessons and science-related careers (Tenenbaum & Leaper, 2003). Parents' lower expectations for girls' achievement in science create a repetitive circle. Today's kids will be tomorrow's parents. Hence, we need to treat girls' expectations, values, and thoughts about science within their social environment.

At this point, education approaches have an influential role. The gender gap in science education might be due to traditional teaching approaches. Girls' expectations are unmet, and their interest in science decreases in these classrooms. Therefore, we should design our classrooms considering female students' perceptions and demands and provide a range of student-centered teaching activities. In this way, this gender gap in science education may close. We should design teaching environments involving gender equity in science classrooms.

Theoretical Framework

Scientific Literacy

Scientific literacy is the knowledge and understanding of science and scientific principles (Dani, 2009). It is concerned with the use of science in real-world situations. Scientific literacy encourages individuals to make their own decisions using scientific concepts and methods in debates about a scientific phenomenon. Scientific literacy is essential to understand and discuss scientific issues impacting society in this era. We should think and analyze like a scientist in our daily lives if we are to become responsible individuals. A person can access information through books, media, and the internet. However, one of the main issues is how to verify whether the information is accurate. At this point, deep thinking and meticulous evaluation become a critical mission for people today.

Contemporary reform in science education has highlighted learners' skills to make their decisions on SSI and prepared them to deal with these problems as an essential purpose of science learning (National Research Council, 2012). In light of this aim, SSI-based activities are significant for developing students' argumentation skills (Erduran et al., 2004; Sadler, 2004). The reason is that SSI creates excellent context and purpose for training in argumentation by engaging learners in an atmosphere of debate (Cavagnetto, 2010). Individuals encounter SSI in many places, such as news, the internet, or even group discussions in the media. People might have opposing ideas and opinions about a specific topic. These different ideas might provide a learning opportunity. SSI-based science teaching instruction uses this opportunity to decide, deal with problems and dilemmas, and understand and interpret the other side's opinions and claims.

Educational policymakers, researchers, and teachers try to advance students' critical thinking skills. Christenson Chang Rundgren (2015) point that SSI and discourse benefit students' argumentation skills because SSI provide an appropriate context within science education to actively argue about socially complex and controversial issues Erduran et al., 2004; Sadler, 2004). Students may not know how to become aware of data interpretation and its sources, factors, and evidence of knowledge. SSI-based learning highlights the evaluation process between pieces of evidence and scientific models (Bickel & Lombardi, 2016). Thanks to SSI-based activities, learners gain the ability to criticize, solve problems, and trust the information in their lives. By constructing and evaluating SSI arguments in science classrooms, students can practice their critical thinking skills and solve real-world issues that people have faced in daily life. SSI-based science teaching is important to promote students' scientific literacy development.

Social Development Theory

Vygotsky (1978) put forward a theory that learning occurs through social interactions when students study a task within their zone of proximal development (ZPD). ZPD is the distance between a student's ability "with the guidance of a more experienced person" and/or with peer collaboration and independently finding solutions. When a student takes information from a group, the student may develop their own argument. Additionally, the learners construct knowledge through interaction with others. Hence, a complicated form of experience may be converted into a less elaborate form via a group participant. In other words, a group member as a catalyst facilitates others' learning processes, so individuals understand a complicated idea more easily in a group discussion.

Many teenagers prefer spending time with their friends rather than listening to the teacher and working individually (Wang et al., 2008). I argue that when the close connections among youth increase during high school education, peer collaboration can be provided more efficiently. Although the communication between youth and parents might decrease, peer interaction increases. Also, some teenagers will join a group instead of being alone. Learning from peers gains importance, especially in their teenage years.

Interacting with more capable peers in the group can improve the progression of argumentation skills. Low-performing students particularly need support from their better-performing peers. Student discourse activities support each participant's active role during a classroom activity. Thus, low-performing students improve their analytical thinking skills throughout the process. ZPD facilitates students to perform beyond their current potential. In particular, critical thinking skill development is tough (Lombardi and Bailey et al., 2018; Willingham, 2008). The students encounter challenges during this development process. ZPD has the power to prevent the challenges in their developing critical thinking skills. SSI-based learning includes peer support studies (Presley et al., 2013). ZPD in SSI-based learning engages the students learning from their peers during the group discussion. Thus, ZPD plays a crucial role in the emergence of unique ideas and advancing learners' argumentation skills in science education.

Expectancy Value Theory

Motivation has been defined as a moving state to do something. It increases learners' performances and efforts in a learning activity and ensures this activity (Makar & Fielding-Wells, 2017). Motivation might be accepted as a prerequisite (Park, 2018). Therefore, it is an essential factor in learning environments. While a person who does not want to act and does not make an effort toward a behavior is deemed to lack motivation, a person who shows desire, interest, patience, and effort to move can be described as motivated (Ryan & Deci, 2000). Eccles et al. (1983) developed an expectancy-value model for individuals' performance and achievement choice. This theory explains individuals' motivation by associating them with individual expectations and values (Atkinson, 1964; Wigfield & Eccles, 2000). Based on this framework, students' expectancies and values predict their achievement performances, motivation, and academic choices (Wigfield et al., 2016).

Wigfield and Eccles (2000) define expectancies as students' beliefs about performing on a future activity or task. The main factor impacting expectancies for achievement is students' beliefs about their competencies. Beliefs about ability refer to students' interpretation of their competence in different subjects. Values influence students' choices because if the activity or task seems valuable to them and if they expect to perform well in it, they prefer to do it. Wigfield and Eccles (1992) defined task value's four components:

- Attainment value (i.e., the importance of doing well on the task to the student identity)
- Intrinsic value (i.e., the enjoyment of doing the task)
- Utility value (i.e., usefulness for completing the task for personal goals)
- Cost (i.e., negative consequences of engaging with a task) (Eccles et al., 1983)

Researchers have found that students' expectations and values in a specific subject or domain are critical predictors of their academic career decisions and educational outcomes in related fields from elementary school to college (Durik et al, 2006; Gaspard & Hulleman, 2019; Musu-Gillete et al., 2015). Gaspard and Hulleman (2019) found that students are more likely to pursue STEM careers if they have strong math and science expectancies and values. Durik et al. (2006) revealed that elementary school students' reports of intrinsic value for reading predicted how much leisure time they spent reading during high school and what courses they preferred to take. Besides, Musu-Gillete et al. (2015) demonstrated that high-school students' math expectations and utility value predicted their math-related academic career choices in college. The learners' expectancies are better predictors of their achievement, whereas their task values are more closely related to their academic preferences (Durik et al., 2006; Wigfield & Eccles, 2000). Also, their expectations are important in critical thinking (Muis et al., 2021).

There is a decrease in students' expectancies and values from elementary school to the end of high school (Vinni-Laakso et al., 2019). Similarly, a majority of studies found that students' interest and motivation in STEM decrease with school years. Barron and Hulleman (2015) highlighted that students might experience costs that negatively impact their motivation and interest. Interestingly, cost-related studies are at the bottom of the ranking among the four elements of value-associated studies. Vinni-Laakso et al. (2019) found different types of costs, such as the necessity to invest too much effort, emotional and psychological demands, and loss of other valuable opportunities. The researcher also highlighted that perceived cost might deter students from being interested and motivated. Therefore, new studies are essential for understanding students' perceived costs.

Another finding is that students' intrinsic value in science and math education predicts their STEM orientations. High science-related intrinsic value tends to be perceived as a low cost in science learning (Vinni-Laakso et al., 2019). Furthermore, according to Watt (2016), gender difference reflects students' cost experiences. This study shows that female students experienced psychological costs, whereas male students experienced mostly social costs. Hence, intrinsic value and cost may be crucial to reducing the gender gap in science education. If the students' understanding of cost changes, they might be more interested in science.

Using SSI-Based Instruction for Facilitating Female Students' Engagement

Several students are not interested in traditional classroom activities, especially female students (Roth & Lee, 2004). In particular, female students may encounter more challenges in remaining engaged or decreasing motivation in science. Female students might accept science as problematic compared to male students (Day & Bryce, 2013). Most gender-based studies demonstrated that male students tend to have higher ability expectancies and values in math, whereas female students tend to have higher expectancies and values in verbal domains (Gaspard & Hulleman, 2019). Traditional science teaching might be a reason for the gender gap in science education. We need to redesign our science teaching activities by engaging both genders in science.

SSI has a great potential to raise student interest and attitude toward science and to facilitate students' motivation in the science learning progress (Sadler, 2009; Sadler et al., 2016). Juuti et al. (2009) and Minner et al. (2010) found that students showed positive attitudes toward chemistry after an inquiry-based SSI learning experience. Uitto et al. (2011) reported that female and male students had an equal interest in environmental issues. Similarly, Ottander and Ekborg (2012) explored that the female and male students were similarly interested in most SSI topics. Khishfe Boujaoude (2014) pointed out that female students tend to study human and caring activities, whereas male students tend to choose science and technology-based activities. According to Herman (2015), female students are more concerned with global threats to the environment. Some studies investigated the differences between men and women in environmental concerns, and they found that females were notably more concerned about the environment than males (Juntunen & Aksela, 2013; Torkar, 2016; Uitto et al., 2011). SSI-based teaching involves diverse topics, which may help increase their interest and encourage active participation in science education.

SSI are debatable and controversial topics in the real world, and students can easily make the connection between their learning and their lives. SSI are real issues. It is highly possible that students encounter SSI in the media, hear about them from other people, or read an article about them. Realizing the relevance of science in the real world might reduce their bias and negative thoughts and shift their lack of interest positively. They might think that gaining knowledge from science lessons would not be useful in their daily lives. Ottander and Ekborg (2012) and Day and Bryce (2013) reported that most students realized the relevance of science to their lives after SSI-based discussion activities. These studies support that we can show this relevance to them by using SSI topics in science classrooms; as a result, both female and male students might realize that their science learning is useful in their daily lives.

SSI-based science instructions are generally based on peer collaboration and group discussion. Peer collaboration is significant in SSI-based activities because group studies provide educational opportunities, such as developing argumentation skills and generating unique ideas (Arvola & Lundegård, 2011). Foong and Daniel (2013) found that the interaction among group members facilitated the progression of argumentation abilities. They can generate unique ideas through group collaboration. Wu and Tsai (2007) discovered that students tend to process reasoning from multiple sides. Group members' different perspectives in the collaborative environment might increase their performance in science learning.

SSI-based teaching activities support open-ended discussions. Students contribute ideas about the topic from various perspectives. These activities are essential to developing argumentation skills. Teachers should moderate students' discussions very well. However, teachers should know what "argument," "evidence," and "justification" are and the importance of these terms (Bossér & Lindahl, 2019). In addition, they need some support developing their skills in managing student discussions. Another issue is that developing a great understanding of some complicated topics such as "global warming" and "genetically modified food" may be difficult. Hence, providing an efficient guideline for the SSI-based classroom activity might reduce both the foreseen and unforeseen challenges.

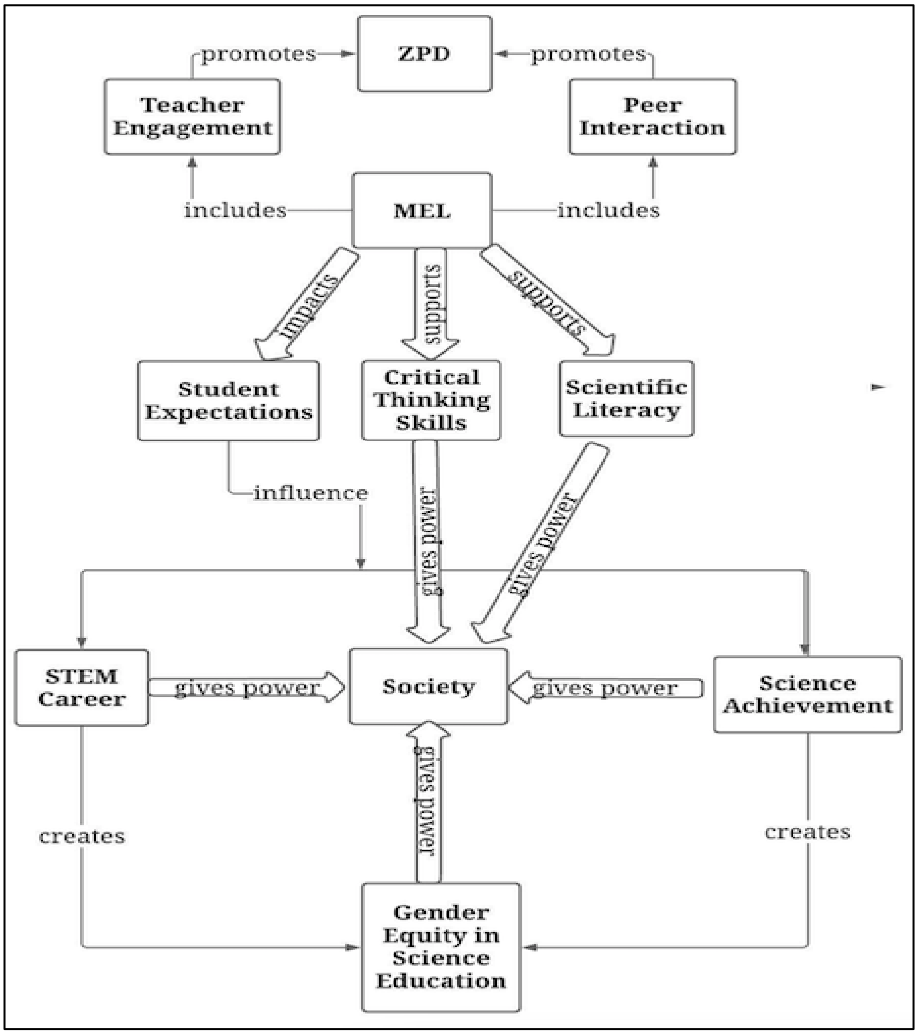
As a guiding tool to facilitate student discussion in science classrooms, Lombardi and Sinatra (2012) integrated the Model–Evidence link (MEL) diagram into climate change. The MEL diagram activities are instructional scaffolds that provide an excellent opportunity for students' conceptual change regarding SSI. Lombardi et al. (2013) explored the significant increase in knowledge about human-induced climate change. Developing great understanding of some complex topics such as global warming and genetically modified food may be difficult. Hence, teacher engagement plays a crucial role in making connections between evidence and explanations. This engagement promotes more critical scientific evaluations, shifts in plausibility judgments, and deeper science learning (Lombardi et al., 2013; Lombardi et al., 2015). The MEL diagram shows how students make connections between evidence and explanations about SSI (Lombardi et al., 2013). Students reflect their understanding and scientific reasoning about plausible alternative models with the explanation task after performing the MEL diagram activity. Thus, I have used the MEL activity in this research.

Current Study

Based on the theoretical framework discussed above, I developed a conceptual framework for promoting gender equity in SSI-based science classrooms (Figure 1). This diagram shows the effectiveness of the MEL activities for gender equity in the science classroom. The MEL activity in the SSI-based science classroom is based on the development of scientific literacy and critical thinking development teacher engagement and peer interaction.

Figure 1

Framework for the Gender Equity in SSI-Based Science Classroom



They can discuss their arguments when making connections between lines of evidence and models. The teacher engagement and peer interaction support the students to develop for socio-scientific reasoning with ZPD. They use student discourse during the activity. This stage is vital for generating unique and well-developed arguments and improving scientific literacy. Critical thinking skill and scientific literacy development, the increase in the number female students choosing a STEM career and their science achievement will give our society power. If the students are engaged very well in SSI-based science classrooms, their expectations and thoughts might change positively toward science and pursuing a STEM field career.

Research Questions and Hypotheses

SSI-based activities engage students in the debate. They can make a connection between knowledge and their life after the activity. Female students can generate good arguments during student discourse. However, we need more studies to obtain diverse knowledge and unique, useful ideas about students' experiences in SSI-based activities. The framework supports that the debatable topic issue-based instruction would lead to desired learning outcomes, such as changing students' expectations, increased engagement and science knowledge, promoting critical thinking skills, and positively pursuing STEM careers for both female and male students. Considering the literature review, I have identified four research question, which I list below with hypotheses.

> Research Question 1: *How does Model Evidence Link (MEL) diagram affect students' plausibility of scientific and alternative models about socioscientific topics? Are there any gender gaps?*

I hypothesize that MEL diagram activities would provide female students with an opportunity to engage in scientific discourse. In turn, it positively affects female students' scientific knowledge and evaluation. The MEL activity provides a useful organization due to submitting a diagram. The students can see the connections between models and lines of evidence. Also, realizing peer support might positively affect females to participate more actively. The participants increase scientific model (Model A) ratings but reduce their alternative model (Model B) ratings. The use of MEL diagram in the

SSI-based instruction enhances students' plausibility ratings. There is no a gender gap in the plausibility ratings of the scientific and alternative models.

Research Question 2: *How does Model Evidence Link (MEL) diagram affect students' scientific knowledge of socioscientific topics? Are there any gender gaps?*

Lombardi et al. (2013) explored that plausibility perceptions about human-induced climate change accounted for statistically significant increases in knowledge. This increase might be seen in the female students' scientific knowledge. This paper hypothesizes that female students are engaged more with the use of MEL diagram and increase their scientific knowledge and evaluation skills. The participants increase their scientific knowledge scores. The students who participated in MEL with arrows-based instruction have higher their scientific knowledge scores than those who do not use arrows in their scientific knowledge scores. I hypothesize that female and male students' post scientific knowledge scores are similar.

Research Question 3: *What are the female students' experiences in SSI-based instructional activity compared to male students?*

In this research question, I will apply a qualitative research approach to understand female students' experiences in SSI-based science classrooms. I expect that both female and male participants have positive experiences after SSI-based science instruction.

Research Question 4: *What is the effect of SSI-based science instruction on female students' experiences for pursuing science related career plans compared to male students?*

The participants might pursue a STEM career after their positive experiences. Also, their thoughts and recommendations ensure valuable contributions to improve SSI-based science learning.

CHAPTER 3

METHODOLOGY

This chapter described the study's participants, research design flow, data collection process, and the research instruments. I used a mixed-methods research approach that integrates qualitative and quantitative research methods to analyze my research questions. Previous studies used a mixed-methods approach for discovering gender in the context of SSI-based. Both Khishfe et al. (2017) and Wu and Tsai (2007) employed quantitative and qualitative measures to analyze their research questions. Wu and Tsai (2007) conducted a mixed-methods approach to gain deeper insights into students' reasoning skills on SSI. They developed an open-ended questionnaire to collect research about students' informal reasoning on nuclear energy usage and categorized their responses.

The mixed methods would enrich the problem's conclusions (Creswell, 2015). Also, the mixed methods design help reduce the challenges of working with the designs that emerged and collected diverse data types (Creswell & Plano Clark, 2011). This mixed-methods study aimed to comprehensively understand female students' engagement and the science learning process. To examine four research questions, I used a convergent parallel design. In this design, qualitative and quantitative data were collected in parallel but analyzed separately. The quantitative and qualitative data results are combined in the interpretation phase (Creswell & Plano Clark, 2011). This triangulation design aims to conclude the research with valid and well-substantiated results (Creswell, 2014).

Research Sample

The Temple University Office of Research's Institutional Review Board approved this research protocol, including its design and procedure to promote the safety and well-being of the participants, on February 19, 2021. Also, I provided student assent and parent consent forms for the participants and their parents before conducting the research. This study involved grade 6-12 students from six different classes and three different teachers from three different large urban US school districts. The teachers had about ten years of experience in science teaching. All three teachers participated in the MEL project. Thus, they also had experience in SSI-based science teaching. Each teacher managed two class as one control and one treatment, separately. The ratio of male students to female students was planned to be approximately equal. The minimum sample size of 120 was aimed due to a 95% ($\alpha = .05$) probability of not committing a Type I error (Tabachnick & Fidell, 2013).

The model plausibility rating study involved 204 students, but the number of the participants was reduced to 186 (97 females and 89 males). The reason for this reduction was that eight students did not complete pre- or post-rating. The number of the treatment group was 95 students (54 females and 41 males), whereas the number of the control group was 91 students (43 females and 48 males). The knowledge survey involved 216 students, but the data was reduced from N=216 to n=126 (65 females and 61 males). The main reason for missing data was student absence on the day of one or more activities. The control group comprised 70 students (33 females and 37 males), while the treatment group comprised 56 students (32 females and 24 males). One hundred fifty-two students (78 females and 74 males) took part in the open-ended question survey.

I did not specifically collect race, ethnicity, or socioeconomic background data from the participants. However, I asked three teachers about their classroom diversity in the teacher interviews. The first teacher described her classroom demographic as primarily white students of a middle-class background. Limited students received free or reduced-price lunches, and there was a relatively even split between genders. The second teacher had very diverse classrooms. 48% of her students spoke a different language at home, and their socioeconomic status ranged from poverty to wealth. Most students had economically stable environments, but many live-in homes were struggling financially. About ⅓ of students are white, ⅓ are Hispanic, ⅙ South Asian, ⅙ African American. The last teacher described his students coming from different school districts due to a vocational high school. The students preferred this high school to follow a specific career path, such as auto mechanic and cosmetologist. Also, 48 of his students took free or reduced-price lunches. Their socioeconomic status is very diverse. He had a mixed population, such as African American, Caucasian, Turkish, and White in his classrooms. Overall, the participants represented a wide range of demographic and socioeconomic backgrounds.

Research Context

I adapted the present study from Lombardi and Bailey et al. (2018) and Lombardi and Bickel et al. (2018) This research contains three stages:

1. Introduction
2. Model Plausibility Ranking Task
3. Explanation Task

This research is based on two different SSI topics: Climate Change (CC) and Wetlands (W). Four classrooms participated in Wetlands (W) topic-based activities, whereas two classrooms took part in Climate Change (CC) topic-based activities. The students took part in the SSI-based activities about one topic (CC or W) and one time. Both treatment and comparison groups participated in these three stages.

I created Table 1 for the research's flow. the participants completed the activities within three days. Three teachers followed this ranking for managing SSI-teaching activities. Also, they arranged the activity groups. The number of group members was at least three students to facilitate the students' discussion activities. The teachers could determine their classroom as a control or treatment group. I submitted the outline to the teacher before doing the activities. Also, they used a presentation to show and explain the materials to the students.

Table 1

The Process of Instructional Activities

Research Stage	Control Group	Treatment Group	Activity Day
1. Introduction	Pre-Knowledge Survey		Day 1
2. Model Plausibility Ranking Task	Model Pre-Plausibility Rating		Day 2
3. Explanation Task	Model Post-Plausibility Rating (SSI-Explanation Task without the MEL Diagram)	Model Post-Plausibility Rating (The MEL-Explanation Task with the MEL Diagram)	Day 2
	Post-Knowledge Survey Open-Ended Survey		Day 3

In the first stage, the teacher introduced the participants to what plausibility is, and the students completed a short survey activity about plausibility (e.g., see Appendix A). Next, both control and treatment groups completed the same CC or W pre-knowledge survey (e.g., see Appendix J and K). In the second stage of this research, both groups completed the model pre-plausibility rating task (e.g., see Appendix B and C). They rated the plausibility of both alternative and scientific models. In the last stage, the treatment group used CC or W MEL diagram (e.g., see Appendix D and E). This group tried to make connections between two models (scientific and alternative) and four lines of evidence using four different arrows. They drew their possible connections with a total of eight arrows. The control group tried to make connections without the MEL diagram. However, both groups discussed the same two models and the same four lines of evidence about CC or W. Table 2 shows these two models (scientific and alternative) and four evidence statements for each model (CC and W).

In addition, both groups examined evidence texts (e.g., see Appendix I or J). These evidence texts included the important graph or figure with a piece of brief and more explanatory information. They discussed the connections between two models and four lines of evidence with their group members when examining four evidence texts. After small group discussion, the control group individually completed the SSI-Explanation Task (see Appendix G), whereas the treatment group individually finished the MEL-Explanation Task (see Appendix F). In this task, both groups rated two models (alternative and scientific). After completing the model plausibility rating, the students answered CC or W knowledge survey (e.g., see Appendix J or K).

Table 2

Models and Evidence Statements of Each MEL Activity

Topic	Models	Evidence Statements
Climate Change	Scientific Model: Our climate change is caused by humans who are releasing gases into the atmosphere. (Model A) Alternative Model: Our climate change is caused by increasing amounts of energy released from the Sun. (Model B)	• Evidence 1: Atmospheric greenhouse gas concentrations have been rising for the past 50 years. Human activities have led to greater releases of greenhouse gases. Temperatures have also been rising during these past 50 years. • Evidence 2: Solar activity has decreased since 1970. Lower activity means that Earth has received less of the Sun's energy. However, Earth's temperature has continued to rise. • Evidence 3: Satellites are measuring more of Earth's energy being absorbed by greenhouse gases. • Evidence 4: Increases and decreases in global temperatures closely matched increases and decreases in solar activity before the industrial revolution.
Wetlands	Scientific Model: Wetlands provide ecosystem services that contribute to human welfare and help sustain the biosphere. (Model A) Alternative Model: Wetlands are a nuisance to humans and provide little overall environmental benefit. (Model B)	• Evidence 1: Wetlands play a role in the global cycles of carbon, nitrogen, and sulfur. Wetlands change these nutrients into different forms necessary to continue their global cycles. • Evidence 2: Flooding is a natural occurrence in low-lying areas and wetlands are places where floodwaters can collect. • Evidence 3: Wetlands contribute 70 percent of global atmospheric methane from natural sources. • Evidence 4: Many wetlands are located in rapidly developing areas of the country.

Note. Adapted from "Plausibility reappraisals and shifts in middle school students' climate change conceptions," by D. Lombardi, E. S. Bickel, J. M. Bailey, S. Burrell, 2018, *Science Education*, *102*(1), 153-177.

Subsequently, both the control and treatment groups completed the same open-ended question survey (e.g., see Appendix L). After two weeks interval, the students took part in the CC or W knowledge test one more time to examine their scientific knowledge retention. After finishing student activities, I conducted teacher interviews separately.

Quantitative Data Collection

The purpose of the quantitative data collection is to explore research question 1 and 2. Quantitative data showed how SSI-based activities affected students' CC or W plausibility and scientific knowledge. I collected the quantitative data from the research's first to the last stage. The teachers conducted the SSI-based regular instruction for the control group and administered the MEL diagram instruction for the treatment group. The main difference between the control and treatment groups is the MEL diagram. Other materials are similar. Each teacher managed both control and treatment group activities separately.

Intervention

Treatment Group

I adapted the treatment group's activities from Lombardi and Bailey et al. (2018) and Lombardi and Bickel et al. (2018). The first stage, the teacher gave brief information about what plausibility is how the scientist works. The students completed the initial ranking paper, the groups read the brief paragraph about the scientific information's tentative nature and falsifiability. The teacher managed a class discussion about the falsifiability reading and clarified their questions about the model and plausibility. Next, they completed re-ranking the importance of the categories. After that re-ranking, the teacher managed a brief discussion with the class on their rankings. This task introduced the participants to what plausibility is. After this task, the participants completed CC or W pre-knowledge survey.

In the second stage of this research, the teacher started a short whole-class discussion about what scientific model and lines of evidence to remember the idea of plausibility. The teacher distributed two models and four evidence statements for CC or W to the classroom. Evidence statements and two models for each SSI are shown in Table 2. However, initially, they did not know which model was scientifically correct. They rated the plausibility of both scientific and alternative models in the Model Plausibility Ranking of CC or W. These rankings were collected as the treatment's group pre-model plausibility scores.

In the last stage, students examined evidence texts and discussed them with their group members. The teacher visited the small groups and engaged them to discuss and expand their arguments for both the control and treatment groups. Also, the teacher tried to clear the students' misunderstandings. The participants discussed the MEL diagram by examining the importance of four categories of connections between evidence and models, such as strongly supports a model, supports a model, has nothing to do with a model, or contradicts a model. The participants completed the MEL-Explanation task by rating scientific and alternative models individually. These ratings are their post-model plausibility scores. Subsequently, they finished CC or W post-knowledge tests individually. Finally, they answered the open-ended question survey. After two weeks interval, the students participated in the CC or W knowledge test one more time to examine their scientific knowledge retention.

Control group

The control group participated in an SSI-Based Instruction that has been adapted by Lombardi et al. (2013). The control group completed the pre-knowledge survey in the research's first stage, rated two models' pre-plausibility ranking in the research's second stage, finished two models' post-plausibility ranking and post-knowledge survey in the research last stage. The control group did not use the MEL diagram in the explanation task for making the connection between four lines of evidence and two models. However, they discussed two models, four different lines of evidence, and evidence texts about CC or W in the small group. They can read the evidence texts together and debate with each other. The teacher helped them to clear their misunderstandings by asking questions. The students collaborated within the group. After the group discussion, the students rated individually two models' plausibility on a scale of 1 to 10 with completing regular SSI-based explanation task. They also completed the open-ended question survey. After a two-week break, the students took the CC or W knowledge test again to assess their retention of scientific information.

The difference between the Control and Treatment Groups

The crucial difference between the control and treatment groups is the MEL diagram. In this research, in particular, I wanted to investigate how the arrows and a diagram were effective when connecting the models and lines of evidence. The treatment group took part in the MEL diagram and MEL-Explanation Task, whereas the control group used a diagram without arrows sections and participated SSI-Explanation task. The MEL diagram is based on arrows connections between lines of evidence and models. The students made connections between lines of evidence and models (scientific and alternative) using four different types of arrows.

Instrument

In this research, I used CC and W knowledge surveys for analyzing scientific knowledge scores and model plausibility rating for analyzing scientific plausibility scores. The research instruments are adapted from Lombardi et al. (2013), Lombardi and Bailey et al. (2018), and Lombardi and Bickel et al. (2018). Table 3 shows the instruments and data sources.

Knowledge Survey

I adapted 5-item CC and W knowledge instruments from Lombardi and Bailey et al. (2018) and Lombardi and Bickel et al. (2018) (e.g., see Appendix J and K). They express that student can reflect their understandings of the related scientific processes with this knowledge survey. Also, they found that reliability of knowledge scores exceeded the threshold considered minimally acceptable according to the previous meta-analysis of behavioral research studies (Tavakol & Dennick, 2011), with Guttman's $\lambda 2$ = .63. Also, their project's advisory panel verified the face and content validity of the knowledge instrument items. I found that the test-retest reliability multiple coefficients (combined CC and W knowledge scores) for a two-week interval were .753. In this knowledge survey, students completed a 5-item knowledge survey instrument about CC or W. Pre, post, and post delayed knowledge surveys have the same five questions.

Both the control and treatment groups completed the pre-knowledge test in the research's introduction plausibility ranking task phase but ranked post-knowledge test in the research's explanation task phase.

Table 3

Instruments and Data Sources

Dependent variable	Measure	Instrument	Description	Purpose
Scientific knowledge scores	Knowledge surveys were used to explore participants' scientific knowledge pre, post, and delayed-post-test scores for both the control and treatment groups	Pre, post, and delayed-post knowledge tests	Students ranked each 5 items on a 5-point Likert scale	To examine whether student knowledge shift
Plausibility judgment scores	Model Plausibility rating as the pre-test were used to explore participants' pre-plausibility judgment scores for both the control and treatment groups	Pre-model plausibility rating	Student ranked each scientific and alternative models on a 1-10 scale	To examine whether student plausibility judgment shift
	Treatment: Model Plausibility rating as the post-test were used to explore the treatment group participants' post-test plausibility scores in the MEL-Explanation	Post-model plausibility rating	The treatment group ranked each scientific and alternative models in the MEL-Explanation based on the MEL diagram on a 1-10 scale	
	Control: Model Plausibility rating as the post-test were used to explore the control group' participants post-test plausibility scores in the regular SSI-Explanation		The control group ranked scientific and alternative models in the regular SSI-Explanation without the MEL diagram on a 1-10 scale	

Note. A 1-10 scale in plausibility rating is that one equals highly implausible and ten equals highly plausible. A 5-point Likert scale in knowledge test is that one equals strongly disagree and 5 equals strongly agree.

The delayed-post knowledge survey was implemented after the MEL activity was finished two weeks later. They rated each item on the instrument using a 5-point Likert-type scale (5=strongly agree, 4=agree, 3=neutral, 2=disagree, and 1=strongly disagree) based on their knowledge. The total possible range of knowledge scores were 5–25 for each topic. Some statements on the instruments were negatively worded. W knowledge instrument has three negatively worded statements, while the CC knowledge instrument has one negatively worded statement. Before analyzing the students' scientific knowledge scores, I reversed the codes of these statements.

Model Plausibility Rating

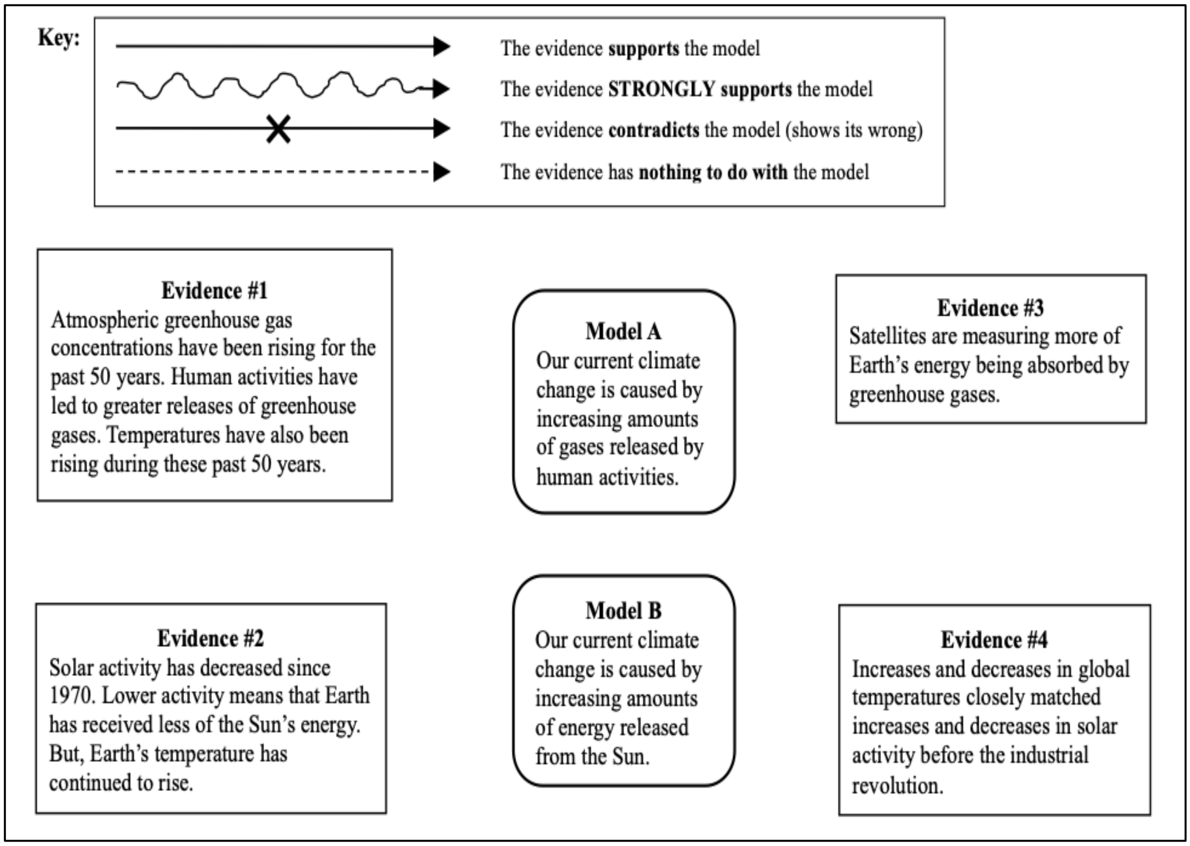
Students rated pre and post plausibility of each two models (alternative and scientific), ranging from 1=greatly implausible to 10=highly plausible. The treatment group did MEL diagram activity before alternative and scientific model post-plausibility ratings. The control group examined alternative and scientific models with the evidence texts without a diagram.

MEL Diagram

The treatment group used the MEL diagram in the research's last stage. The students make connections between four lines of evidence and these two models (scientific and alternative). One of the models is accepted as highly plausible by the scientific community; another is evaluated as a highly implausible alternative model. This information was not given to them. The students discussed the connections and examined the evidence texts in small groups. They used four different kinds of arrows and drew a total of eight arrows between four lines of evidence and these two models on the MEL diagram (see the top section in Figure 2).

Figure 2

A Model-Evidence Link (MEL) Diagram



Adapted from "Plausibility reappraisals and shifts in middle school students' climate change conceptions," by D. Lombardi, G. M. Sinatra, E. M. Nussbaum, 2013, *Learning and Instruction, 27*, 50-62.

Figure 2 illustrates the MEL diagram, which are based on the links between different lines of evidence and models. Four arrows are straight, squiggly, dashed, and straight-arrow with an X. The arrows have a different meaning; straight-arrow shows that evidence supports the model; squiggly arrow shows that evidence strongly supports the model; straight arrow with an "X" through the middle shows the evidence contradicts the model, and dashed-arrow shows that the evidence has nothing to do with the model.

MEL Explanation

The treatment participants completed the MEL explanation task (see Figure 3), which includes the students detailing their making evidence-to-model links and their alternative and scientific models' post-plausibility ratings.

Figure 3

MEL Explanation

MEL Explanation

Name: ________________________________ **Date:** ______________ **Teacher:** ____________________ **Period:** ____________

1. **What were your previous rankings?** Model A: _____________ Model B: _____________
2. **Provide a reason for three of the arrows you have drawn. Write your reasons for the three most interesting or important arrows.**
   - A. Write the number of the evidence you are writing about.
   - B. Circle the appropriate word (**strongly supports | supports | contradicts | has nothing to do with**).
   - C. Write which model you are writing about.
   - D. Then write your reason.

   1. **Evidence # ____ strongly supports | supports | contradicts | has nothing to do with Model _____ because:**
   2. **Evidence # ____ strongly supports | supports | contradicts | has nothing to do with Model _____ because:**
   3. **Evidence # ____ strongly supports | supports | contradicts | has nothing to do with Model _____ because:**
3. **Circle the plausibility of each model. [Make two circles, one for each model.]**

	Greatly implausible (or even impossible)									Highly plausible
Model A	1	2	3	4	5	6	7	8	9	10
Model B	1	2	3	4	5	6	7	8	9	10

4. **For the model you selected as most plausible, explain why you think so**

Adapted from "Plausibility reappraisals and shifts in middle school students' climate change conceptions," by D. Lombardi, G. M. Sinatra, E. M. Nussbaum, 2013, *Learning and Instruction, 27,* 50-62.

This task helped them make more critical evaluations on two models, and they could construct their critical scientific evaluations more systematically. The treatment group rated the post-plausibility of each model (alternative and scientific) using a using a 1-10 scale (1 = greatly implausible and 10 = highly plausible) based on their scientific evaluations.

Regular SSI-based Explanation

The control group completed regular SSI-based explanation in the research's last stage (see Figure 4).

Figure 4

Regular SSI Explanation Task

SSI Explanation Task

Name: ________________________________ **Date:** ______________ **Teacher:** ____________________ **Period:** ____________

1. **What were your previous rankings?** Model A: _____________ Model B: _____________
2. **Provide a reason that you choose three evidence and models.**

   A. Write the number of the evidence you are writing about.
   B. Circle the appropriate word (**strongly supports | supports | contradicts | has nothing to do with**).
   C. Write which model you are writing about.
   D. Then write your reason.

   1. **Evidence # ____ strongly supports | supports | contradicts | has nothing to do with Model _____ because:**
   2. **Evidence # ____ strongly supports | supports | contradicts | has nothing to do with Model _____ because:**
   3. **Evidence # ____ strongly supports | supports | contradicts | has nothing to do with Model _____ because:**

3. **Circle the plausibility of each model. [Make two circles, one for each model.]**

	Greatly implausible (or even impossible)								Highly plausible
Model A	1	2	3	4	5	6	7	8	9	10
Model B	1	2	3	4	5	6	7	8	9	10

4. **For the model you selected as most plausible, explain why you think so**

Adapted from "Plausibility reappraisals and shifts in middle school students' climate change conceptions," by D. Lombardi, G. M. Sinatra, E. M. Nussbaum, 2013, *Learning and Instruction*, 27, 50-62.

Regular SSI-based explanation did not include arrow relations using the MEL diagram. After small group discussion about the alternative and scientific models and four evidence texts, they individually rated the post-plausibility of each model (alternative and scientific) using a 1-10 scale (1 = greatly implausible and 10 = highly plausible) based on their scientific evaluations.

Qualitative Data Collection

Qualitative data focused on the participant's behavior and insights in a natural setting. The purpose of the qualitative data collection was to explore research questions 3 and 4. The qualitative phase of this study consists of students' reflections about SSI-based science learning and teacher interview. Female students' experiences in the SSI-based science classroom seem a comprehensive phenomenon. I needed the full range of female students' possible responses. Thus, I created 12 open-ended question surveys to collect detailed data from the participants. The open-ended question survey helped explore students' concerns, experiences, thoughts about science learning and SSI-based science classrooms.

I aimed to identify students' transformative experiences based on their open-ended question survey answers. Of the 151 students, 78 female and 73 male students reflected their experiences about SSI-based science learning with the open-ended question survey. For qualitative analysis, I followed Creswell (2014)'s qualitative analysis steps. First, raw data transferred into Microsoft Office Excel Document. I separated the female and male students' answers for each question. Next, I read each question's answers a few times, and I tried to write some keywords in a full sentence. I then re-read these keywords and developed the appropriate codes. In the next step, I tried to emerge similar and different themes and patterns among these codes and triangulate them with the research's theoretical and conceptual frameworks from the data.

Also, I conducted a semi-structured interview with three teachers managing the SSI-based science learning separately. The purpose of the interview is to gather information from teachers about their experiences and comments about the SSI-based science teaching activity. The teacher interviews provided a data triangulation to assure the validity of current research by using different data sources on SSI-based science classrooms.

Open-ended Question Survey

In an open-ended question survey, I tried to explore both female and male students' experiences in the SSI-based science classroom from their sides. I wanted that they could reflect on their experiences and inner voices without worry. Feeling relaxed is vital to collect detailed and correct data from the participants. Thus, I created an open-ended question survey (e.g., see Appendix L). They did not write their names on the survey, and no name survey might have been provided an opportunity to express themselves without fear or inconvenience. The survey contained 12 questions. Both female and male participants answered these same 12 questions at the end of the research's explanation task stage. They gave remarkably detailed data about their experiences in SSI-based science learning. Also, they reflected on some ideas for redesigning science classrooms.

Teacher Interview

The teachers' experiences managing the SSI-based activity are crucial to advance the SSI-based science teaching designs and create gender equity in science classes. I wanted to add the teachers' experiences, perspectives, and thoughts to this study. After the students finished the activities, I interviewed three teachers separately. In teacher interviews, I aimed to gain a comprehensive and supplemental understanding of the SSI-based teaching from teachers' sides. I preferred a semi-structured interview approach because this interview was much freer for the researchers. I asked some additional questions based on the teachers' answers to understand their experiences, ideas, and perceptions. Also, I tried to ask open-ended response questions instead of closed-versus to collect detailed data.

Each interview takes approximately one hour. The interview started with initial open-ended questions. I created a teacher interview protocol (e.g., see Appendix M). Following this protocol, I asked the interview questions. Also, based on its semi-structured, I added some further questions during the interview. The interview protocol contains five sections:

1. Background information
2. Teaching
3. SSI-based science teaching
4. Gender gap
5. Professional development.

In the first section, they mentioned their teaching background and how to decide to be a science teacher. Also, they provided some additional information about their students' demographics and socioeconomic statements. In the second section, they explained their science teaching strategies and how to decide these strategies. In the SSI-based science teaching section, they reflected their MEL activity experiences by explaining deficiencies, difficulties, and positives of the MEL activity from their side. They also gave some ideas about how to re-design the MEL activity. In the gender gap section, they expressed their observation and thoughts about the gender gap. Moreover, they shared how the female students reacted to the SSI-based science teaching. In the last section, they stated their professional development experiences and ideas about effective professional development.

CHAPTER 4

RESULTS

Based on the highlights of the literature review, I identified four research questions:

- Research question 1 (RQ_1): How does Model Evidence Link (MEL) diagram affect students' plausibility of scientific and alternative models about socioscientific topics? Are there any gender gaps?
- Research question 2 (RQ_2): Does Model Evidence Link (MEL) diagram affect students' scientific knowledge of socioscientific topics? Are there any gender gaps?
- Research question 3 (RQ_3): What are the female students' experiences in SSI-based instructional activity compared to male students?
- Research question 4 (RQ_4): What is the effect of SSI-based science instruction on female students' experiences for pursuing science related career plans compared to male students?

This chapter will present the analysis of the data in order of these four research questions. The analysis will begin normality assumptions testing and descriptive statistics. Next, I will continue by analyzing students' combined topics (Climate Change (CC) and Wetlands (W)) alternative and scientific model plausibility scores and their CC and W knowledge scores separately. Next, I will analyze students' experiences and career plans in SSI-based science classrooms, especially females. Finally, I presented a summary of the analyses.

I did not analyze the students' alternative and scientific model plausibility ratings by topic (CC or W). However, I examined their scientific knowledge scores by combined topics (CC and W) CC, and W. Also, I investigated whether there is a gender gap in their alternative and scientific model plausibility and scientific knowledge ratings. I used two different graphs (bar and line) for showing the results on figures. I wanted to show the increase or the decrease in the students' plausibility ratings or scientific knowledge scores from pre- to post-instruction using bar graph figures. With line graph figures, I wanted to show whether the gender gap is in their post-plausibility scores or post-knowledge scores using line graph figures depending on the groups. The line graph highlights the interaction effect between gender and groups on the post-plausibility and the post-knowledge scores.

Normality Assumptions Testing: Examination of Skewness and Kurtosis

I examined the normality of the data for each dependent variable using histograms and descriptive statistics. All variables were within an approximately normal distribution, with skewness values ranging from -0.608 to 0.530 and values of kurtosis ranging from -0.770 to 0.300 except Model A post-plausibility score with skewness of -1.322 (SE = 0.178) and kurtosis of 2.185 (SE = 0.355). The variables had a suggesting normal distribution of the data for skewness and kurtosis, $|Z| < 2.50$ (Hair et al., 2010).

Bivariate Correlations

A correlation shows the strength of linkage or co-occurrence between two variables. The Pearson correlation coefficients measure the potential statistical relationship or association between two continuous variables (Field, 2018). I computed the Pearson's Correlations for each dependent variable using SPSS version 27.

Table 4

Means, Standard Deviations, and Pearson Correlations

Variable	*M*	*SD*	1	2	3	4	5	6	7	8	9	10	11	12
1. Model A pre-plausibility	7.13	1.826												
2. Model A post-plausibility	8.32	1.522	.314**											
3. Model B pre-plausibility	5.22	2.345	-.162*	-.248**										
4. Model B post-plausibility	4.15	1.857	-.038	-.304**	.300**									
5. CC pre-knowledge	16.785	2.629	.145	.132	-.029	.233								
6. CC post-knowledge	18.964	2.285	.207	.055	.116	-.135	-.118							
7. CC delayed-post-knowledge	18.892	2.249	.16	.256	-.158	-.242	.359	.244						
8. W pre-knowledge	13.561	2.758	-.006	-.053	-.055	.015	-.006	-.224	-.216					
9. W post-knowledge	15.214	2.912	.023	.057	.117	.095	.16	.027	.109	.175				
10. W delayed-post-knowledge	14.918	2.738	-.024	.128	-.062	-.086	.076	.119	.055	.137	.442**			
11. Pre-knowledge	14.476	3.224	.067	-.008	.038	.047	-.006	-.224	-.216	1.000**	.175	.137		
12. Post-knowledge	16.023	3.186	.056	.093	.148	.088	.16	.027	.109	.175	1.000**	.442**	.335**	
13. Delayed-post-knowledge	15.888	3.205	.068	.141	.073	-.009	.076	.119	.055	.137	.442**	1.000**	.389**	.603**

Note. M and *SD* are used to represent mean and standard deviation, respectively. ** $p< 0.01$ (2-tailed); * $p < 0.05$

I combined the participants' CC and W topics scientific model pre-and post-plausibility scores under Model A pre- and post-plausibility scores, whereas I combined their CC and W topics alternative model plausibility scores under Model B pre- and post-plausibility scores. In addition, their pre-, post-, and delayed-post knowledge scores include their combined CC and W topics scores.

Table 4 shows Pearson bivariate correlations between the dependent variables. The degree of the statistically significant relationships between the variables can be seen almost moderate degree range (-.162 to .1). The most moderate correlation is between total pre-knowledge and total post-knowledge scores ($r = .603$, $p \leq .01$). There are three positive significant and perfect correlations (i.e., between W pre-knowledge scores and total pre-knowledge scores; between W post-knowledge score and total post-knowledge scores; between W delayed post knowledge scores and total delayed-post knowledge scores).

Model A pre-plausibility scores show positive and medium correlation with model A post-plausibility scores ($r = .314$, $p \leq .01$). Model B pre-plausibility scores showed a positive moderate correlation with Model B post-plausibility scores ($r = .300$, $p \leq .01$). There is an almost moderate positive correlation between the total pre-knowledge scores and the total post-knowledge scores, ($r = .335$, $p \leq .01$). Also, there is a similar correlation between total post-knowledge scores and delayed post knowledge scores, ($r = .389$, $p \leq .01$).

Effectiveness of SSI-Based Instruction in Students' Plausibility

Both the control and treatment groups' participants rated the plausibility of two models: Model A is currently a scientifically accepted model, and Model B is not accepted by scientists. Based on their plausibility ratings, I analyzed RQ_1:

- How does Model Evidence Link (MEL) diagram affect students' plausibility of scientific and alterative models about socioscientific topics? Are there any gender gaps?

First, I examined their Model B and Model A ratings regardless of gender or group to examine the overall effectiveness of SSI-based instruction in students' plausibility. Next, I analyzed their alternative and scientific model ratings regarding genders and groups to further investigate whether there are any differences in SSI-based instruction's effectiveness depending on genders and the use of MEL diagrams.

Based on literature review, SSI-based classroom may create the gender equity in the science learning, Thus, I did not expect the gender gap in the present study. In addition, I anticipate that the students who participated in the treatment group had higher scientific model plausibility post-test scores than those who did not use arrows for MEL in their scientific model plausibility post-test scores. Also, the students who participated in MEL with arrows-based instruction had lower alternative model plausibility post-test scores than those who did not use arrows for the MEL in their alternative model plausibility post-test scores. For the first research question, my hypotheses:

- **Hypothesis (H_1):** The participants increase scientific model (Model A) ratings but reduce their alternative model (Model B) ratings.

- **Hypothesis (H_2):** The use of MEL diagram in the SSI-based instruction enhances students' plausibility ratings.
    - **$H_{2\text{-}a}$**: The students who participate in MEL with arrows-based instruction have higher scientific model plausibility ratings than those who do not use arrows in their model plausibility ratings.
    - **$H_{2\text{-}b}$:** The students who participate in MEL with arrows-based instruction have lower alternative model plausibility ratings than those who do not use arrows in their model plausibility ratings.
- **Hypothesis (H_3):** There is no gender gap in the plausibility ratings of the scientific and alternative models.
    - **$H_{3\text{-}a}$**: The male participants' alternative model post-test ratings are similar to female participants' alternative model post-test ratings.
    - **$H_{3\text{-}b}$:** The male participants' scientific model post-test scores are similar to the female participants' scientific model post-test scores.

Overall Effectiveness of SSI-Based Instruction in Students' Plausibility

In this section, I analyzed how SSI-based instruction affects the students' alternative and scientific model plausibility ratings from pre- to post-instruction. I used a repeated measures Analysis of Variance (ANOVA) test to analyze their alternative and scientific plausibility ratings.

Alternative Model Plausibility Ratings

A repeated measures ANOVA was conducted to determine differences in the students' combined topics pre-and post-plausibility rating scores for combined groups (control and treatment) from pre- to post-instruction, with Model B pre- and post-plausibility scores as a dependent variable and time as a within-subjects factor. Table 5 shows descriptive statistics for the alternative model plausibility pre-and post-test scores. The repeated measures ANOVA revealed that there was a significant decrease in the participants' Model B plausibility scores from pre- to post-test, Wilks' $\lambda = .847$, $F(1, 185) = 33.293$, $p < 0.001$, $\eta^2 = .153$ (medium effect size). This result supported my hypothesis (H_1). Based on this outcome, the participants successfully eliminated the alternative model.

Table 5

Adjusted Means, Standard Errors, and Confidence Intervals for Alternative Model Plausibility Pre- and Post-Test Scores

	Mean	*S.D.*	Skewness		Kurtosis	
			Statistics	Std. Error	Statistics	Std. Error
Alternative Model Pre-Plausibility Score	5.22	2.345	.211	.178	-.563	.355
Alternative Model Post-Plausibility Score	4.15	1.857	.530	.178	.300	.355

Note. Model plausibility scores each range between 1 and 10 (1=highly implausible and 10=highly plausible).

Scientific Model Plausibility Ratings

I conducted a repeated measures ANOVA to analysis the participants' combined topics scientific model plausibility ratings for combined groups (control and treatment) from pre- to post-instruction, with Model A pre and post plausibility scores as a dependent variable and time as a within-subjects factor. Table 6 represents descriptive statistics for scientific model plausibility pre- and post-test scores.

Table 6

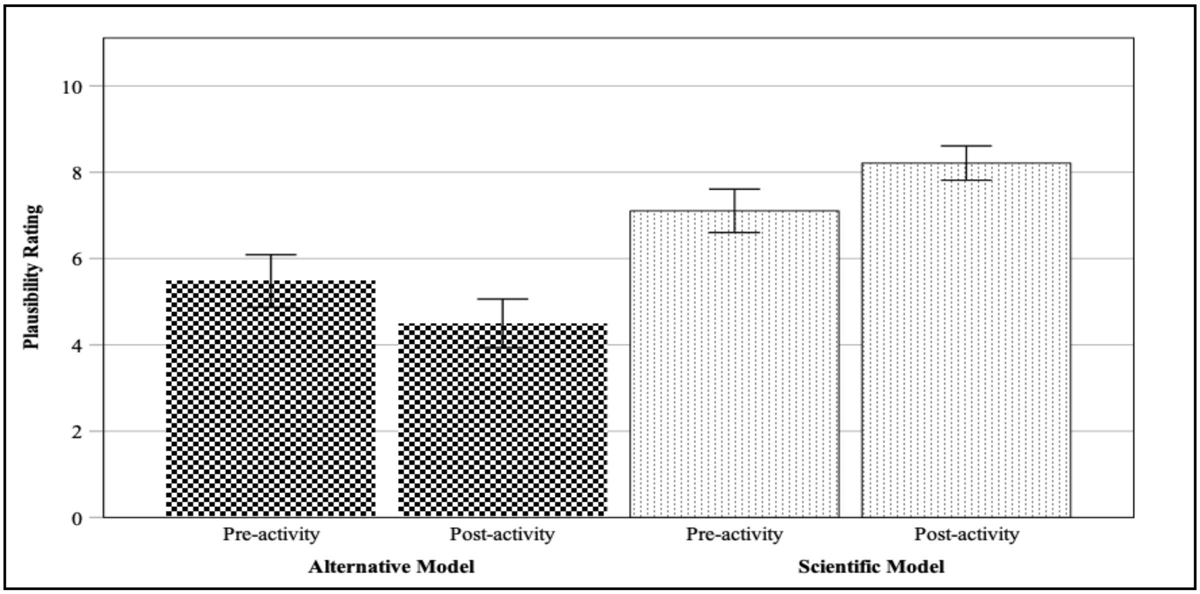
Adjusted Means, Standard Errors, and Confidence Intervals for Scientific Model Plausibility Pre- and Post-Test Scores

	Mean	S.D.	Skewness		Kurtosis	
			Statistics	Std. Error	Statistics	Std. Error
Scientific Model Pre-Plausibility Score	7.13	1.826	-0.608	0.178	0.16	0.355
Scientific Model Post-Plausibility Score	8.32	1.522	-1.322	0.178	1.385	0.355

Note. Model plausibility scores each range between 1 and 10 (1=highly implausible and 10=highly plausible).

Figure 5

Alternative and Scientific Model Plausibility Pre- and Post-Ratings



Note. Plausibility scores range from 1 to 10 (1=highly implausible and 10=highly plausible). Error bars indicate ±1 standard error.

The repeated measures ANOVA showed that there was a statistically increase in the participants' scientific model plausibility scores from pre- to post-test, Wilks' λ = .733, $F(1, 185) = 67.245$, $p < 0.001$, $\eta^2 = .267$ (large effect size). The significant increase in Model A plausibility scores between pre- and post-test scores and the significant decrease in Model B plausibility scores between pre- and post-test scores supported my hypothesis (H_1). This outcome showed that the participants accepted Model A as more plausible by eliminating Model B. The decrease from pre- to post-instruction in their alternative model plausibility ratings and the increase between pre- and post-instruction in their scientific model plausibility ratings can be seen on Figure 5 above.

Effectiveness of SSI-Based Instruction in Students' Plausibility by Gender and Group

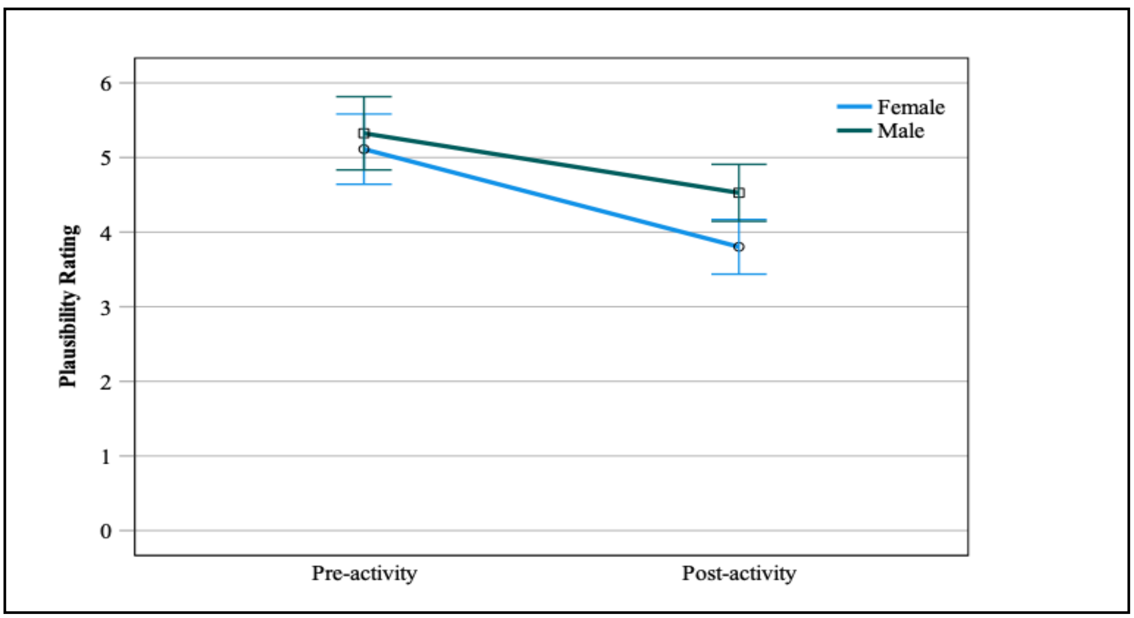
First, I analyzed the students' alternative and scientific model plausibility ratings by gender using a repeated measures ANOVA with alternative or scientific model pre- and post-plausibility scores as the dependent variable, time as the within-subjects factor, and gender as the between-subjects factor. Next, I analyzed how the MEL instruction impacted the female and male students' alternative and scientific model post-plausibility ratings comparing the control group instruction. Also, I examined whether the gender gap was in the SSI-based classrooms using a two-way Analysis of Covariance (ANCOVA) test with alternative or scientific model post-plausibility ratings as the dependent variable, gender and groups as the fixed factors, and alternative or scientific model pre-plausibility ratings as the covariate.

Alternative Model Plausibility Rating by Gender

I conducted a repeated ANOVA with Model B plausibility scores as the dependent variable, time as the within-subjects factor, and gender as the between-subjects factor. The main effect of gender was insignificant, $F(1, 184) = 3.569$, $p = .060$, $\eta^2 = 0.019$ (small effect size). The test revealed statistically insignificant interaction between time and gender Wilks' $\lambda = 0.990$, $F(1, 184) = 1.928$, $p = .167$, $\eta^2 = 0.010$ (small effect size). Both female and male students' decreased Model B scores from pre to post instruction (Females Pre: M = 5.11, SD =2.40, Post: M = 3.80, SD = 1.73; Males Pre: M= 5.33, SD = 2.29, Post: M = 84.53, SD = 1.92). These decreases can be seen in Figure 6. Based on this figure, the female students' alternative model post-plausibility scores were lower than the male students' alternative model post-plausibility scores. The decrease in Model B plausibility ratings supported that both genders evaluated Model B as less plausible after the post-instruction.

Figure 6

The Comparison of Female and Male Students' Alternative Model Plausibility Pre- and Post-Ratings



Note. Plausibility scores range from 1 to 10 (1 highly implausible and 10 highly plausible). Error bars indicate ±1 standard error.

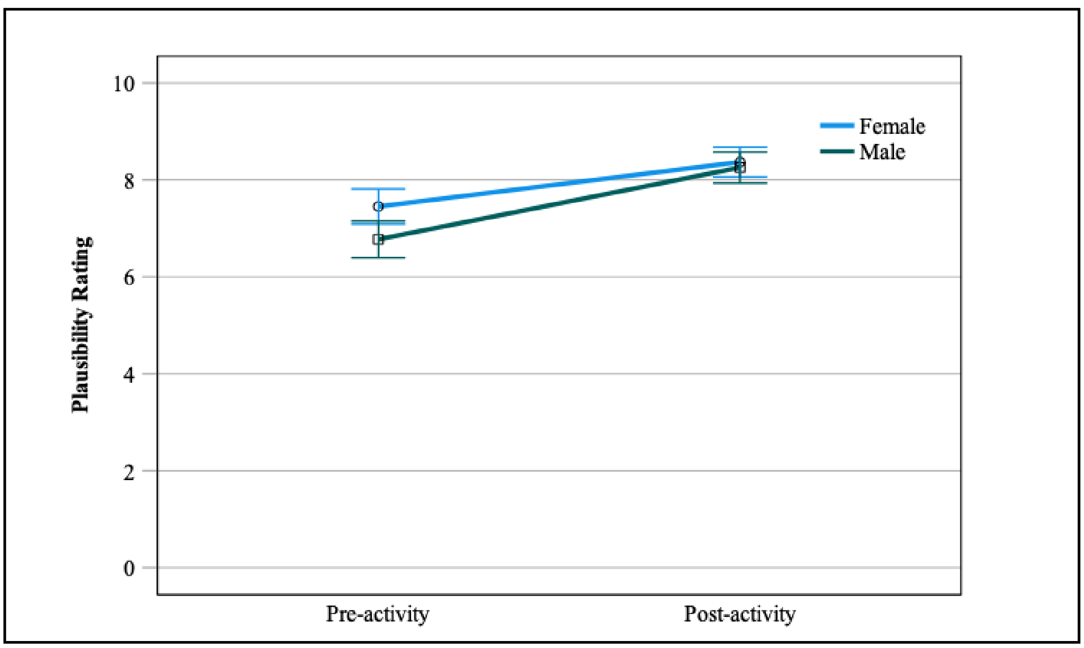
Scientific Model Plausibility Rating by Gender

A repeated ANOVA was run with Model A plausibility scores as the dependent variable, time as the within-subjects factor, and gender as the between-subjects factor.

The main effect of gender was significant, $F(1, 184) = 3.99$, $p= .047$, $\eta^2 = 0.021$ (small effect size). The test revealed statistically insignificant interaction between time and gender, Wilks' $\lambda = 0.979$, $F(1, 184) = 3.86$, $p= .051$, $\eta^2 = 0.021$ (small effect size). Both female and male students' Model A plausibility scores increased from pre to post instruction (Females Pre: $M = 7.45$, $SD = 1.70$, Post: $M = 8.37$, $SD = 1.51$; Males Pre: $M= 6.78$, $SD = 1.89$, Post: $M = 8.26$, $SD = 1.53$). Figure 7 below shows that these increases in their scientific model plausibility scores from pre- to post-instruction.

Figure 7

The Comparison of Female and Male Students' Scientific Model Plausibility Pre- and Post-Ratings



Note. Plausibility scores range from 1 to 10 (1 highly implausible and 10 highly plausible). Error bars indicate ±1 standard error.

The increases in both female and male students' scientific model plausibility ratings and the decreases in both their alternative model plausibility ratings between pre-and post-instruction promoted that all genders evaluated scientific model as more plausible and alternative model as less plausible after the post-instruction. In addition, these results supported the SSI-based instruction effectiveness on the students' plausibility shift toward the scientific model by choosing Model A as scientifically more plausible rather than Model B. The insignificant effect of the gender on their alternative and scientific model post-plausibility promoted that SSI-based science learning provided equal opportunities for both genders.

Alternative Model Plausibility Rating by Genders and Groups

A two-way ANCOVA test was run to analyze the female and male students' alternative model post-plausibility ratings for the groups (control and treatment) with Model B post-plausibility ratings as the dependent variable, gender and groups as the fixed factors, and Model B pre-plausibility ratings as the covariate. In this two-way ANCOVA test, Levene's test indicated equal variances (F = 1.255, p = .291). Table 7 represents descriptive statistics for the female and male students' Model B post-test plausibility ratings by the groups.

The two-way ANCOVA test revealed that there was a statistically significant effect of gender on Model B post-plausibility ratings after controlling for Model B pre-plausibility ratings, $F(1, 181)= 8.14$, $p= .005$, $\eta^2 = .043$ (small effect size). Also, there was a statistically significant effect of groups on Model B post-plausibility ratings after controlling for Model B pre-plausibility ratings, $F(1, 181)= 5.29$, $p= .023$, $\eta^2 = .028$ (small effect size). However, there was no statistically significant interaction between gender and group on Model B post-plausibility ratings, whilst controlling for Model B pre-plausibility ratings, $F(1, 181) = 2.643$, $p = .106$, $\eta^2 = .014$ (small effect size). ANOVA results can be seen in Table 8.

Table 7

Adjusted Means, Standard Errors, and Confidence Intervals for Alternative Model Plausibility Ratings by Gender and Groups

Group	Gender	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Control	Female	3.904	.234	3.441	4.366
	Male	5.042	.269	4.511	5.573
Treatment	Female	3.731	.263	3.211	4.25
	Male	4.043	.248	3.553	4.533

Note. Plausibility scores range from 1 to 10 (1=highly implausible and 10=highly plausible).

Table 8

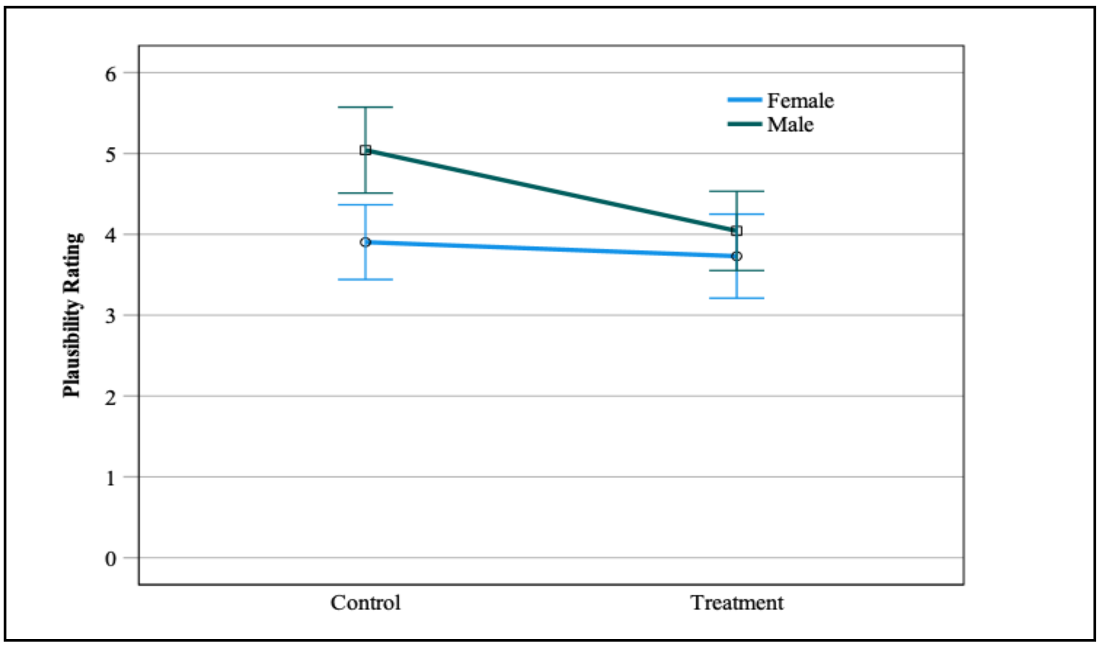
Fixed-Effects ANOVA Results for Alternative Model Plausibility Ratings by Gender and Groups

Predictor	Sum of Squares	*df*	Mean Square	*F*	*p*	*η*
Intercept	280.387	1	280.387	94.609	0	0.343
Model B pre-plausibility	50.578	1	50.578	17.066	0	0.086
Group	15.694	1	15.694	5.295	0.023	0.028
Gender	24.132	1	24.132	8.143	0.005	0.043
Group*Gender	7.834	1	7.834	2.643	0.106	0.014
Error	536.42	181	2.964			

Figure 8 below shows the female and male students' Model B post-plausibility scores for the control and treatment groups. The female students' alternative model plausibility post-test scores were lower than those of the male students' plausibility post-test scores for both the control and treatment groups. There was a moderate gender gap in the control group with females in favor. This outcome did not confirm my hypothesis (H_3). The gender gap in the treatment was smaller than the gender gap in the control group. Females and males had almost similar alternative model plausibility ratings in the treatment group. These findings did not support my hypothesis (H_{3-a}). Overall, both genders successfully eliminated the alternative model, and the treatment group had less gender gap than the control group, with females in favor.

Figure 8

The Comparison of Female and Male Students' Alternative Model Post-Plausibility Ratings by Groups



Note. Plausibility scores range from 1 to 10 (1 highly implausible and 10 highly plausible). Error bars indicate ±1 standard error.

Scientific Model Plausibility Ratings by Genders and Groups

I conducted a two-way ANCOVA to analyze the female and male students' scientific model post-plausibility ratings for the groups (control and treatment) with Model A post-plausibility ratings as the dependent variable, gender and groups as the fixed factors, and Model A pre-plausibility ratings as the covariate. Table 9 depicts descriptive statistics for both control and treatment groups Model A post-plausibility scores by gender. Levene's test indicated equal variances (*F* = .688, *p* = .561). The two-way ANCOVA test confirmed that there was no statistically significant effect of gender on Model A post-plausibility ratings after controlling for Model A pre-plausibility ratings, $F(1, 181)= .061$, $p=.805$, $\eta^2 = .000$ (small effect size).

Table 9

Adjusted Means, Standard Errors, and Confidence Intervals of Scientific Model Plausibility Ratings by Gender and Groups

Group	Gender	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Control	Female	8.101	.201	7.706	8.497
	Male	8.402	.228	7.952	8.852
Treatment	Female	8.509	.221	8.072	8.946
	Male	8.316	0.21	7.901	8.731

Similarly, there was no a statistically significant effect of group on Model A post-plausibility ratings after controlling for Model A pre-plausibility ratings. Similarly, there was no statistically significant interaction between gender and group on Model A post-plausibility ratings, whilst controlling for Model A pre-plausibility ratings, $F(1, 181) = 1.313$, $p = .253$, $\eta^2 = .007$ (small effect size). Table 10 below indicates ANOVA results.

Both female and male students' Model A plausibility scores increased for both the control (Females Pre: *M* = 7.70, *SD* = 1.78, Post: *M*= 8.26, *SD* = 1.60; Males Pre: *M* = 6.73, *SD* = 1.98, Post: *M*= 8.29, *SD* = 1.52) and treatment (Females Pre: *M* = 7.14, *SD* = 1.56, Post: *M*= 8.51, *SD* = 1.40; Males Pre: *M* = 6.81, *SD* = 1.83, Post: *M*= 8.23, *SD* = 1.56) groups. Also, treatment group's Model A post-plausibility scores slightly were higher than the control group's Model A post-plausibility scores. This finding favored my hypothesis ($H_{2\text{-}a}$).

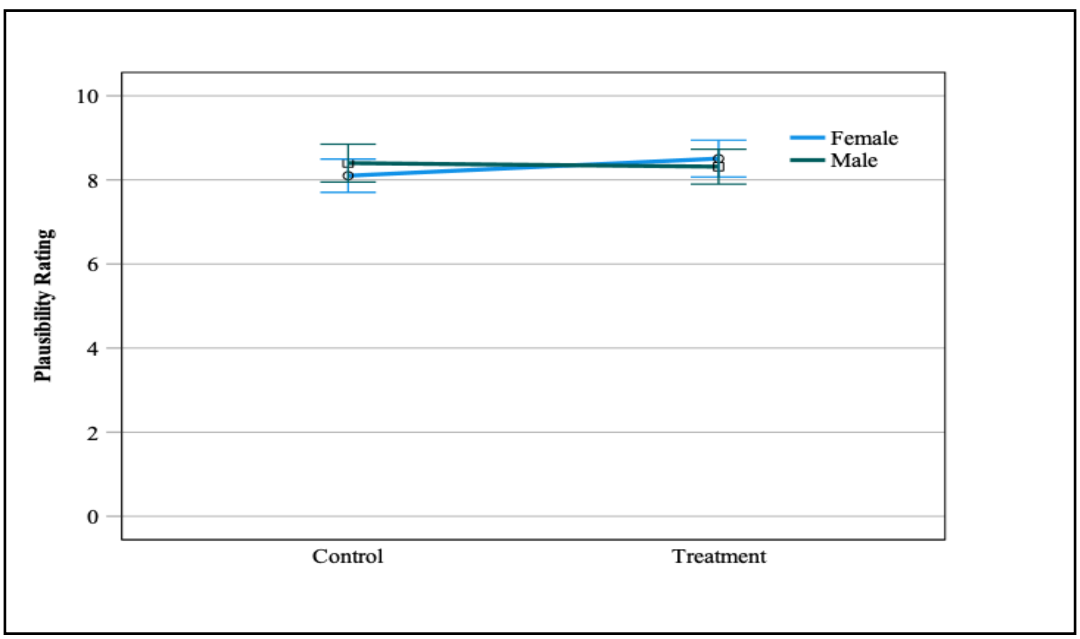
Table 10

Fixed-Effects ANOVA Results for Scientific Model Plausibility Ratings by Genders and Groups

Predictor	Sum of Squares	*df*	Mean Square	*F*	*p*	*η*
Intercept	445.98	1	445.98	211.435	0	.539
Model A pre-plausibility	44.297	1	44.297	21.001	0	.104
Group	1.183	1	1.183	0.561	0.455	.003
Gender	.129	1	.129	0.061	0.805	0
Group*Gender	2.771	1	2.771	1.313	0.253	.007
Error	381.784	181	2.109			

Figure 9

The Comparison of Scientific Model Plausibility Post-Test Scores by Genders and Groups



Note. Plausibility scores range from 1 to 10 (1 = highly implausible and 10 = highly plausible). Error bars indicate ±1 standard error.

Figure 9 above depicts the comparison of female and male students' Model A plausibility scores for each group. The gender gap was very close for the treatment group. Moreover, female students in the treatment group had higher post-test scores compared with male students. Both group’s female and male students had almost the same scientific model post-plausibility scores. This outcome did not support the gender gap expectation and my hypotheses (H_3 and H_{3-b}).

Overall, both the female and male students confirmed Model A scientifically more plausible by eliminating Model B less plausible. The female and male students had similar scientific model post-plausibility scores. However, there was a moderate gender gap for the control groups’ alternative model plausibility ratings with females in favor. However, the less gender gap in the treatment group supported that MEL instruction seems highly effective for creating gender equity in the classrooms.

Effectiveness of SSI-Based Instruction in Students’ Scientific Knowledge

The participants completed five items CC or W pre- and post-knowledge tests. Also, they participated delayed-post-test after two-week interval. Pre, post, and delayed-post-tests included the same five questions. In this section, I investigated RQ_2:

- How does Model Evidence Link (MEL) diagram affect students’ scientific knowledge of socioscientific topics? Are there any gender gaps?

Initially, I analyzed their combined topics, CC, and W scientific knowledge scores between the pre, post, and delayed-post-test regardless gender and group. Subsequently, I analyzed the participants’ combined and each topic pre, post, and delayed-post-test scientific knowledge scores by groups and genders. In this part, I anticipated that the students who participated in the MEL diagram activity had higher scientific post-knowledge scores than those who participated the control group activity in their post-knowledge scores. According to the gender gap highlighted in the literature review, I expected the gender gap in the present study. Last, I submitted the analysis of delayed-post-test results. In this analysis, I expected that the participants maintained the positive knowledge shift with their delayed-post-test knowledge scores.

For the second research question, my hypotheses:

- **Hypothesis (H_4):** The participants' scientific knowledge scores improve from pre- to post-instruction.
    - **Hypothesis ($H_{4\text{-}a}$):** The participants' delayed-post-test scores are almost similar to their post-test scores.
- **Hypothesis (H_5):** The students who participate in MEL with arrows-based instruction have higher scientific knowledge post-test scores than those who do not use arrows for MEL in their post-knowledge scores.
- **Hypothesis (H_6):** There is no a gender gap in their scientific knowledge post-test scores.
    - **Hypothesis ($H_{6\text{-}a}$):** The male participants' scientific knowledge post-test scores are similar to the female participants' scientific knowledge post-test scores.
    - **Hypothesis ($H_{6\text{-}b}$):** The male participants delayed-post-test scores are similar to the female participants delayed-post-test scores.

Overall Effectiveness of SSI-based Instruction on Students' Scientific Knowledge

In this section, I analyzed how SSI-based instruction influences the students' scientific knowledge from pre- to post-instruction. I used a repeated measures ANOVA test to analyze their knowledge test scores.

Combined Topics Knowledge Scores

To gain oversight of how SSI-based instruction was effective on the students' knowledge, I analyzed the students' overall knowledge scores. Thus, I combined the students' CC and W knowledge scores. I conducted a repeated measures ANOVA test to analyze the students' combined topics (CC and W) scientific knowledge scores for the combined groups (control and treatment), with scientific knowledge pre-and post-test scores as a dependent variable and time as a within-subjects factor. Table 11 depicts descriptive statistics for combined topics (CC and W) scientific knowledge pre- and post-test scores.

Table 11

Adjusted Means, Standard Errors, and Confidence Intervals for Combined Topics Knowledge Pre-and Post-Test Scores

	Mean	*S.D.*	Skewness		Kurtosis	
			Statistics	Std. Error	Statistics	Std. Error
Total pre-knowledge score	14.47	3.22	.356	.216	-.590	.428
Total post-knowledge score	16.02	3.18	.133	.216	-.770	.428

Note. Knowledge scores range from 5 to 25 (Each knowledge question ranges from 1=strongly disagree scientific knowledge to 5=strongly agree scientific knowledge).

The repeated measures ANOVA test revealed that there was a significant increase in their scientific knowledge scores between pre-and post-test, Wilks' $\lambda = .850$, $F(1, 125) = 22.096$, $p < 0.001$, $\eta^2 = .150$ (medium effect size). This outcome supported my hypothesis (H_4). In general, the students gained scientific knowledge after the SSI-based instruction.

Delayed-Post-Test Scores

The participants participated the knowledge test after two-week interval. I analyzed their delayed-post-test scores whether they retain their scientific knowledge gains after the MEL instruction. I conducted a repeated measures ANOVA to compare combined CC and W knowledge scores with time (pre, post, and delayed-post) as a within variable and knowledge score as the dependent variable. Table 12 shows descriptive statistics for pre, post, and delayed-post test scores.

Table 12

Adjusted Means, Standard Errors, and Confidence Intervals for Pre, Post, and Delayed-Post-Test Scores

	Mean	*S.D.*	Skewness		Kurtosis	
			Statistics	Std. Error	Statistics	Std. Error
Pre-knowledge	14.4762	3.22419	.356	.216	-.59	.428
Post-knowledge	16.0238	3.18613	.133	.216	-.77	.428
Delayed-post knowledge	15.8889	3.20555	-.015	.216	-.549	.428

Note. Knowledge scores range from 5 to 25 (Each knowledge question ranges from 1=strongly disagree scientific knowledge to 5=strongly agree scientific knowledge).

The repeated measures ANOVA revealed that there were significant increases in the participant's knowledge scores from pre- to delayed-posttest, Wilks' $\lambda = 0.834$, $F(2, 124) = 12.350$, $p < .001$, $\eta^2 = 0.166$ (large effect size). However, there was no significant decrease between post- and delayed-posttest, Wilks' $\lambda = 0.998$, $F(1, 125) = .283$, $p = .596$, $\eta^2 = 0.002$ (small effect size). The students' delayed-post knowledge scores decreased slightly compared to their post-test scores but still higher than their pre-knowledge test scores (Pre: $M = 14.47$, $SD = 3.22$, Post: $M = 16.02$, $SD = 3.18$, Delayed-post *M* = 15.88, *SD* = 3.20). This outcome backs my hypothesis ($H_{4\text{-a}}$). The participants retained their knowledge even two weeks interval.

Climate Change Knowledge Scores

A repeated measures ANOVA test was run to examine the students' CC scientific knowledge scores for the combined groups (control and treatment), with scientific knowledge pre-and post-test scores as a dependent variable and time as a within-subjects factor. Table 13 depicts descriptive statistics for CC scientific knowledge pre- and post-test scores.

Table 13

Adjusted Means, Standard Errors, and Confidence Intervals for CC Knowledge Pre-and Post-Test Scores

	Mean	*S.D.*	Skewness		Kurtosis	
			Statistics	Std. Error	Statistics	Std. Error
Total CC pre-knowledge score	16.85	2.69	0.028	0.441	-1.033	0.858
Total CC post-knowledge score	18.96	2.284	-0.555	0.441	-0.886	0.858

Note. Knowledge scores range from 5 to 25 (Each knowledge question ranges from 1=strongly disagree scientific knowledge to 5=strongly agree scientific knowledge).

The repeated measures ANOVA test showed that there was a significant increase in their scientific knowledge scores between pre-and post-test, Wilks' λ = .734, $F(1, 27) = 9.801$, $p = 0.004$, $\eta^2 = .266$ (large effect size). This finding supported my hypothesis (H_4). The students gained a meaningful CC knowledge with the SSI-based instruction.

Wetlands Knowledge Scores

A repeated measures ANOVA test was conducted to analyze the participants' W scientific knowledge scores for the combined groups (control and treatment), with scientific knowledge pre-and post-test scores as a dependent variable and time as a within-subjects factor. Table 14 represents descriptive statistics for CC scientific knowledge pre- and post-test scores. The repeated measures ANOVA test revealed that there was a significant increase in their scientific knowledge scores between pre-and post-test, Wilks' $\lambda = .828$, $F(1, 97) = 20.165$, $p < 0.001$, $\eta^2 = .172$ (large effect size). In this test, the participants improved their W knowledge. Thus, this result promoted my hypothesis (H_4). Overall, SSI-based instruction seemed highly effective for the participants gaining significant CC or W knowledge.

Table 14

Adjusted Means, Standard Errors, and Confidence Intervals for W Pre-and Post-Test Knowledge Scores

	Mean	*S.D.*	Skewness		Kurtosis	
			Statistics	Std. Error	Statistics	Std. Error
Total W pre-knowledge score	13.56	2.758	.410	.244	-.429	.858
Total W post-knowledge score	15.21	2.911	.330	.244	-.286	.858

Note. Knowledge scores range from 5 to 25 (Each knowledge question ranges from 1=strongly disagree scientific knowledge to 5=strongly agree scientific knowledge).

Effectiveness of SSI-Based Instruction in Students' Scientific Knowledge by Gender and Group

First, I analyzed the students' knowledge test scores from pre- to post-instruction by gender. Also, I examined their delayed-post-test scores by gender. A repeated ANOVA was run with knowledge scores as the dependent variable, time as the within-subjects factor, and gender as the between-subjects factor. Next, I analyzed how the MEL instruction impacted the female and male students' scientific knowledge post-test scores comparing to the control group instruction. Also, I examined whether the gender gap is for their post-test scores. ANCOVA tests were conducted in these analyses. Last, I analyzed their delayed-post-test scores by gender and groups.

Combined Topics Scientific Knowledge Scores by Gender and Groups

I conducted a two-way ANCOVA to examine the female and male participants' combined topics (CC and W) knowledge scores for the control and treatment groups with the post-knowledge scores as the dependent variable, gender and groups as the fixed factors, and the pre-knowledge scores as the covariate. Table 15 represents descriptive statistics for combined topics post-test scores regarding genders and groups.

Table 15

Adjusted Means, Standard Errors, and Confidence Interval of the Combined Topics Post-Test Scores by Genders and Groups

Group	Gender	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Control	Female	16.001	.536	14.939	17.063
	Male	15.851	.501	14.859	16.843
Treatment	Female	16.288	.541	16.682	17.360
	Male	15.969	.625	14.732	17.207

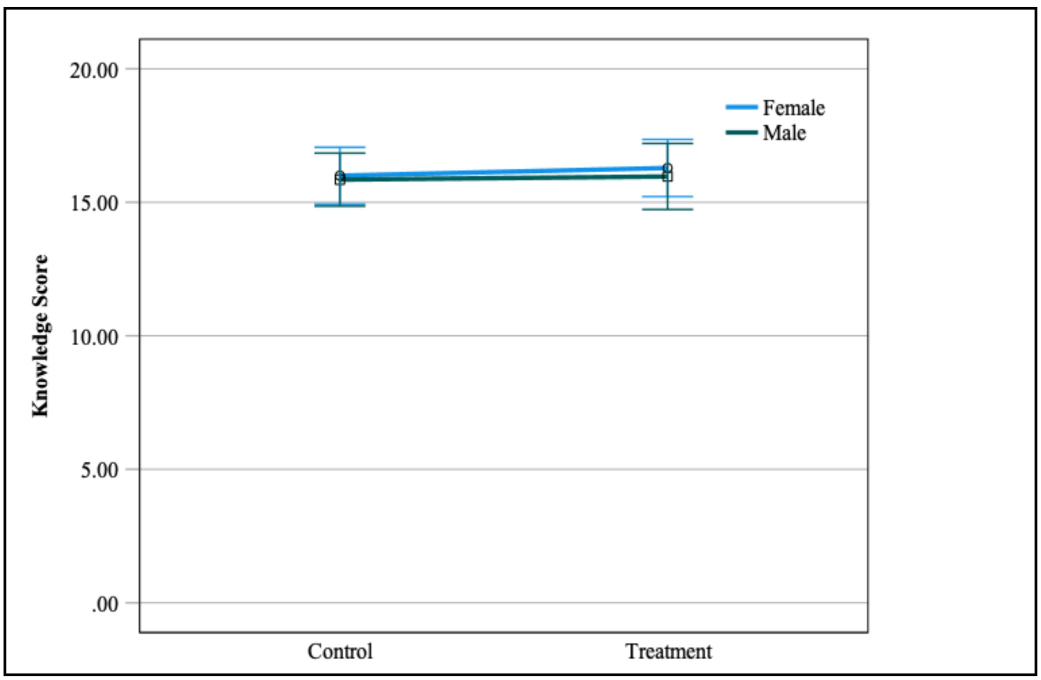
Note. Knowledge scores range from 5 to 25 (Each knowledge question ranges from 1=strongly disagree scientific knowledge to 5=strongly agree scientific knowledge).

Levene's test showed equal variances (F = 1.319, p = .271). The two-way ANCOVA reveals that there was no statistically significant effect of gender on combined topics post-knowledge scores after controlling for the combined topics pre-knowledge scores, $F(1, 121)$= .181, p= .671, η^2 = .001 (small effect size). Similarly, the main effect of group on combined topics post-knowledge scores was no statistically significant after controlling for the combined topics pre-knowledge scores, $F(1, 121)$= .131, p= .718, η^2 =

.001 (small effect size). The comparison of female and male students' combined topics post-knowledge scores can be seen on Figure 10. The females' post-test scores were slightly higher than males' post-test scores for both the control and treatment groups, but this difference was not significant. The similarity in the female and male students' combined topics knowledge scores supports my hypothesis ($H_{6\text{-}a}$). Based on this result, there was no gender gap for combined topics post-knowledge scores.

Figure 10

The Comparison of the Female and Male Participants' Combined Topics Post-Knowledge Scores by Groups



Note. Knowledge scores range from 5 to 25 (Each knowledge question ranges from 1 strongly disagree scientific knowledge to 5 strongly agree scientific knowledge). Error bars indicate ±1 standard error.

Climate Change Knowledge Scores by Gender and Groups

A two-way ANCOVA test was run to analyze the female and male students' CC knowledge scores for the groups (control and treatment), with the CC post-test scores as the dependent variable, gender and groups as the fixed factors, and the CC pre-knowledge scores as the covariate. Table 16 represents descriptive statistics for CC post-test scores regarding genders and groups and Table 17 shows the ANOVA results for CC post-knowledge scores by gender and groups.

Table 16

Adjusted Means, Standard Errors, and Confidence Interval of CC Post-Test Scores by Genders and Groups

Group	Gender	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Control	Female	19.392	.916	17.496	21.287
	Male	19.308	.915	17.415	21.201
Treatment	Female	18.457	.858	16.682	20.233
	Male	18.741	.996	16.681	20.8

Note. Knowledge scores range from 5 to 25 (Each knowledge question ranges from 1=strongly disagree scientific knowledge to 5=strongly agree scientific knowledge). Error bars indicate ±1 standard error.

Table 17

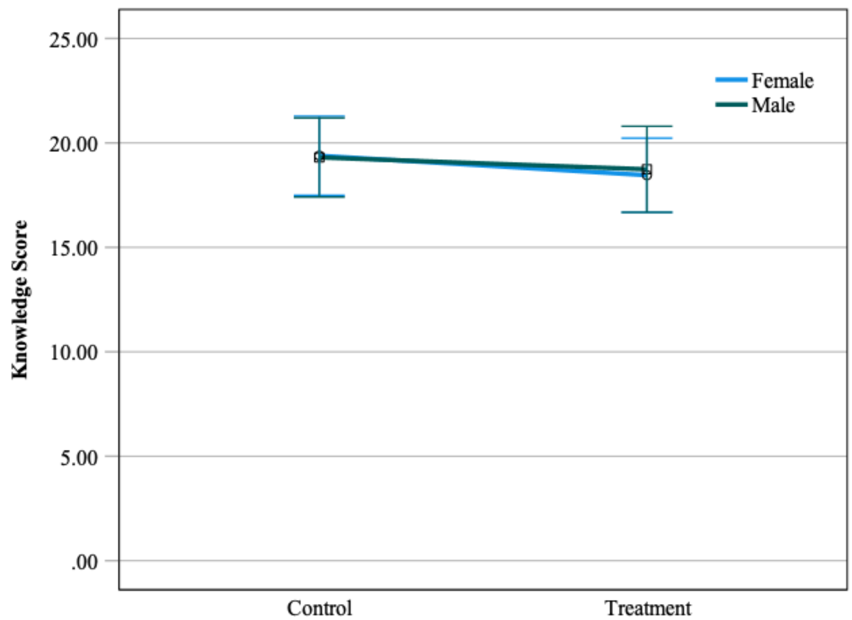
Fixed-Effects ANOVA Results for CC Post-Test Scores by Genders and Groups

Predictor	Sum of Squares	*df*	Mean Square	*F*	*p*	*η*
Intercept	268.303	*1*	268.303	45.871	< 0.001	.666
CC Pre-Knowledge	1.949	1	1.949	.333	.569	.014
Group	3.896	1	3.896	.666	.423	.028
Gender	.067	1	.067	.012	.916	.000
Group*Gender	.233	1	.233	.04	.844	.002
Error	134.527	23	5.849			

Levene's test showed equal variances (F = .230, p = .875). The two-way ANCOVA revealed that there was no statistically significant effect of gender on CC post-knowledge scores after controlling for the CC pre-knowledge scores, $F(1, 23)$= .012, p= .916, η^2 = .000. Similarly, the main effect of group on CC post-knowledge scores was no statistically significant after controlling for the CC pre-knowledge scores, $F(1, 23)= .666$, $p= .423$, $\eta^2 = .028$ (small effect size).

Figure 11

The Comparison of CC Post-Test Knowledge Scores by Genders and Groups



Note. Knowledge scores range from 5 to 25 (Each knowledge question ranges from 1=strongly disagree scientific knowledge to 5=strongly agree scientific knowledge). Error bars indicate ±1 standard error.

Also, the effect of the interaction between gender and groups on the combined CC post and delayed-post-test scores was not significant, whilst controlling for the CC pre-knowledge scores, $F(1, 23) = .040$, $p = .844$, $\eta^2 = .002$ (small effect size). The test results can be seen Table 17. Figure 11 above shows the comparison of their CC post-test knowledge scores for the control and treatment groups. For the control group, both genders increased their CC knowledge scores from pre- to post-test (Females Pre: M = 16.42, SD =2.63, Post: M = 19.42, SD = 2.50; Males Pre: M= 17.00, SD = 2.44, Post: M =

19.28, *SD* = 2.28). For the treatment group, both genders increased their CC knowledge scores from pre- to post-test (Females Pre: *M* = 16.37, *SD* =2.38, Post: *M* = 18.50, *SD* = 2.61; Males Pre: *M*= 17.50, *SD* = 3.56, Post: *M* = 18.66, *SD* = 1.96). These results did not support my hypothesis (H_5). However, the treatment group's post test scores were slightly lower than the control group's post-test scores.

Another finding is that females' and males' post-test scores were almost identical for both the control and treatment groups. These similarities can be seen in Figure 11. Based on the two-way ANCOVA results, my hypotheses (H_6 and $H_{6\text{-}a}$) were backed. Overall, females and males had similar CC post-test knowledge scores, and they gained meaningful CC knowledge after SSI-based instructions.

Wetlands Knowledge Scores by Gender and Groups

I conducted a two-way ANCOVA test to analyze females' and males' W knowledge scores for the groups (control and treatment), with the W post-knowledge scores as the dependent variable, gender and groups as the fixed factors, and the W pre-knowledge scores as the covariate. Table 18 depicts adjusted means, standard errors, and confidence interval for females' and males' W post-test scores by groups. Based on the two-way ANCOVA, Levene's test confirmed equal variances (F = .458, p = .712). There was no statistically significant effect of gender on the W post-knowledge scores after controlling for the W pre-knowledge scores, $F(1, 93)$= .181, p= .672, η^2 = .002 (small effect size). The main effect of group on W post-knowledge scores was not significant after controlling for the W pre-knowledge scores, $F(1, 93)$= .765, p= .384, η^2 = .008 (small effect size). Also, there was no statistically significant interaction between gender and groups on the W post test scores, whilst controlling for the W pre-knowledge scores, $F(1, 93) = .000$, $p = .997$, $\eta^2 = .000$. Table 19 shows ANOVA results.

Table 18

Adjusted Means, Standard Errors, and Confidence Interval of W Post-Test Scores by Genders and Groups

Group	Gender	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Control	Female	15.106	.585	13.944	16.268
	Male	14.854	.532	13.798	15.91
Treatment	Female	15.649	.608	14.441	16.857
	Male	15.392	.687	14.027	16.757

Note. Knowledge scores range from 5 to 25 (Each knowledge question ranges from 1=strongly disagree scientific knowledge to 5=strongly agree scientific knowledge).

Table 19

Fixed-Effects ANOVA Results for W Post-Test Scores by Genders and Groups

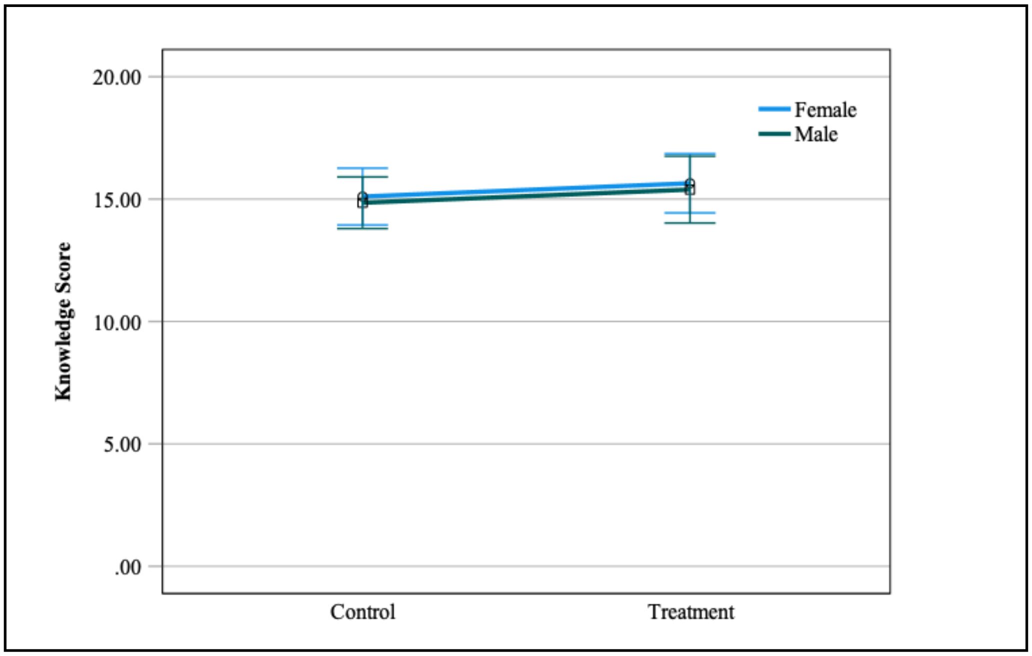
Predictor	Sum of Squares	*df*	Mean Square	*F*	*p*	*η*
Intercept	595.335	1	595.335	70.219	0	.43
W pre-knowledge	17.312	1	17.312	2.042	.156	.021
Group	6.483	1	6.483	.765	.384	.008
Gender	1.534	1	1.534	.181	.672	.002
Group*Gender	0	1	0	0	.997	0
Error	788.479	93	8.478			

Both groups' female and male students increased their W knowledge scores from pre-to post-test for both groups (Control (Females Pre: M = 12.42, SD =2.31, Post: M = 14.92, SD = 3.18; Males Pre: M= 13.43, SD = 3.03, Post: M = 14.83, SD = 3.00); Treatment (Females Pre: M = 14.70, SD =2.27, Post: M = 15.83, SD = 2.49; Males Pre:

M= 13.88, *SD* = 2.96, Post: *M* = 15.44, *SD* = 2.93)). Genders' similar results for both groups can be seen on Figure 12. The treatment group's W post-test scores were somewhat higher than the control group's W post-test scores. This statement supported my hypothesis (H_5). However, females' W post-test scores were slightly higher than males' W post-test scores. This result supported my hypothesis ($H_{6\text{-}a}$).

Figure 12

The Comparison of W Knowledge Post-Test Scores by Genders and Groups



Note. Knowledge scores range from 5 to 25 (Each knowledge question ranges from 1=strongly disagree scientific knowledge to 5=strongly agree scientific knowledge). Error bars indicate ±1 standard error.

Combined Topics Delayed-Post-Test Scores by Gender and Groups

I examined the female and male participants combined topics delayed-post-test knowledge scores by groups. A two-way ANCOVA test was run with the combined topics post-knowledge scores as the dependent variable, gender and groups as the fixed factors, and the combined topics post-knowledge scores as the covariate. Table 20 shows the descriptive statistics for the female and male participants' combined topics knowledge delayed-post test scores by the groups.

Table 20

Adjusted Means, Standard Errors, and Confidence Interval of the Combined Topics Delayed-Post Test Scores by Genders and Groups

Group	Gender	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Control	Female	15.775	0.45	14.884	16.666
	Male	15.865	0.458	14.959	16.772
Treatment	Female	16.282	0.425	15.441	17.123
	Male	15.471	0.527	14.427	16.514

Note. Knowledge scores range from 5 to 25 (Each knowledge question ranges from 1 = strongly disagree scientific knowledge to 5 = strongly agree scientific knowledge).

Table 21 above shows the two-way ANCOVA results. Levene's test showed equal variances (F = .694, p = .558).

Table 21

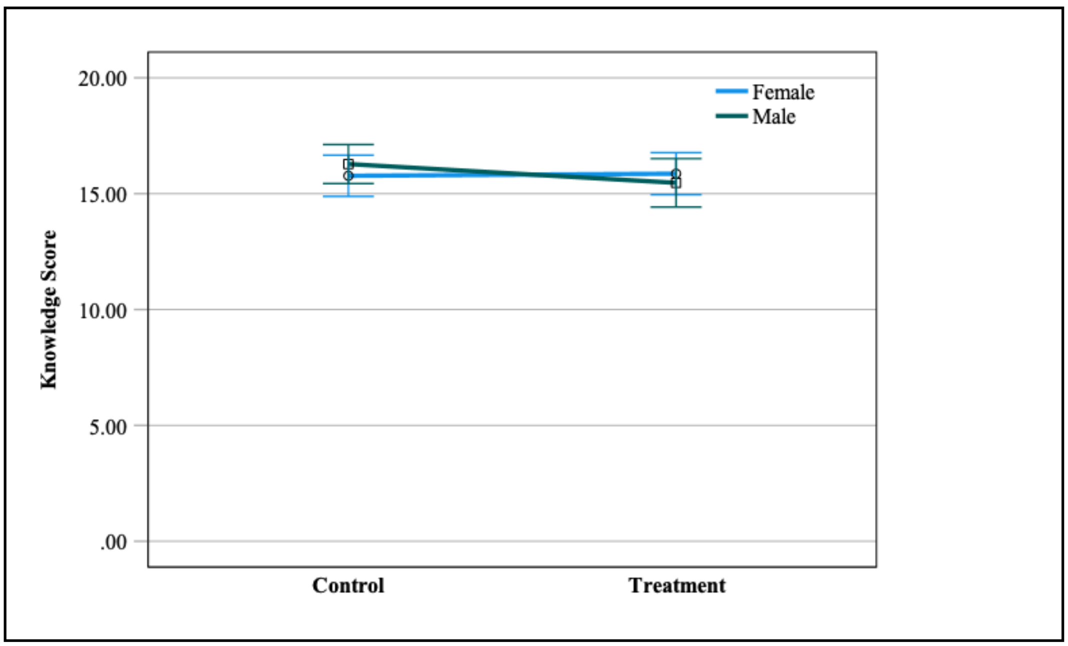
Fixed-Effects ANOVA Results for the Female and Male Participants' Combined Topics Delayed-Post Test Scores by Groups

Predictor	Sum of Squares	*df*	Mean Square	*F*	*p*	*η*
Intercept	172.407	*1*	172.407	25.868	< 0.001	.176
Post-Knowledge	467.976	1	467.976	70.214	< 0.001	.367
Group	3.953	1	3.953	.593	.443	.005
Gender	.096	1	.096	.014	.905	.000
Group*Gender	6.230	1	6.230	.935	.336	.008
Error	806.461	121	6.665			

There was no statistically significant effect of gender on combined topics delayed-post knowledge scores after controlling for the combined topics post-knowledge scores, $F(1, 121) = .014$, $p = .905$, $\eta^2 = .000$. Similarly, the main effect of group on combined topics delayed-post knowledge scores was no statistically significant after controlling for the combined topics post-knowledge scores, $F(1, 121) = .593$, $p = .443$, $\eta^2 = .005$ (small effect size).

Figure 13

The Comparison of the Female and Male Participants' Combined Topics Delayed-Post Knowledge Scores by Groups



Note. Knowledge scores range from 5 to 25 (Each knowledge question ranges from 1 = strongly disagree scientific knowledge to 5 = strongly agree scientific knowledge). Error bars indicate ±1 standard error.

The female and male students had similar combined topics delayed-post test scores for both groups (see Figure 13). This outcome supported my hypothesis ($H_{6\text{-}a}$).

However, for the treatment group, female students' delayed-post-test scores were slightly higher than females' delayed-post-test scores. These results partly confirmed my hypothesis ($H_{6\text{-}b}$). Looking at Figure 13, females' and males' similar delayed-post-test scores can be seen for both and control groups. Overall, female and male students' scientific knowledge retained very-well for both the control and treatment groups after the two-week interval. Also, there was no remarkable gender gap for their delayed-post-test scores.

Student Experiences in SSI-based Classroom

Research Question 3 (RQ_3): What are the female students' experiences in SSI-based instructional activity compared to male students?

First, I examined 151 (78 females and 73 males) students' general experience in SSI- based learning. Thus, I examined their three open-ended question survey questions' answers: overall activity experience, activity suggestion, and dream class questions (Open-ended question survey questions: Q_1, Q_2, and Q_7, see Appendix L). Next, I analyzed whether they would suggest this activity to other friends. Based on their cognitive and emotional experience reflections, I investigated why they wanted to recommend or not to suggest this activity to other friends. Subsequently, I analyzed their favorite and difficult features of SSI-based learning. I selected the most detailed, explanatory, and common statements for tables showing students representative statements about their SSI-based learning. Also, for each analysis, I examined whether the gender difference is in the participants" overall experience, activity suggestion, and the activity's favorite and difficult features evaluations.

Students General Experiences in SSI-Based Science Learning

In the first question in the survey, the participants evaluated their overall experiences. Table 22 shows the number of participants answering questions about general activity experience and activity suggestions. Seventy-seven females and seventy males reflected on your general experiences with SSI-based science learning. Seventy-three females and seventy-eight males answered the SSI-based activity suggestion choices. I added a few students' dream science classroom answers to analyze students' general experiences in SSI-based science classrooms. For a reason, surprisingly, thirteen students (six females and seven males) matched the SSI-based science classroom with their dream science classroom. Thus, I included these answers to investigate their general experiences in SSI-based science learning.

Table 22

The Numbers of Females and Males Answering Questions for Activity Experience, Activity Suggestion, and Dream Science Classroom

Gender	General Activity experience	Activity Suggestion	Dream Science Classroom
Male	70	73	7
Female	77	78	6

To evaluate general activity experiences, I asked the students Q_1:

- What kind of experience did you have with a socio-scientific issue-based learning activity?

In general, both genders used brief expressions when answering Q1. Their positive experience answers include words such as pretty cool, a very fun concept, good experience, useful learning. Negative experience statements contain terms such as boring, complicated, decent experience.

Figure 14

The Frequency and Percentage of Female Students' Overall Experience about SSI-based Science Learning

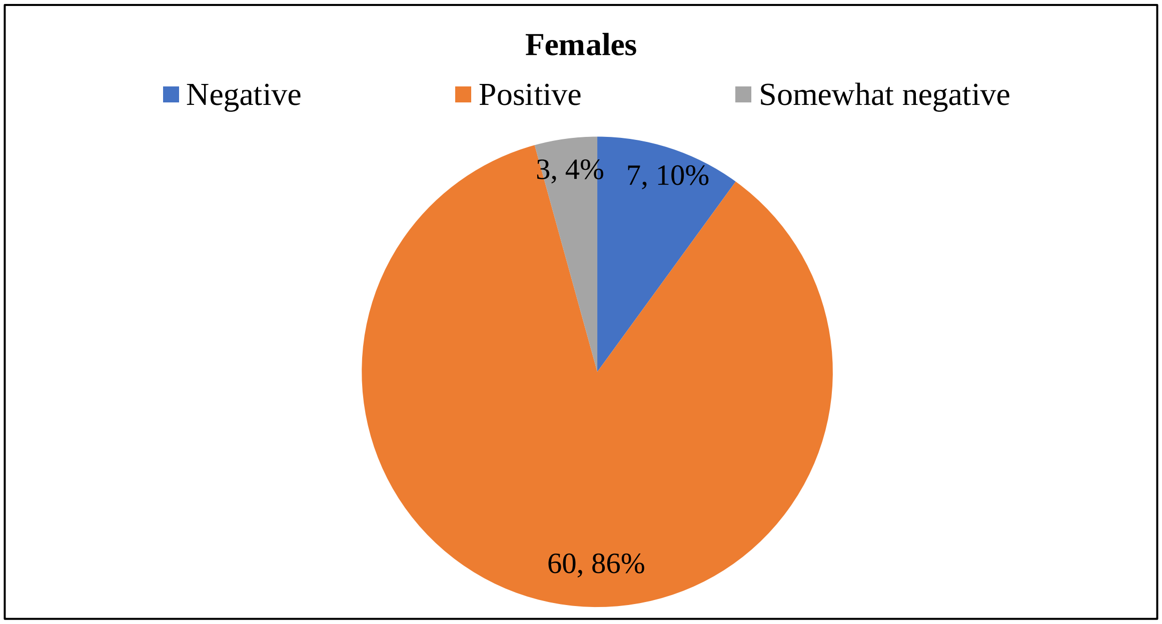
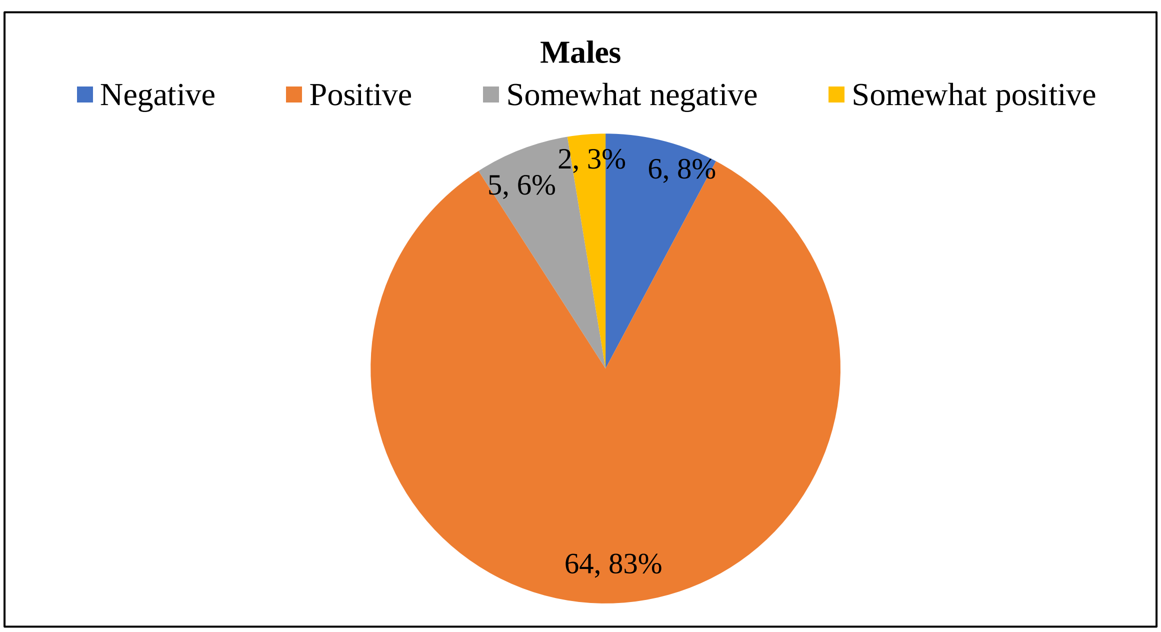


Figure 15

The Frequency and Percentage of Male Students' Overall Experience about SSI-based Science Learning



Figures 14 and 15 show the numbers and percentage of females' and males' overall experience with the SSI-based science classroom, respectively. Thirteen participants (seven females and six males) had negative experiences overall. However, over 80% of students (60 females and 64 males) had positive experiences in general.

Table 23

The Representative Responses to Students' General Experiences

Experience	Students	Representative Examples
Positive Experience	Female 94	"I had a good experience, I've never done something like this before."
	Female 98	"My experience was very informational, I never knew what wetlands were until now."
	Female 113	"I had a pleasurable experience I was not stressed and felt as if it was a nice minor load of work."
	Female 124	"I had a good experience while learning about climate changed because the activities were very organized and it was not boring to do. "
	Female 138	"I liked it I think it was fun and engaging that we got to look at different graphs"
	Male 3	"I like working in groups we learned a lot and did pretty well."
	Male 14	"It was pretty good, I got good knowledge of things."
	Male 30	"I've had fun. I enjoyed the socio-scientific activity quite a bit. More than I expected. Wasn't too challenging."
	Male 61	"I had a fun experience taking two really good pieces of evidence and narrowing it down to one better source."
Negative Experience	Female 81	"It was kind of boring."
	Female 107	"It was somewhat boring because it was designed to appeal to college students."
	Male 7	"It was very confusing also I think I would do better if I was working alone, would have made it a lot easier on me."
	Male 46	"Boring"
	Male 56	"It was tough especially learning how humans are most likely the main cause of climate change."

Note. The written statements are based on the general experience question answers.

Table 23 above shows the representative examples of some students having positive experiences in SSI-based science classroom. Looking at the students' negative experience, both genders mainly found the activity as boring. For positive experience statements, both genders mainly found it as informative and fun.

To understand the students' thoughts about SSI-Based learning, I argued that if they had good experiences, they would like to suggest it to their friends. Thus, I asked them as second question (Q_2) in the open-ended question survey:

Q_2: Would you suggest this activity to other friends? Why?

The participants answered, such as yes, no, probably yes, probably no, and unsure. Figures 16 and 17 below shows females' and males' activity suggestion rate and numbers, respectively. The total number of students answering the related question was 151, as 81 females and 73 males.

Figure 16

The Frequency and Percentage of Female Students' SSI-Based Science Learning Suggestion

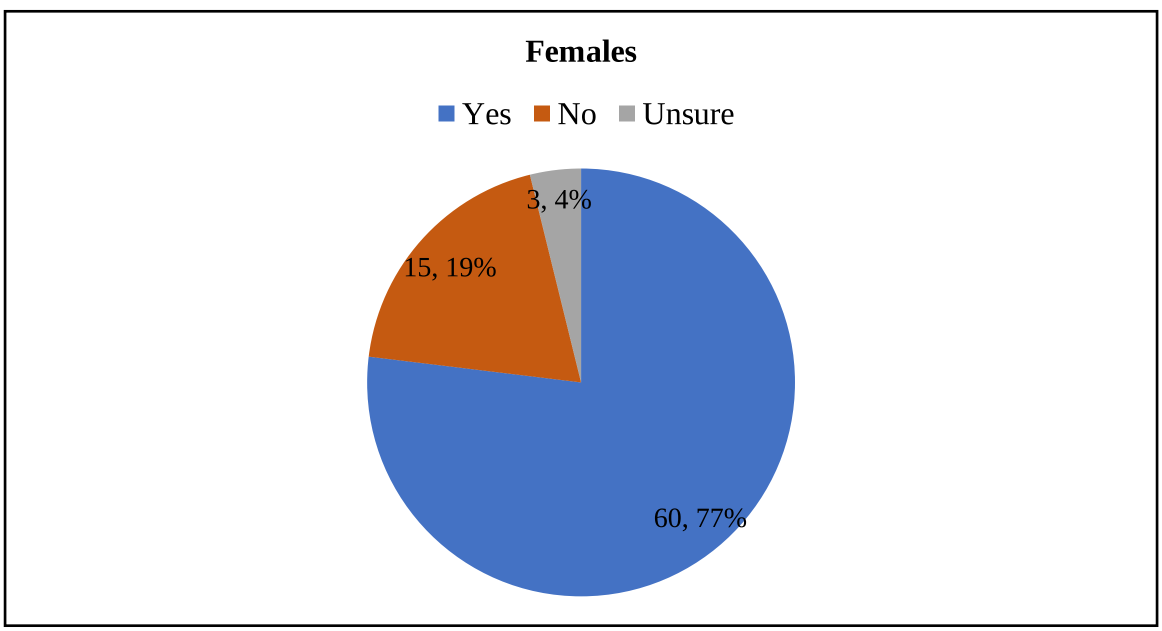
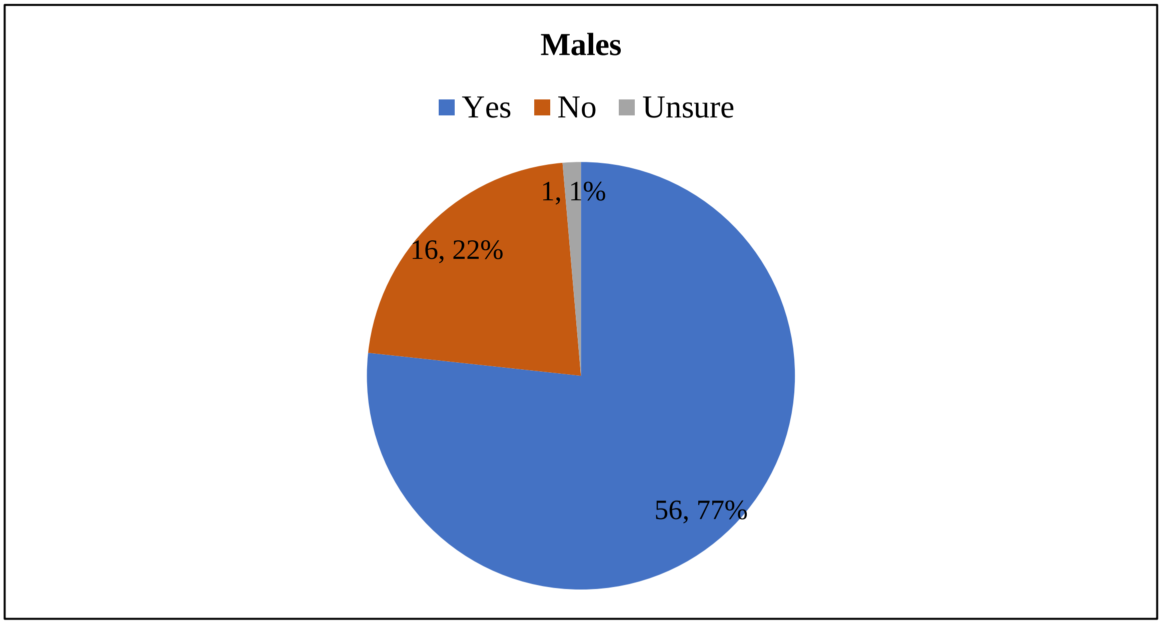


Figure 17

The Frequency and Percentage of Male Students' SSI-Based Science Learning Suggestion



Most females and males (60 females and 56 males) wanted to suggest this activity to their friends. However, 16 males and 15 females did not prefer to offer SSI-based learning to their friends. Also, four students (three females and one male) were unsure of recommending this learning to others.

Another indicator of their positive experience is their answers to the dream question (Q_7):

- If you were a science teacher, how would you design your 'dream' science classroom?

Table 24 shows the students' positive representative answers to the dream classroom question.

Table 24

The Representative Responses to Students' Dream Science Classroom

Students	Representative Examples
Male 29	*"I would design it with these activities."*
Male 62	*"I would make like these charts and plots to help them."*
Male 125	*"Just like this one."*
Male 1130	*"I would have my lessons similar to this science learning."*
Male 3211	*"My dream science classroom would probably be not different to the MEL."*
Female 131	*"I would design my science classroom with many visual and interactive activities like the MEL."*
Female 135	*"I would have lots of posters and visuals as well as doing these surveys and group workings."*
Female 1119	*"I like the set up like this activity."*
Female 3316	*"I would use the MEL because I feel it is a fun and easy way for students to learn material without me telling them the answers."*

Note. The written statements are based on the dream science classroom question.

Based on thirteen students' (six females and seven males) in Q_7 answers, SSI-based classroom took place in these students' reflective statements. Male 125 and Female 1119 participated the control group activity. In particular, the difference between the control and treatment groups can be seen in their dream classroom answers. The number can be seen as minor. However, although the students took part the first time in SSI-based learning, they could match this new learning with their dream science classroom.

Overall, based on the responses to three questions (general SSI-based science learning activity experience, SSI-based science learning suggestion to their peers, and dream science classroom), the students wrote positive expressions about their experiences. Most females and males evaluated their experiences in SSI-based science activities as positive. The majority of females and males wanted to suggest the SSI-based learning activity. Last, even though they participated in this activity for the first time, they accepted this new pedagogical approach for their dream science classroom. In general, both female and male students had positive experiences with SSI-based science learning.

Students' Cognitive and Emotional Experiences in SSI-Based Science Learning

I classified the student open-ended question responses into three main categories: Cognitive, Emotional, and Cognitive-Emotional Experiences related to the students' reflective responses in the open-ended survey. Cognitive Experiences are based on the activities' mental process of gaining knowledge and understanding the connection between models and lines of evidence through the SSI-based science activities. Some students reflected their cognitive experiences such as easy or difficult to learn, informative learning, understanding in supporting or contradicting evidence process, matching of arrows to models. Also, some students reflected on their experiences using emotional expressions related to their level of psychological mood, such as interested, disinterested, enjoyed, unenjoyed, bored, or fun. I associated these kinds of experiences with Emotional Experience. Some students reflected both cognitive and emotional experiences in their answers. These answers were categorized under the Cognitive-Emotional Experience.

Each experience has both positive and negative sides. I investigated the students' experience as positive, negative, or positive and negative. To clarify, informative learning, useful learning, easy to understand are under the Positive Cognitive Experience category. Difficult, useful, or uninformative learning is in the Negative Cognitive

Experience category. The expressions such as interested, engaged, enjoyed are under the Positive Emotional Experience category. Their disinterested, disengaged, unenjoyed statements are under the Negative Emotional Experience category.

I examined the students' cognitive, emotional, and cognitive-emotional experiences based on their activity suggestion (Q_2) and activity favorite (Q_3) and difficult features (Q_4) open-ended question answers. First, I analyzed their experiences based on their activity suggestion explanation. Next, I investigated their activity favorite and challenging features together to understand both females' and males' SSI-based science learning experiences.

Students Cognitive and Emotional Experiences Considering Activity Suggestion Evaluations

I argued about participant experiences relating open-ended questions to the activity suggestion. Based on Figures 16 and 17, almost similar number of females and males wanted to suggest (60 females and 56 males) or not to suggest (15 females and 16 males) the SSI-based science learning to their peers. Also, three females and one male were unsure to suggest the activity. First, I examined the participants' experience statements to understand why suggest or not suggest this learning to their friends. 68 females and 69 males explained their suggestion or not suggestion reason. Table 25 shows the number of females' and males' cognitive, emotional, and cognitive-emotional experiences based on their activity suggestion question responses.

Looking at Table 25, there are some similarities between females' and males' experiences. In general, both genders expressed positive cognitive experiences. The number of males having positive cognitive experiences is higher than that of females having positive cognitive experiences. The number of females and males having cognitive experiences was higher than females and males having emotional experiences. The total number of students having negative cognitive experiences is relatively small (four females and four males). For emotional experience, the number of females is higher than the number of males. Twenty females and nine males expressed positive cognitive-positive emotional experiences as the suggestion reason for their open-ended writings.

Table 25

The Number of Students' Cognitive, Emotional, and Cognitive-Emotional Experiences

Gender	Total Number	Categories					
		Cognitive Experience		Emotional Experience		Cognitive-Emotional Experience	
		Negative	Positive	Negative	Positive	Positive-Positive	Positive-Negative
Male	69	4	39	12	4	9	1
Female	68	4	26	10	8	20	-

Note. The results are based on the students' activity suggestion answers.

Based on Table 25, a small percent had negative Cognitive and Emotional experiences for the SSI-based science learning. The number of females and males who had negative emotional experiences was higher than females and males who had negative cognitive experiences. Table 26 represents the representative examples for the students not wanting to offer the SSI-based science learning to their peers. Six students evaluated the activity as boring. Most students who did not want to suggest the SSI-based science learning reflected on the statements related to the lack of interest in science. These reflective statements show a similarity in the reason for not suggesting for males and females. Most students who did not recommend this learning assumed their friends as disinterested in science.

Table 26

The Representative Responses Related to Not Suggestion the SSI-Based Science Activity

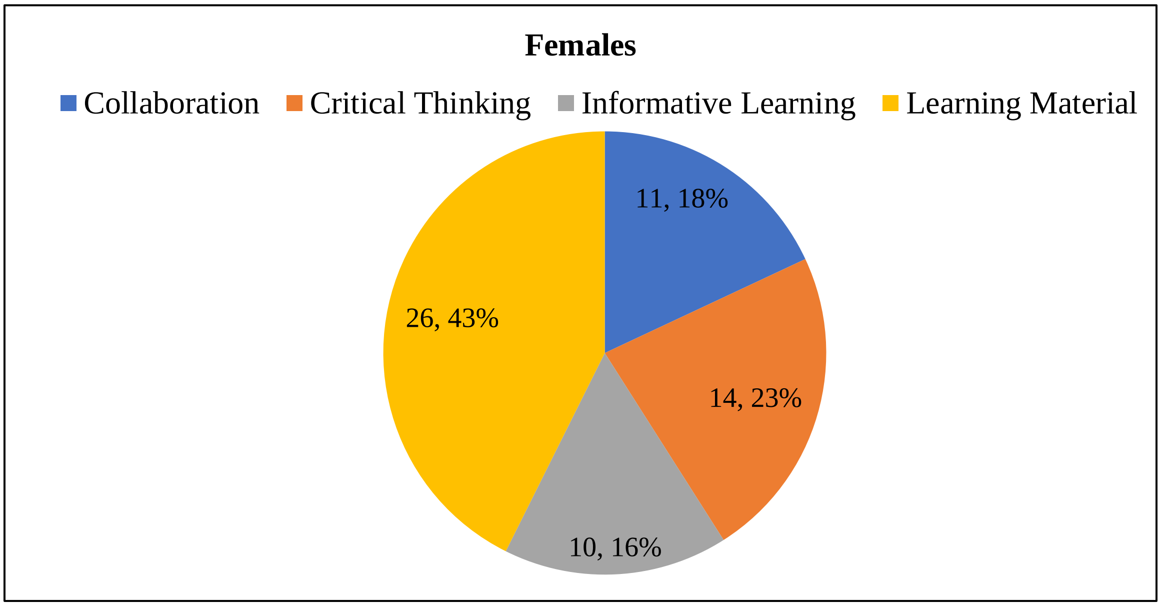
Students	Representative Examples
Male 5	*"No, it's boring."*
Male 6	*"Online schooling and activities are hard."*
Male 18	*"Probably not they may not interest in it."*
Male 20	*"No because I am, pretty sure people would rather do other important work than this."*
Male 25	*"No, my friends aren't interested in science."*
Male 39	*"It was boring."*
Male 40	*"It is time consuming and also the words are complicated."*
Male 47	*"Not really because my friends don't like science."*
Female 73	*"No, because I don't think they would be interested."*
Female 83	*"This boring."*
Female 91	*"No, because they are not interested in science."*
Female 96	*"Probably not, some of them aren't into science topics."*
Female 99	*"No. It seems a little complicated."*
Female 135	*"No because I didn't really learn a lot and it was confusing."*

Note. The results are based on the students' activity suggestion answers

On the other hand, I investigated why the students suggested SSI-based science learning to their friends. According to Table 25, both females and males who wanted to recommend this science instruction to their peers explained their recommendation reasons, expressing mainly positive cognitive experiences. Thus, I investigated their activity suggestion reasons considering the participants positive cognitive experiences.

Figure 18

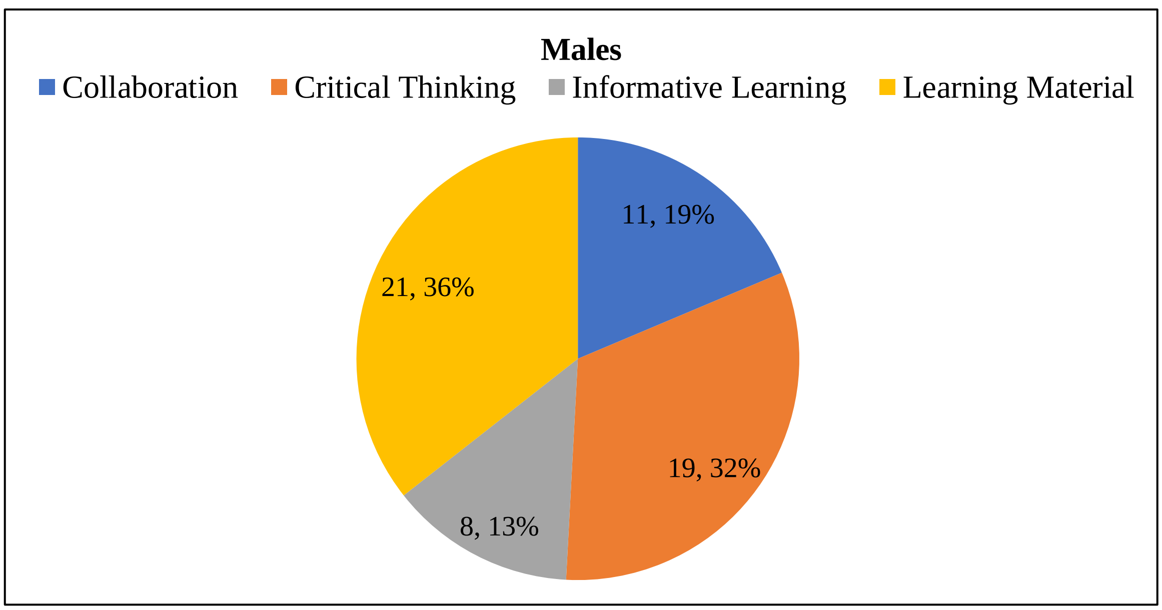
Female Students' the Activity Suggestion Categories



Note. The figure is based on the males' activity suggestion open-ended question responses.

Figure 19

Male Students' the Activity Suggestion Categories



Note. The figure is based on the males' activity suggestion open-ended question responses.

The Figures 18 and 19 above show the activity suggestion categories for females and males based on their positive cognitive experiences. Most females and males who had positive cognitive experiences explained the suggestion of gaining scientific knowledge with SSI-based learning. Second, all genders wanting to suggest the activity with its critical thinking feature, and females did not reflect this learning's collaborative learning as the suggestion reason. However, nine males highlighted the collaboration in the activity for the recommendation of their friends. These results show that females and males had similar positive cognitive experiences in the SSI-based classrooms.

Looking at the emotional experiences, 12 students wanted to recommend the activity with their positive emotional experiences. In specific, four males and eight females wanted to suggest SSI-based science activities with its enjoyable side. Last, nine males and twenty females tried to offer it with their positive cognitive-emotional experiences.

Table 27

The Categories of Males' and Females' Cognitive and Emotional Experiences

Gender	Categories	Number
Male	Collaboration-Enjoyment	1
	Collaboration-Interest	1
	Critical Thinking-Enjoyment-Interest	1
	Critical Thinking-Interest	2
	Informative-Interest	2
	Informative-Enjoyable Learning	2
Female	Critical Thinking-Enjoyable Learning	2
	Critical Thinking-Enjoyable-Informative Learning	2
	Critical Thinking-Interesting Learning	3
	Informative- Enjoyable Learning	10
	Informative-Interesting Learning	3

Note. The figure is based on the students' activity suggestion open-ended question responses.

Table 27 above shows the categories for males' and females' cognitive and emotional experiences. For combined cognitive and emotional experiences, informative- enjoyable learning is the first ranking for females, while the suggestion reasons are very diverse for females and males.

Students Cognitive and Emotional Experiences Considering Activity Favorite and Difficult Features Evaluations

The students evaluated the SSI-based science learning's favorite and difficult features in the open-ended question surveys. 70 males and 70 females expressed their activity favorite feature(s). Five males and eight females did not have favorite feature of this activity. 44 males and 53 females assessed this science learning difficult side(s). Table 28 shows how to evaluate the activity expressing students' cognitive, emotional, cognitive, and cognitive-emotional experiences. Interestingly, the students did not express cognitive-emotional experiences for the activity difficult feature question. When examining the categories for each experience, I found some gender similarities for each experience. Both genders mainly evaluated both the activity favorite and difficult features with their cognitive experiences.

Table 28

The Number of Students' Cognitive, Emotional, and Cognitive-Emotional Experiences

Gender	Total Number	Categories				
		Cognitive Experience		Emotional Experience		Cognitive-Emotional Experience
		Negative	Positive	Negative	Positive	Positive-Positive
Male	69	-	59	1	6	3
Female	69	-	61	-	4	4

Note. The results are based on the students' activity favorite feature question.

Figures 20 and 21 show the categories for females' and males' the SSI-based science learning activity favorite feature.

Figure 20

The Categories for Females' SSI-Based Science Activity Favorite Features

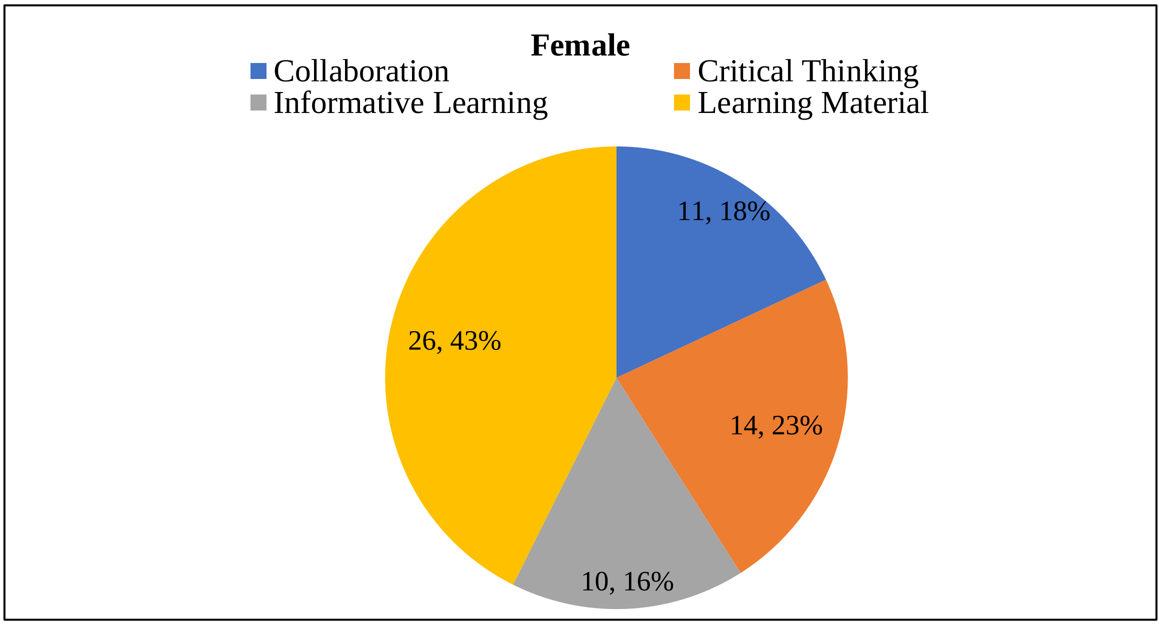
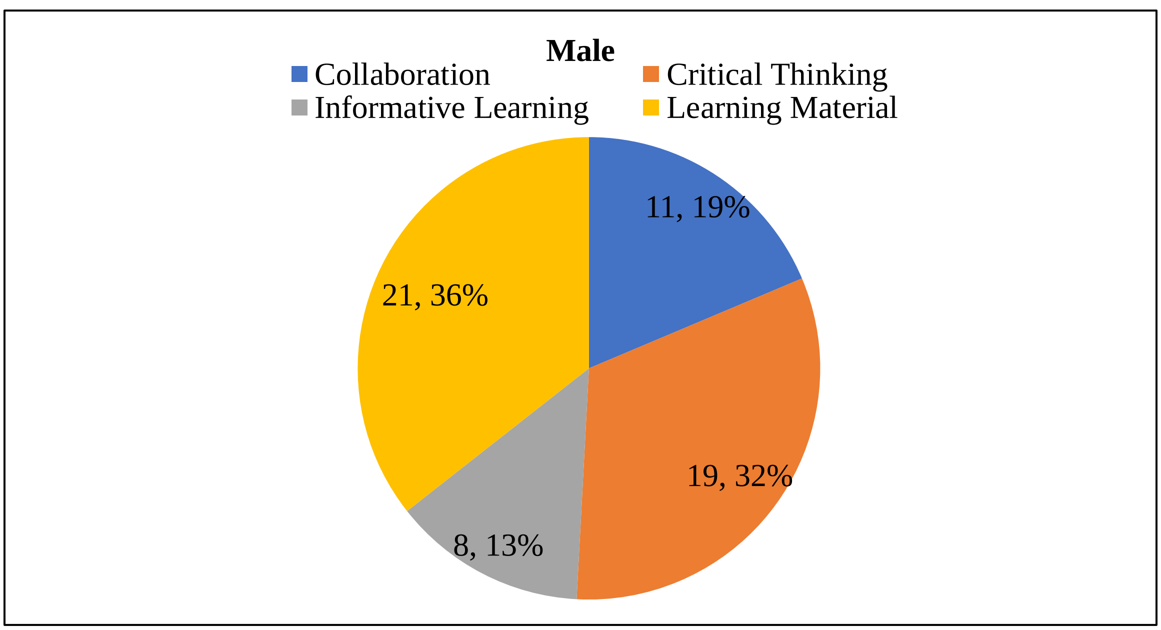


Figure 21

The Categories for Males' Favorite SSI-Based Science Activity Favorite Features



The most favorite feature is the activity instruments, and critical thinking is the second favorite feature for both males and females. Similarly, collaboration and gaining knowledge are the third and fourth favorite features for both genders. After analyzing the students' positive emotional experiences, I found engagement and enjoyment in their favorite features for both males and females. For the cognitive-emotional experience main category, both genders chose the features under critical thinking enjoyment and informative-enjoyment categories. They evaluated the SSI-based learning favorite features similarly.

78 females and 68 males answered the SSI-based science learning difficult feature based on their experiences. 19 females and 26 males did not find any difficult feature in this science learning. Males found critical thinking as the most difficult feature. 59 females and 42 males described the activity's difficult sides based on their cognitive and emotional experiences. They did not reflect the statement related to cognitive-emotional experience category. Table 29 shows the numbers of females' and males' activity difficult feature question evaluations based on their cognitive and emotional experiences.

Table 29

The Number of Students' Cognitive, Emotional, and Cognitive-Emotional Experiences

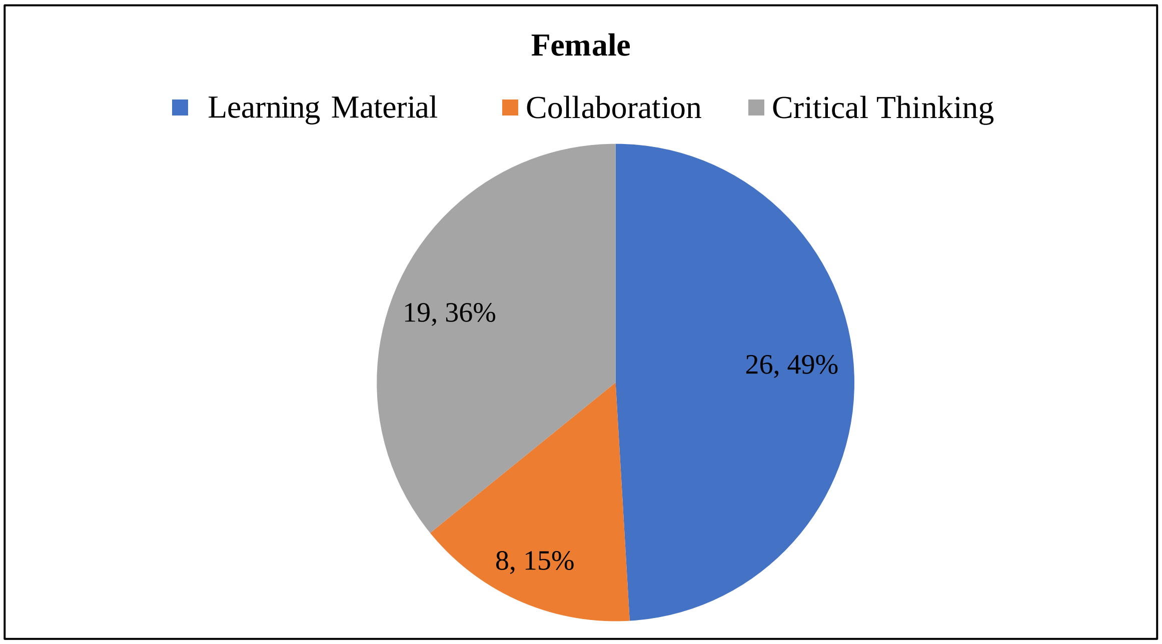
Gender	Total Number	Categories			
		Cognitive Experience		Emotional Experience	
		Negative	Positive	Negative	Positive
Male	42	37	-	5	-
Female	59	53	-	6	-

Note. The results are based on the students' activity difficult feature question.

They mainly described the difficult features with their negative cognitive experiences. Six females and five males matched them with negative emotional experiences. Figures 22 and 23 depict the categories for the activity complicated features by females and males, respectively.

Figure 22

The Categories for Females' Activity Difficult Features



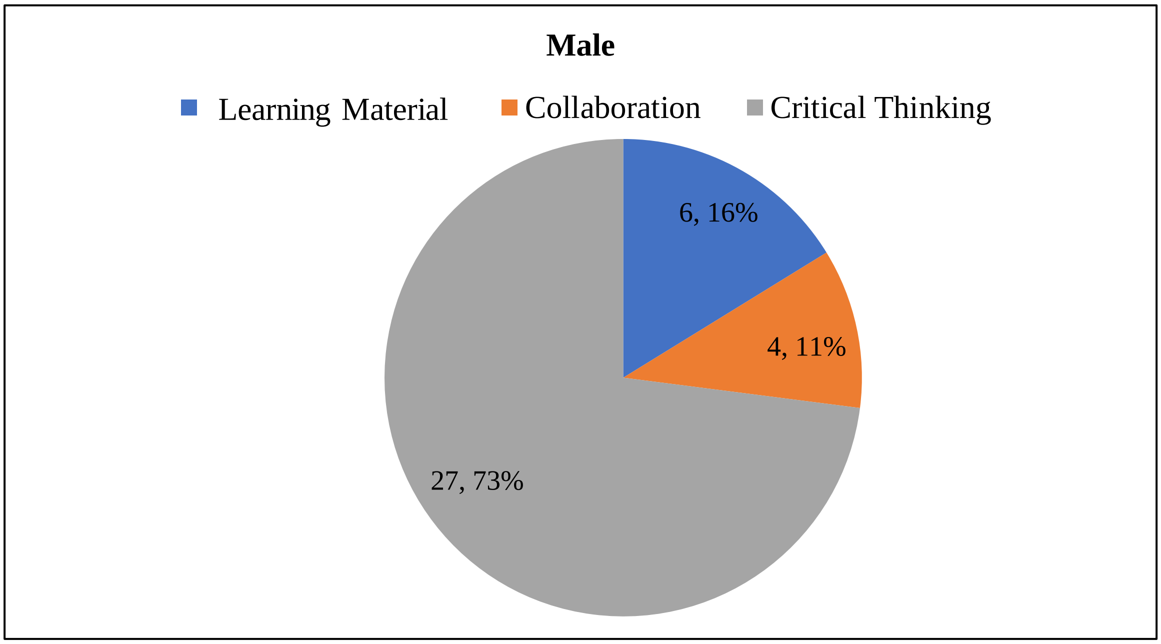
Over %70 of males found the activity's critical thinking as complex. Also, activity instruments and collaboration were evaluated as difficult. Similarly, almost half of the females categorized the activity instrument is challenging. Second, 36% of females defined critical thinking as difficult, and 15% found collaboration as challenging. For the collaboration, both genders expressed that their group members did not efficiently participate in the discussion. For example:

> Female 75: "*My group didn't want to share their arrows ideas*."
> Female 77: "*Just my group honestly I just carried all the weight of the assignment on my shoulders*."

Male 4: "*Working with team, what make it difficult because other student don't participate*."
Male 27: "*It was kinda hard to get people to work or talk during the discussion part of the activity*."

Figure 23

The Categories for Males' Activity Difficult Features



Teacher 3 explained the collaboration challenge with the students' first-time experience with the MEL and also the MEL's virtual version because they did not feel so relax in the virtual MEL compared to the in-person version.

The students expressed the learning material challenges. They mainly encountered drawing arrows in online version. For example:

- Female 148: "*My computer crashed when drawing arrows*."
- Boy 6: "*Trying to connect the arrow correctly*."
- Boy 66: "*On the slides for the model and evidence, a little connection issue.*"

Also, they found some instructions' and evidence texts' reading level higher.

- Female 95: "*The instructions were a little confusing so i had to read them a few times*."
- Female 96: "*I didn't understand some of the questions*."

- Female 102: "*Some of the questions I had to reread multiple times to understand it.*."
- Male 11: "*Nothing really maybe the wording just got me confused. But other than that it was good*."
- Male 48: "*I had difficulty understanding some of the graphs and texts*."

Looking at the critical thinking category, both female and male students wrote similar challenges in their answers.

- Female 94: "*The hardest part was probably analyzing the models to see if it supported, contradicted, etc.*."
- Female 139: "*I found it hard to rate the*."
- Male 26: "*I didn't really have any except the compare and contrast*."
- Male 33: "*The only difficulty during this activity was creating a final ranking for the models.*"
- Male 51: "*I did not really face any issues besides matching*."

Based on both genders' answers, there was a similarity in the activity feature difficulties between females and males. They reflected same challenges for each category.

Students Career Plans

Research Question 4 (RQ4): What is the effect of SSI-based science instruction on female students' experiences for pursuing science-related career plans compared to male students?

To answer this research question, I analyzed students' answers about future career jobs, the factors for choosing their career jobs, and their science person identity's questions answers. 64 females and 65 males shared their future career jobs. Fourteen females and eight males did not determine their future career jobs. The number of female students who did not decide their career jobs was approximately twice as the number of male students not deciding their future jobs.

I tried to categorize the students' future career jobs based on three categories: Biomedical science, STEM, and other. Biomedical science includes the fields of biology and medicine. The careers in biomedical sciences (BS) are biology, dentistry, medicine, pharmacy, and veterinary medicine. The jobs in STEM are related to, chemistry, engineering, mathematics, physics, and technology. Non-STEM/BS are unrelated to STEM and BS with a diversity, such as art, business, music, and sports. Figures 24 and 25 represent the percentage of these three categories for females' and males' future career jobs, respectively. Other jobs category came first for both genders. Even though many the male students, 37%, wanted to continue STEM career jobs, a small minority of the female students, 13%, wanted to pursue a STEM field jobs.

Figure 24

Females' Future Career Jobs

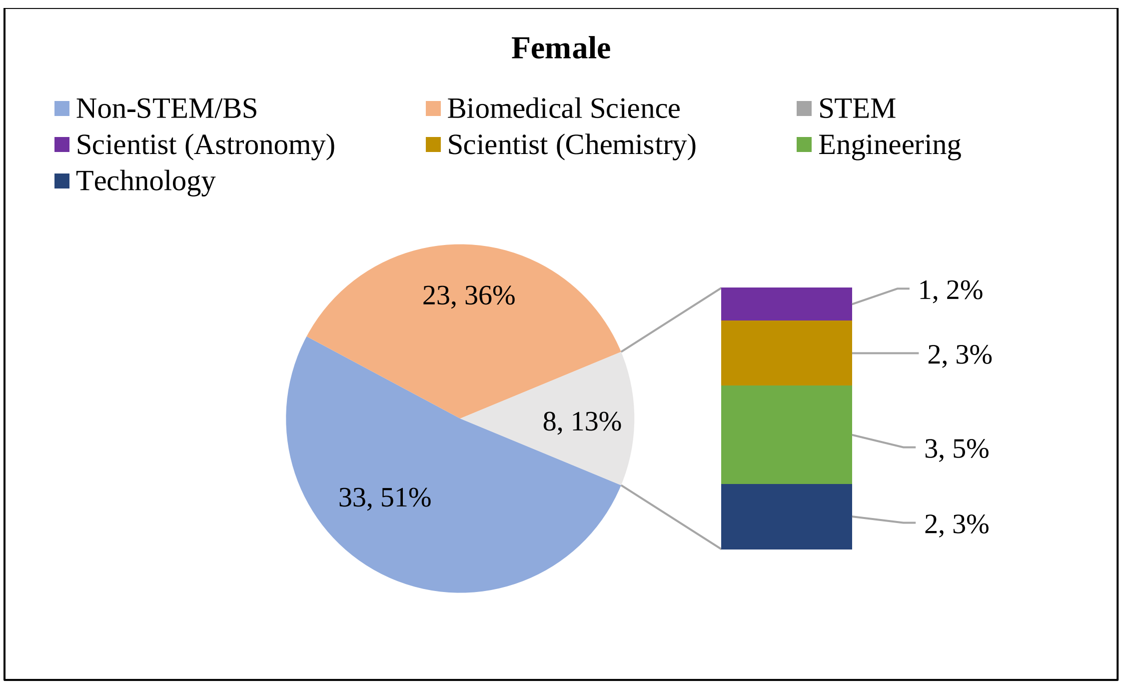
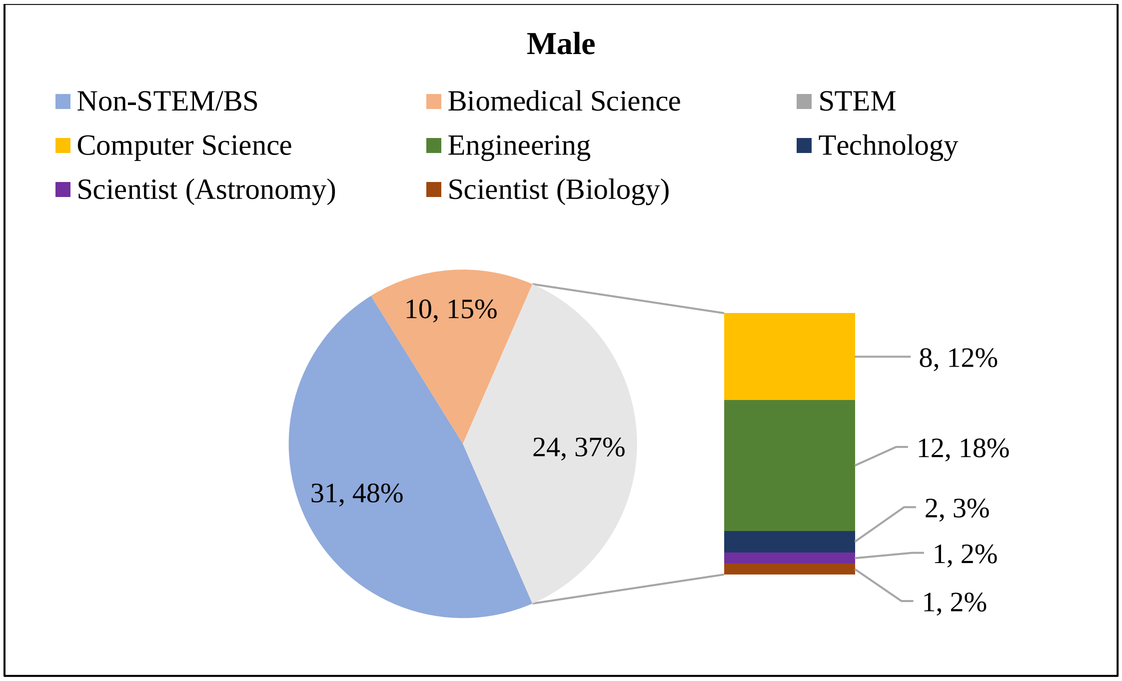


Figure 25

Males' Future Career Jobs



Females mostly preferred biomedical science fields of over 20% as opposed to males who numbered around 10. The results shows that there is a gender gap for choosing science-related career plans. Looking at to how to diverse biomedical field career jobs, four male students wanted to be a career in the medicine, three males wanted to be veterinarian, two male students wanted to be a dentist, and one male wanted to pursue a career in the pharmacy. The female students who wanted a biomedical career mainly wanted to be doctor (twelve females), nursing (four females) followed the medicine, and the dentist and veterinarian came next. Similarly, only one male student wanting the pharmacy future career job, only one female wanted to be a career in the pharmacy. The number of female students who wanted to be a career in the biomedical science fields were higher than the number of male students. However, both genders wanted mostly to be a doctor.

Figure 26

The Factors of Females Choosing the Career Job

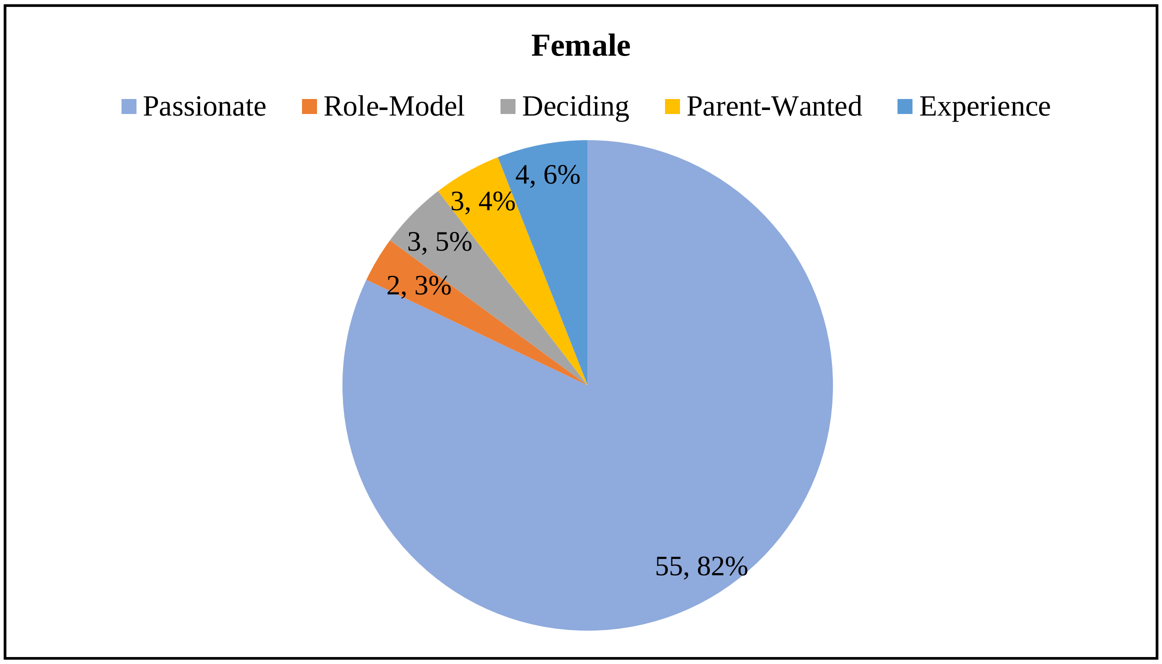
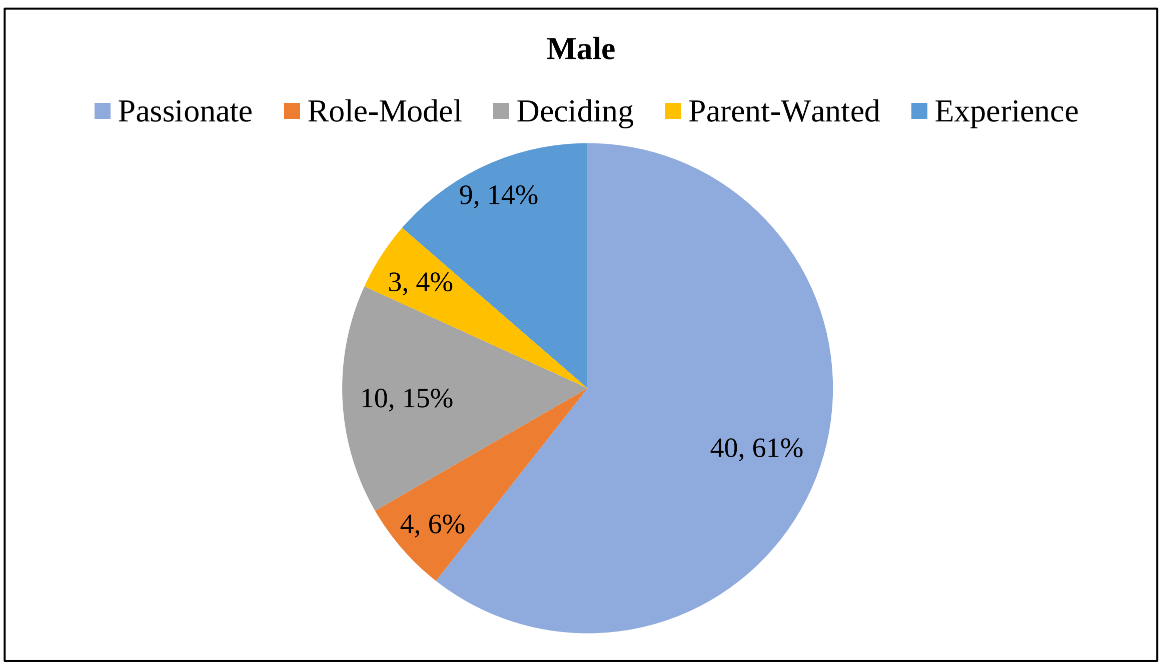


Figure 27

The Factors of Males Choosing the Career Job



Second, I analyzed the open-ended question responses regarding how to determine the future career jobs. Figures 26 and 27 above shows factors of females' and males' future jobs choosing factors. Based on figures, passionate played a crucial key for choosing the future job for both males and females. In specific, the females with passionate determined your careers. Males also considered their experiences and decisions for following the career jobs.

I also asked them whether they describe themselves as a science person. The number of participants who described themselves as "science person" is similar for both genders. These similar rates can be seen on Figure 28 and Figure 29. Even though %12 females wanted to continue a STEM career, over half of females described themselves as science person.

Figure 28

The Frequency and Percentage of Females Describing themselves as Science Person

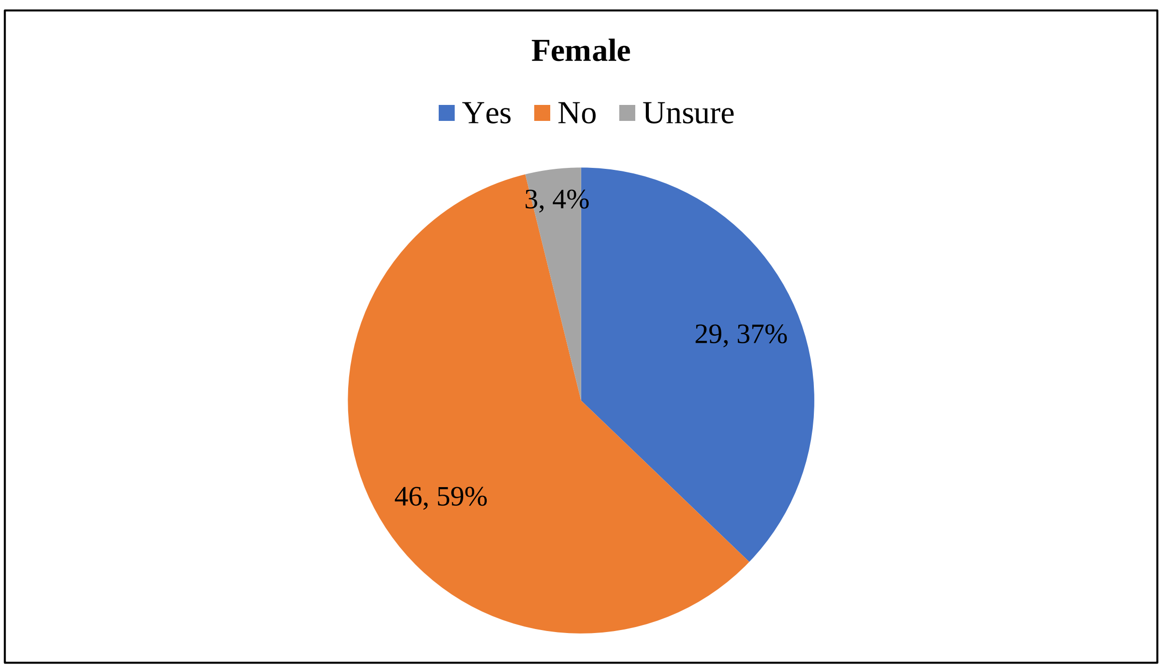
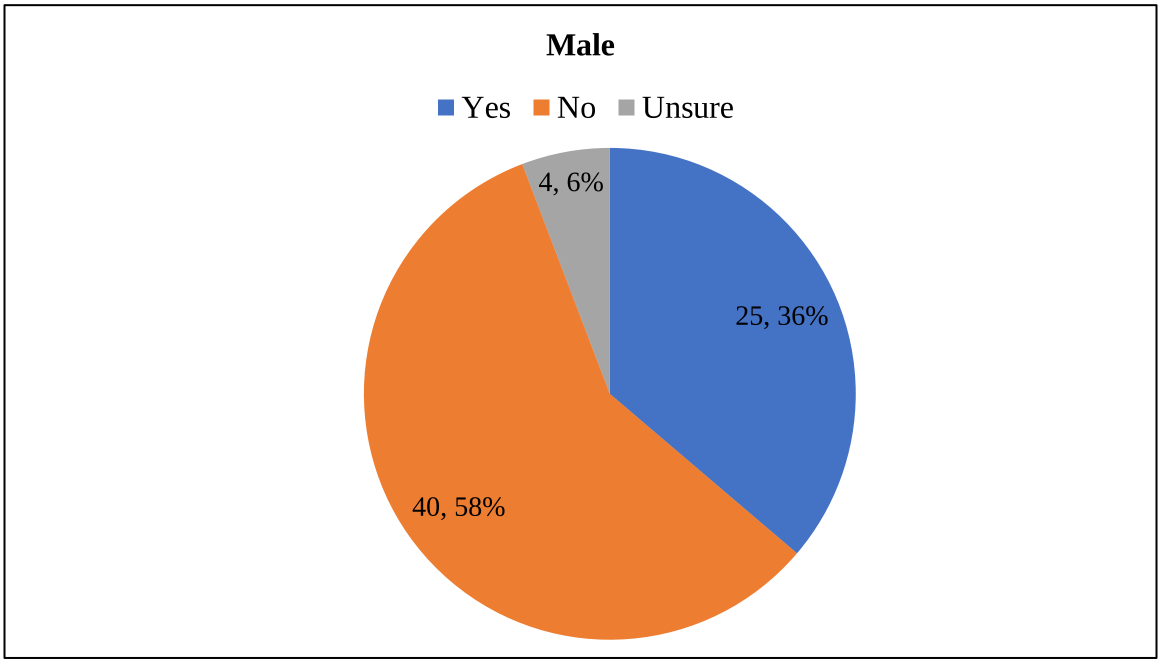


Figure 29

The Frequency and Percentage of Males Describing themselves as Science Person



Overall, similar percent females and males described themselves as science person. However, females did not prefer STEM career even though most males wanted to pursue STEM career.

Dream Science Classroom

Student views are essential for further research steps. Thus, I asked a question in the open-ended question survey for the students to describe their dream science classroom. The main purpose of this question is to get ideas on how SSI-based learning could be developed better. I created two categories (i.e., Classroom atmosphere and Teaching designs) by analyzing the female and male students' written explanations. The categories are visualized in Figures 30 and 31.

Figure 30

Female and Male Participants' Dream Science Classroom Atmosphere Design

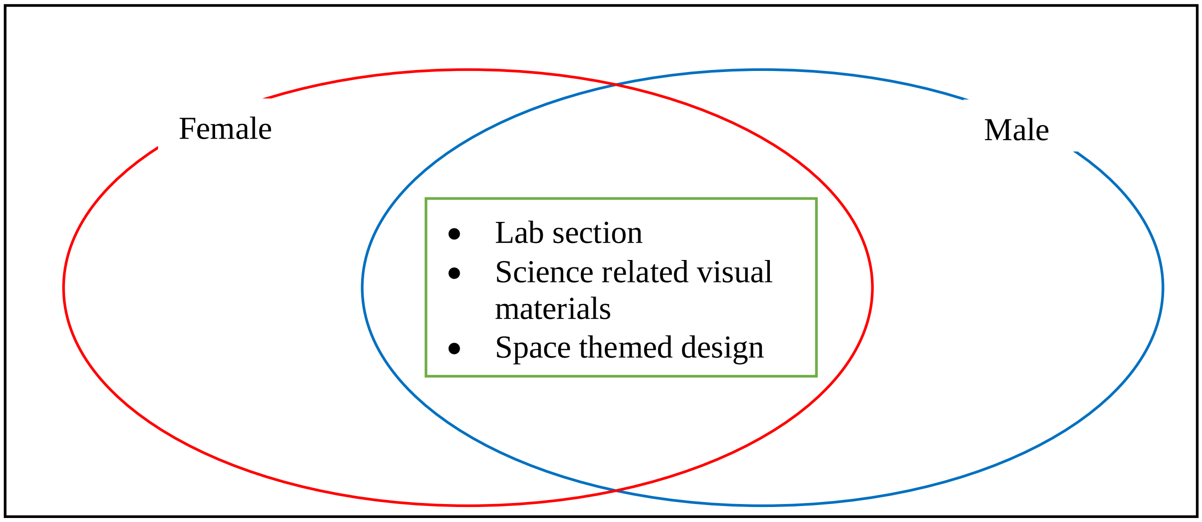
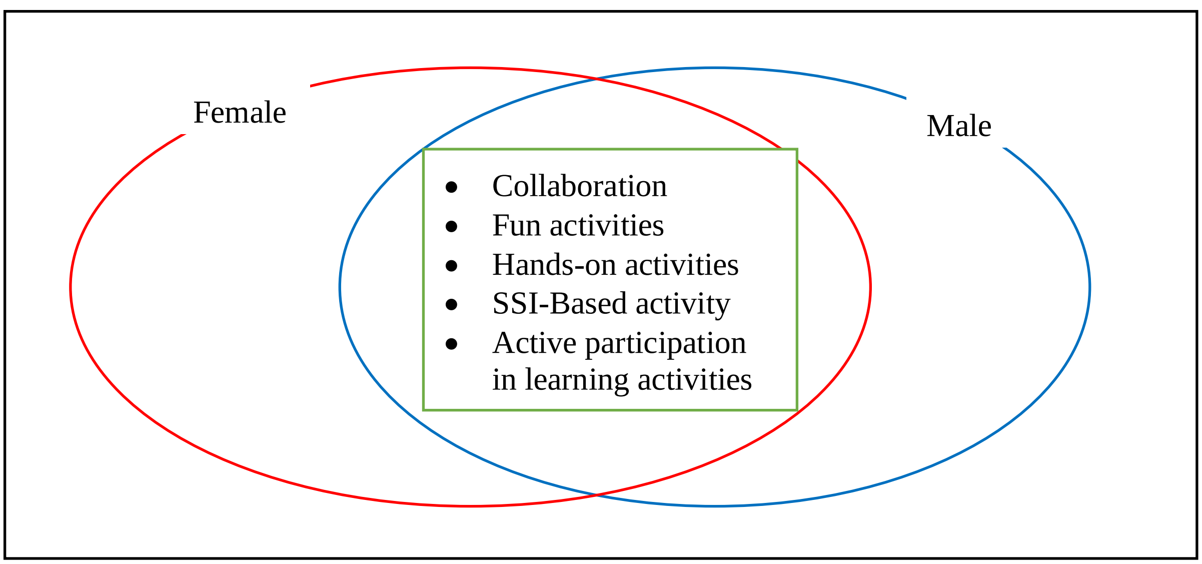


Figure 31

Female and Male Participants' Dream Science Classroom Teaching Design



For the classroom decoration design category, both genders imagined their dream class, adding some science-related visual materials, such as charts, graphs, famous scientists, and posters. Also, they wanted to create a space themed science classroom using LED, lights, and objects. The third similarity is adding a lab side in the classroom. Looking at dream classroom teaching design ideas, I found similarities between female and male students' answers, such as using teamwork, fun activities, hands-on activities, SSI-based science teaching, and student engagement.

Teacher Interview

I separately interviewed three teachers who managed the SSI-based science teaching activities to collect supplemental data. The interview contained five parts: background information, teaching, SSI-based science teaching, gender gap, and professional development. Three teachers shared their teaching techniques, the SSI-based teaching experiences, and the gender gap perceptions in their classrooms. In specific, the teacher interview gave an understanding of SSI-based instruction from the teachers' perspectives.

Background Information

In the first part, after the teachers described their teaching background and gave some information about their classroom diversity, I asked them Q_4: When you are a child, did you want to be a science teacher? The first teacher (T_1) wanted a science teacher, the second teacher (T_2) wanted an art teacher, the third teacher (T_3) wanted a veterinarian when they were a child. The fifth question: How did you decide being a science teacher? T_1 expressed her/his science teacher encouraged him/her explaining scientific concepts to other peers, and s/he realized her/his interest in science teaching. T_2 and T_3 realized their interest in science teaching career after completing their college educations. When asking them Q_7: How effective was your pre-service program preparing you to be a science teacher? Three teachers took short classes in science teaching. T_1 and T_3 found their pre-service science teacher programs as successful. They expressed that their programs prepared hands-on lessons that demonstrated concepts in a way that made students figure out what caused them. However, T_2 found her/his program somewhat effective by expressing not being fully prepared.

Science Teaching

In the second part, I asked three teachers about their teaching and student evaluation methods. Based on their answers, all teachers used student-based science teaching in their classrooms. For example:

- T_1: "*I like the show students phenomena and make them build from their prior knowledge to figure out why or what is happening. I also like giving them challenges and making them come up with solutions*."
- T_2: "*I attempt to align my classroom to a 3D framework associated with the NGSS. There is little direct instruction, instead focusing on guided inquiry activities with an emphasis on the development of the science and engineering practices*."
- T_3: "*I teach content through investigation and care more about the development of scientific literacy and skills than the actual retention of specific information*."

Also, I asked them how to evaluate their students' science learning. Three teachers preferred a variety of assessments, including very short quizzes, performance assessments, evaluation strength of their arguments, portfolio, and multiple-choice tests.

SSI-Based Science Teaching

` In this part, I asked them the first question: How comfortable do you feel using the MEL activity? All three teachers found the MEL activity as very comfortable. For example:

- T_1:" *I am very comfortable with it. It is a long process for students so I get antsy as they become restless and sometimes work avoidant. If I don't add visuals and break it into smaller chunks, the students become overwhelmed*."
- T_2: "*I very much enjoy how the MEL mimics actual scientific discovery by encouraging students to formulate a claim based on best-available evidence*."
- T_3: "*I love MEL*."

However, they found the MEL activity's in-person version more comfortable compared to the virtual MEL activity due to the internet connection and uploading document issues and their first-time experiences in the virtual version of MEL activity. In addition, the virtual version took more time compared to the in-person version.

Next question, the teachers expressed their MEL activity's favorite features T_1 and T_2 highlighted their students forming their own opinion with the MEL diagram, and T_3 emphasized the MEL activity's real-world connection. For example:

- T_1: "*I love the diagram since it helps them organize their thinking*.".
- T_2: "*It is important for students to realize there isn't an authority who tells us when we are right or wrong*.".
- T_3: "*Kids liked the MEL because they found it's really relevant with the real world*".

On the other hand, they stated three different MEL activity's difficult features. T_1 underlined the issue of higher reading levels in the evidence texts. Also, some concepts were needed pre-information before conducting the MEL activity. T_2 and T_3 encountered engagement issue during the MEL activity. T_3 determined virtual version as this issue's reason. The teachers' reflections are below about MEL's activity difficult features:

- T_1: "*Students needed the information to be "digested" for them and presented with visuals and check-ins since the reading level is too high for most*."
- T_2: "*The biggest challenge is keeping them engaged in the activity over the course of several days*."
- T_3: "*There would be one or two students in different groups that didn't want to participate at all okay and sometimes it's especially when they're virtual versus*."

In addition, they gave some information about redesigning MEL activity. T_1 wanted to reduce some detailed information to understand clearer it for the student level. T_2 wanted to alter the change the introduction activities. T_3 expressed that her/his some students could not remember their initial alternative and scientific model pre-plausibility ratings. So, the section is needed to see their previous section ratings on the MEL-Explanation task. Three teachers' reflections were about the redesigning MEL diagram activity:

- T_1: "*I would cut down the details to short digestible chunk because they don't understand the details about the cycles*"
- T_2: "*I would try to change some of the first time activities, such as pre-plausibility rating. They encounter some understanding challenges*"
- T_3: "*When they have to go at the end and they have to go back and say what they did previously for the models and then after they do the activity they couldn't remember some of them*."

Another question was related to the students' liking the MEL activity. All three teachers expressed their students enjoyed and liked this activity. For example:

- T_1: "*I think they enjoyed feeling like they could make a respectable and complex opinion about something that is important.*"
- T_2: "*I think they enjoyed the work. This has been a very unusual year in terms of teaching but their feedback was positive, overall. They like grappling with problems so this activity is right up their alley*."
- T_3: "*They seemed to have a good time they were all pretty much engaged on task the whole time*."

Next question was related to whether the teachers want to use the MEL activity when they teach science. All of them wanted use the MEL activity in their classrooms. Their reflections:

- T_1: "*Yes, I had to look up what SSI means, but I do love to see students construct their own opinions on important issues. I love having multiple answers to a question since that is how reality and interesting challenges actually are*."
- T_2: "*Yes I enjoy the MEL activity. It is great for developing several of the science and engineering practices upon which my district's curriculum is based*."
- T_3: "*Yes I believe this is an authentic approach that yields valuable insight into students' actual aptitude for science*."

Looking at the three teachers' answers about the MEL diagram, their responses support their having positive experiences in the SSI-based science classrooms. Also, they confirmed the students' positive experiences. However, they encountered some engagement and online instruction challenges.

Gender Gap

I asked three teachers whether the gender gap in their classrooms. T_1 highlighted the female and male students' activity interest differences in science classroom. However, T_2 reflected there was no gender gap in her science classroom. T_3 stated the gender gap was close because T_3's female students came the school after determining their career job fields.

- T_1: "*I think boys are more energetic in the lab and do better with hands-on activities. They can be loud and dominant during STEM activities. Girls can are often better at focusing through reading and writing assignments*."
- T_2: "*I don't observe it too frequently in my classroom. In fact, many of my female students are extremely conscientious and strong, academically, so they tend to exce*l."
- T_3: "*We are closing the gender gap. The girls actually participate more and are not afraid to share their opinions and be the group leaders but we're a special kind of you know the kids choose to come here so they're already*."

Also, three teachers answered the question: What do you think about SSI-based instruction's effectiveness in the gender equity? All of three teachers mentioned about positive statements about the MEL diagram activity's impacts on the female students.

- T_1: "*I think it can benefit girls because they are more likely to engage in reading and writing about how changes in the environment affect people*."
- T_2: "*I believe that females are interested in science when the content is relevant to them. In environmental science this is a bit easier than, say, physics or chemistry. Also, female students are more likely to enjoy and focus on a reading assignment*"
- T_3: "*Mel is good because it allows to talk, and the girls tend to be more talkative and they thought that person was capable enough to be able to manage the discussions*."

Overall, the three teachers' feedback is positive for this new learning and expressed their students enjoyed SSI-based science learning. However, they highlighted some challenges about the SSI-based science activities. In specific, the virtual MEL created some issues for the collaboration. In addition, the teachers faced the main issue that is keeping the students engaged in the activities. They felt overwhelmed and exhausted at times. Another challenge is that some visual and writings levels are too high for most students. Some ideas and explanations seem more complex for the learners. Another finding is that the teachers are needed a more understandable presentation for the students to follow the activity steps. In addition, three teachers mentioned the female students' positive engagement and interest in the MEL activity.

Summary

Scientific Plausibility

Both males and females decreased alternative model plausibility scores but increased their scientific model plausibility ratings from pre- to post-instruction. They evaluated the alternative model as a less plausible and scientific model as more plausible after the post-instruction, especially female students. This result promotes SSI-based instruction effectiveness on the students' plausibility shift toward the scientific model. Looking at the effectiveness of MEL diagram, both genders successfully eliminated the alternative model, and the treatment group has less gender gap than the control group, with females in favor. There is a moderately gender gap for the control groups' alternative model plausibility ratings with females in favor. The MEL instruction seems highly effective for creating gender equity in science classrooms.

Scientific Knowledge

Both genders increased their scientific knowledge scores from pre- to post-instruction for each topic (climate change and wetlands) and group (control and treatment). Female students' post-knowledge scores are slightly higher than males' post-test scores. The treatment group's CC post test scores slightly lower than the control group's CC post-test scores. Females and males had similar CC post-test knowledge scores. The treatment group's W post-test scores are somewhat higher than the control group's W post-test scores. Female s' W post-test scores are slightly higher than males' W post-test scores. Female, and male students' scientific knowledge retained very-well. There is a similarity between males' and female s' delayed-post-test scores.

Student Experiences

Most males and females (over %80) evaluated their SSI-based science learning as positive. Most males and females (56 males and 60 female s) wanted to suggest this activity to their friends. SSI-based classroom took place in thirteen students' (seven males and six female s) dream science classroom. Overall, both genders expressed positive cognitive experiences. The number of males having positive cognitive experiences is higher than that of females having positive cognitive experiences. The number of females and males having cognitive experiences was higher than females and males having emotional experiences. The total number of males and females having negative cognitive experiences is relatively small (four males and four females).

Males and females who wanted to recommend this science instruction to their peers explained their recommendation reasons with mainly positive cognitive experiences. Their main suggestion reason was gaining scientific knowledge with SSI-based learning. Critical thinking was the second reason for both males and female s. Both genders who had positive cognitive experiences evaluated their most favorite features of the SSI-based learning activities as the activity instruments and critical thinking. Males and females who had emotional experiences evaluated their most favorite features of the

SSI-based learning activities as engagement and enjoyment. both genders who had the cognitive-emotional experiences chose the features under critical thinking enjoyment and informative-enjoyment categories.

Students Career Plans

Over half of males and females described themselves as science person. However, a small minority of the female students wanted to pursue STEM field jobs, but many the male students, 37%, wanted to continue STEM career jobs. Females mostly preferred biomedical science fields of over 20% as opposed to males who numbered around 10. Based on these outcomes, there is a gender gap for choosing science-related career plans. Looking at the factors for choosing their future career job, most males expressed passion as the most crucial factor for determining their works, especially female s. Males also considered their experiences and decisions for following the career jobs.

CHAPTER 5

DISCUSSION

This chapter review a summary of the research findings and discuss each research question separately. Next, I submit a combined research questions discussion. Finally, I conclude with some future ideas for SSI-based science teaching implications and research studies.

Students' Plausibility Rating and Gender Gap

Lombardi et al. (2013) found that the students' plausibility judgments shifted toward the scientifically accepted CC model by engaging in the critical evaluation based on the literature review. Also, Lombardi and Bickel et al. (2018) found that the meaningful difference between the MEL diagram and the MEL table version. In the present study, the students' alternative model plausibility ratings decreased, but their scientific model plausibility ratings increased from pre- to post-instruction. I see the same statement for both the control and treatment groups. They accept Model A as scientifically more plausible by determining Model B as less plausible. The treatment group's scientific model plausibility post-test scores were higher than the control group's scientific model plausibility post-test scores. In addition, the treatment group's alternative model plausibility post-test scores were lower than the control group's alternative model plausibility post-test scores. In particular, the considerable decrease in participants' alternative model plausibility ratings in the MEL group confirms their deep evaluation. Furthermore, the significant difference between the control and treatment groups' alternative model post-plausibility rating. This statement supports the effectiveness of MEL diagram for eliminating as less plausible model.

Before this study, previous studies do not examine whether there is a gender difference in the students' positive plausibility shift in the MEL-based science instruction. According to the research outcomes, both females' and males' scientific model plausibility ratings increased but decreased their alternative model plausibility ratings. Both group's female and male students have almost the same scientific model post-plausibility scores. However, there is a gender gap between female and male students' alternative model post-plausibility scores for the control group with females in favor. In other words, the females participating the control group have lower alternative model post-plausibility scores compared to their male peers in the control group. The treatment group's female and male students have closer alternative model plausibility scores. These results promote that both genders view the scientific model (Model A) as more plausible than the non-scientific model (Model B). Both female and male students did deeper evaluations in the explanation stage, especially the treatment group. Females eliminated the alternative model very well compared with males.

The MEL activity played a crucial key in reducing the gender gap. They simulated a scientist's thinking, such as understanding scientific evidence, evaluating their ideas and arguments, discussing each other, trying the best connections between evidence and models. The MEL activities are mainly based on all these critical simulations. Thinking on the link between lines of evidence and models and using arrows for creating connections between them may develop a deeper understanding of why the scientific model is evaluated as more plausible, and the non-scientific model is less plausible. The results show that the MEL diagram provided equal opportunities regarding both females' and males' positive plausibility shifts. This positive plausibility shift supports the MEL effectiveness in gender equity and their deeper evaluation during the activities.

Students' Scientific Knowledge and Gender Gap

Bickel and Lombardi (2016) express that students who better understand and critically evaluate an SSI topic might transfer these skills to grow scientific knowledge. The positive shift in plausibility judgments would lead to restructuring their CC scientific knowledge. Medrano et al. (2020) explored a significant positive shift in knowledge toward the scientifically accepted model. I found that there is a growth in their CC and W scientific knowledge after the SSI-based activities. The positive shift in the students' knowledge score results confirm the previous studies (Lombardi et al., 2013; Lombardi and Bailey et al., 2018). They gained a piece of significant knowledge by evaluating two models and lines of evidence overall.

The MEL diagram group's post-knowledge test scores are higher than the control group's post-test scores. In addition, the treatment group's W post-knowledge test scores are higher than the control group's W post-knowledge test scores. Both the control and MEL group's CC post-knowledge scores are almost similar. The main reason of these similarities in both the control and treatment groups' CC and W post knowledge scores is the research design similarity. In this research, I focused on how using arrows on the diagram is effective for making connections between models (scientific and alternative) and lines of evidence. Thus, I designed the control and treatment groups with this main idea. However, using similar materials for both groups might create the similar CC and W knowledge scores even though we see the difference in the students' post-plausibility scores for between the control and treatment groups.

In addition, when examining the participants' post-knowledge scores by gender, both genders increased their knowledge scores from pre- to post-instruction for the control and treatment groups. Also, I found the similar CC and W post-knowledge scores in the control and treatment groups' females and males.

Lombardi et al. (2013) found that the students maintained their knowledge even after six months. In this study, I examined the participants' delayed post-test scores after a two-weeks interval. I found similar results with Lombardi et al. (2013) that the participants' delayed-post-test scores are almost the same as their post-test scores. Furthermore, males' delayed-post-test scores are slightly higher than female s' delayed-post-test scores in the control group. In the MEL group, females' delayed-post-test scores are slightly higher than males' delayed-post-test scores. The similar scores between males and females in their knowledge scores was kept after a two-week interval.

Overall, SSI-based instructions provide triple opportunities for the science classrooms, such as positive plausibility judgment shift, gaining scientific knowledge growth, and gender equity. The participants' positive plausibility shifted toward the scientific model positively correlates with their scientific knowledge gains. The similarities between the females' and males' CC and W knowledge post-test scores promoted that SSI-based science teaching instructions provided equal opportunities for both genders in science classrooms.

Students' Experiences in SSI-Based Science Classrooms

Based on the students' open-ended question survey answer, over eighty percent female and male students reflected their overall experiences about SSI-based science learning as positive. They used common terms for expressing positive experiences using pretty cool learning, a very fun concept, good experience, useful learning as well as negative experiences using boring, complicated, decent experience. The general experience question, they did not detail their experience, only evaluated their genereal experience about SSI-based science learning.

Also, I asked the students whether they would recommend this learning to their friends. Interestingly, 16% males and 15% females did not want to recommend this science learning with thinking their friends as disinterested in science. The same percent 77% female and male students wanted to suggest the SSI-based science instructions to their friends. Even though the students participated the SSI-based science learning as the first time, they wanted to suggest this activity with a high percent. In addition, even though the related question Q_7 did not include matching the SSI-based classroom with their science dream classroom, the students mentioned about this learning in their open-ended question answers. Accepting the SSI-based science classroom as the science dream class and wanting to suggest this classroom to other friends promote both female and male students perceived this new design as positive. Maltese and Tai (2010) found that the experience of education activity is one of important sources for the interest in science and also this experience has a greater impact on females than males. In this study, SSI-based science learning provided them positive and equal opportunities for both genders.

Looking at the activity suggestion reasons, they highlighed this learning’s features as critical thinking, critical thinking-informative learning, collaborative learning, easy learning, easy-informative learning, informative learning. Over fifty percent female and male students choose activity’s suggestion reason as informative learning. Interestingly, the second activity suggestion reason is critical thinking for both genders. Most students having positive cognitive experiences wanted to suggest activities with two main reasons: informative learning and critical thinking. However, the reasons are very diverse for the female and male students having emotional and cognitive-emotional experiences.

Collaboration is male students' one of the activity suggestion categories. The female students did not mentioned about the collaboration as the activity suggestion reason to other friends. Also, both gender expressed collaboration as the challenge when answering the activity difficult feature question. The small group structure (only females, only males, or mixed-genders) might have impacted the collaboration. I did not specially collect the data about the small group participants' gender. The small groups' diversity might connect the collaboration. In addition, T_3 stated that the SSI-based activity's online version created the challenge for the student collaboration.

T_3: "It was obviously a little bit different getting used to it online. I had a couple of them where you know like there would be one or two students in different groups that didn't want to participate at all okay and sometimes it's especially when they're virtual. They didn't get to actually you know see that here in the headlights look on the camera.."

The online version and small group's structure might have decreased the collaboration.

The Impact of SSI-Based Science Instructions on Female Students' Career Plans

More than half of both males and females identified themselves as science person. Only a small percentage of female students desired to pursue STEM field jobs, whereas 37 percent of male students wanted to continue STEM career jobs. Females preferred biomedical scientific disciplines by a margin of more than 20% to males by a margin of around 10%. Based on these findings, there is a gender gap in the selection of science-related career paths. When asked what factors influenced their decision to pursue a career, males and especially females stated that passion was the most significant factor in determining their careers. These results confirm the literature because most gender studies found that female students choose medical/health and biology careers and male students choose engineering and computer sciences even within STEM, career choices tend to follow a gendered pattern with females choosing medical/health and biology careers and males choosing engineering and computer sciences (Sikora and Pokropek, 2012).

In addition, some females described themselves as “science person” after this SSI-based learning.

- Female 124: *“Thank you for such a wonderful eye-opening experience. Now, I am.”*
- Female 223: *“Not really but after this study I am.”*
- Female 3225: *“Thank you for the time put into this, this gave me as a learned a peak into the mind of a scientist.”*

These examples may be important as the beginning step for the STEM career enthusiasm. I think that determining a career is not easy and quick process. Also, they participated this science learning activties as the first and one time. However, we need a longer-term research design of the career determination process. This design might give a more detaled and specific data about this process.

Conclusion

MEL diagram was used as an SSI-based instructional scaffold to engage students in making connections between models and lines of evidence (Lombardi and Bailey et al., 2018; Lombardi and Bickel et al., 2018). The MEL instructional activity is based on two models (alternative and scientific models) and four different lines of scientific evidence. Chin and Osborne (2010) highlighted that this activity helped develop argumentation skills because the participants tried to defend and support their arguments and reject or accept their peer's counterarguments. Also, the students can work on the real issue and elaborate on this issue related to two models and lines of evidence. This practice is significant for the development of their critical thinking.

In this study, the students experienced this critical thinking process. In particular, both females' and males' plausibility judgments shifted toward the scientific model by eliminating the alternative model. Furthermore, their scientific knowledge scores were similar. They gained scientific knowledge about CC and W. However, they encountered some challenges during the MEL activity. The collaboration was challenging for them due to using the virtual MEL version. Thus, we redesign the MEL activities by adding some interval activities. Also, live recording student discussions will provide more understanding of their collaboration.

This research confirms the literature about the genders' career choices in the science fields. The number of males preferred STEM careers was higher than the number of females preferred STEM careers. Most females wanted to enter the medicine as the biomedical science career instead of choosing STEM career. However, both most genders described themselves as science person with the similar rate. Furthermore, both most genders explained the choosing career job reason with the passionate. Guo et al. (2018) and Eccles and Wang (2016) highlighted that gender stereotypes impact their individual career choices in science. Females often choose a profession where they can help people, continue careers in biomedical science, especially medicine even though these females may be interested in chemistry, physics, math, and engineering. According to Eccles et al.

(2004), females tended to choose majors and careers in the biomedical sciences as accepted more people-oriented and placed a higher value for the society. Also, they suggest that science education should provide the opportunities them to fulfill their broader occupational and personal goals for the society.

Both genders expressed having positive experiences with the SSI-based learning. Most female and male participants wanted this learning to other friends. The MEL diagram contains the real issue that highly impact the societies. The MEL activity might be more effective for showing the connection between science and society. Also, they gain scientific knowledge and develop critical thinking skills with elaboration the models and evidence texts. SSI-based learning can increase females’ interest in science and raise girls’ awareness toward entering a STEM career. Future studies help to understand the MEL design’s impact on female’ experiences and future career choices.

Significance of the Research

This research is important, giving insight into using SSI-based learning for the gender gap issue. The female participants did similar performances as much as their male peers with this new science instruction. This dissertation might be a scaffold for taking place SSI-based instructions not only gaining scientific knowledge, developing critical thinking skills but also reducing gender gap issue in science classrooms.

Research Limitations

This study took place during the time when COVID-19 has affected the world. Education in this pandemic has significantly disrupted. Thus, some students could not complete all activities. They might have impacted their families’ economic instability and health problems. Some students and teachers may have faced motivation issues and felt less engagement due to overwhelmed atmosphere. Unfortunately, the pandemic restricted this research too.

The research instruments' virtual versions were used in this study. The students participated the first time in SSI-based the activities via the internet. Some participants encountered some internet connection and technical issues, such as weak internet connection, microphone issues. Also, the group collaboration was restricted because of the online version. They may not have discussed efficiently, specifically the connections between lines of evidence and models compared to in-person version. Furthermore, the students who participated the MEL diagram activity faced the challenges for drawing and moving arrows in the virtual version. Examining materials may have been somewhat problematic in the online version comparing to the paper version. These technological problems and the online version restricted this study.

Another limitation is that the control and treatment groups' activities were almost similar except the MEL diagram. I found some results of the two groups to be very close to each other. The design similarity also restricted this study. I mainly aimed to investigate how arrows are affective in the students' plausibility judgment possible shiftment. However, the design similarity created the issue with the control and treatment groups' knowledge scores similarities due to using similar documents.

The students participated in the SSI-based activities for the first time and in a very short time. However, a much longer and detailed study is needed to understand the career determination process of students. This structure did not give a detailed understanding of career plans, and this statement limited this research's fourth research question.

Future Directions

For research future recommendations, the student interview can be conducted to gain a deep understanding of their experiences. They reflected on their experiences, but their answers are needed to explore the exact meaning, such as what boring, fun, or difficult as one word and even their reflection sentence's actually mean for them. During the interview, their answers and experiences can be detailed by asking additional questions.

Another recommendation is that a study with live recordings of students' arguments during MEL activities is essential to understand the collaboration during the discussion and analyze their arguments. Also, the small groups' relations with gender and different topics are needed to explore how to affect the collaboration. For example, the small groups can be created only females, only males, and mixed-gender groups with different SSI-based topics. The live recording might provide new ideas for the SSI-based science teaching design and collaboration for the educational researchers and even determine an issue for students or teachers.

MEL diagram activity includes most of students' dream class components, such as using teamwork and active participation. However, based on these ideas, most males and females gave importance to the classroom atmosphere. Thus, we can add some changes to the classroom atmosphere. Students can prepare some related posters and objects together with an SSI topic for the classrooms and place them on their classroom walls. In addition, some short and easy hands-on experiences can be designed for this topic. the MEL design can be renewed by adding some initial and interval funny short activities to prepare students for critical thinking and keep them more engaged during the activities. Also, the teachers need a straightforward presentation to follow the steps with the students. Last, adding teacher perspective provides more opportunity to create efficient activity design and implement the MEL activity more efficiently. Also, this collaboration might reduce teaching challenges. Hence, we should redesign the MEL activity by considering teachers' ideas.

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APPENDIX A

INTRODUCTION PLAUSIBILITY RANKING

Name________________ Gender________ Teacher______________ Date_________

How do scientists change their plausibility judgments?

Plausibility is a judgment we make about the potential truthfulness of one model compared to another. The judgment may be tentative (not certain). You do not have to be committed to that decision.

Scientists may change their plausibility judgments about scientific ideas.

They do this by looking at the connections between evidence and the idea. Evidence may:

1. *Support* an idea
2. *Strongly* support an idea
3. *Contradict* (oppose) an idea
4. Have *nothing to do* with the idea

Which type of evidence do you think is most important to a scientist's plausibility judgment? Use numbers 1 to 4 to *rank* each evidence. (1 = most important and 4 = least important). Use each number only once.	
Type of evidence	**Your ranking**
Evidence supports the idea	
Evidence strongly supports the idea	
Evidence contradicts (opposes) the idea	
Evidence has nothing to do with the idea	

When instructed, flip over to Page 2

Carefully read the following paragraph.

Scientific ideas must be *falsifiable*. In other words, scientific ideas can never be proven. But, ideas can be disproven by opposing evidence. When this happens, scientists must revise the idea or come up with another explanation. *Falsifiability* is a very important principle when evaluating scientific knowledge.

As a reminder, scientists may change their plausibility judgments about scientific ideas and they do this by looking at the connections between evidence and the idea. Evidence may:

1. *Support* an idea
2. *Strongly* support an idea
3. *Contradict* (oppose) an idea
4. Have *nothing to do* with the idea

With *falsifiability* in mind, *re-rank* each evidence from 1 to 4. (1 = most important and 4 = least important). Use each number only once.	
Type of evidence	**Your ranking**
Evidence supports the idea	
Evidence strongly supports the idea	
Evidence contradicts (opposes) the idea	
Evidence has nothing to do with the idea	

APPENDIX B

MODEL PLAUSIBILITY RANKING OF CLIMATE CHANGE

Name________________ Gender________Teacher________________Date_________

Please work on this individually

Read the following information carefully.

Humans create *models* to help explain things.

Below are two models. These provide different explanations for why global temperatures

have increased over the past 100 years and average sea levels have increased over the

Model A: Our climate change is caused by humans who are releasing gases into the atmosphere.

A person who supports this model makes the following argument:

A few gases in Earth's atmosphere prevent some of Earth's energy from escaping out into space. Human activities are increasing the amount of these gases in the atmosphere. Therefore, humans are causing climate change.

Model B: Our climate change is caused by increasing amounts of energy released from the Sun.

A person who supports this model makes the following argument:

The Sun is the main source of energy for planet Earth. Scientists have shown that for thousands of years Earth's average temperature increases when the Sun releases more energy. Therefore, the Sun is causing climate change.

Plausibility is a judgment we make about the potential truthfulness of one model compared to another. The judgment may be tentative (not certain). You do not have to be committed to that decision.

Circle the plausibility of each model. [Make two circles. One for each model.]

	Greatly implausible (or even impossible)									Highly Plausible
Model A	1	2	3	4	5	6	7	8	9	10
Model B	1	2	3	4	5	6	7	8	9	10

APPENDIX C

MODEL PLAUSIBILITY RANKING OF WETLANDS

Name_______________ Gender________ Teacher________________ Date_________

Please work on this individually.

Read the following information carefully.

Humans create *models* to help explain things.

Below are two models. These provide different explanations about how wetlands affect humans and the environment.

Model A: Wetlands provide ecosystem services that contribute to human welfare and help sustain the biosphere.

A person who supports this model makes the following argument:

Wetlands help humans and the environment by purifying water, providing flood protection, helping to keep shorelines stable, recharging groundwater, and maintaining valuable habitat for fish, birds, other animals, and plants.

Model B: Wetlands are a nuisance to humans and provide little overall environmental benefit.

A person who supports this model makes the following argument:

Wetlands create many problems for humans, including flooding at times of heavy rainfall, providing a breeding ground for mosquitos and other pests, and preventing development of commercial and residential areas.

Plausibility is a judgment we make about the potential truthfulness of one model compared to another. The judgment may be tentative (not certain). You do not have to be committed to that decision.

Circle the plausibility of each model. [Make two circles. One for each model.]

	Greatly implausible (or even impossible)									Highly Plausible
Model A	1	2	3	4	5	6	7	8	9	10
Model B	1	2	3	4	5	6	7	8	9	10

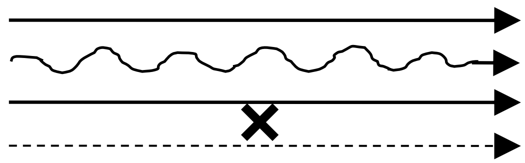
APPENDIX D

CLIMATE CHANGE MEL DIAGRAM

Name: ______________________________ **Date:** ____________**Teacher:**_______________________**Gender:**_____________

Directions: Draw 2 arrows from each evidence box, one to each model. You will draw a total of 8 arrows.

Key:



The evidence **supports** the model
The evidence **STRONGLY supports** the model
The evidence **contradicts** the model (shows its wrong)
The evidence has **nothing to do with** the model

Evidence #1
Atmospheric greenhouse gas concentrations have been rising for the past 50 years. Human activities have led to greater releases of greenhouse gases. Temperatures have also been rising during these past 50 years.

Model A
Our current climate change is caused by increasing amounts of gases released by human activities.

Evidence #3
Satellites are measuring more of Earth's energy being absorbed by greenhouse gases.

Evidence #2
Solar activity has decreased since 1970. Lower activity means that Earth has received less of the Sun's energy. But, Earth's temperature has continued to rise.

Model B
Our current climate change is caused by increasing amounts of energy released from the Sun.

Evidence #4
Increases and decreases in global temperatures closely matched increases and decreases in solar activity before the industrial revolution.

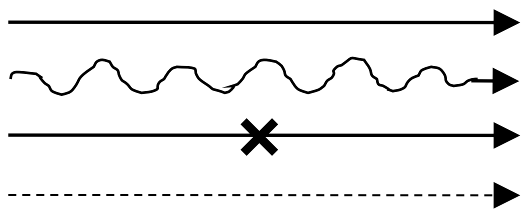
APPENDIX E

WETLAND MEL DIAGRAM

Name: ________________________ Date: _______________ Teacher: _________________ Gender:_________

Directions: Draw 2 arrows from each evidence box, one to each model. You will draw a total of 8 arrows.

Key:



The evidence **supports** the model

The evidence **STRONGLY supports** the model

The evidence **contradicts** the model (shows its wrong)

The evidence has **nothing to do with** the model

Evidence #1

Wetlands play a role in the global cycles of carbon, nitrogen, and sulfur. Wetlands change these nutrients into different forms necessary to continue their global cycles.

Model A

Wetlands provide ecosystem services that contribute to human welfare and help sustain the biosphere.

Evidence #3

Wetlands contribute 70 percent of global atmospheric methane from natural sources.

Evidence #2

Flooding is a natural occurrence in low-lying areas and wetlands are places where floodwaters can collect.

Model B

Wetlands are a nuisance to humans and provide little overall environmental benefit.

Evidence #4

Many wetlands are located in rapidly developing areas of the country.

APPENDIX F

MEL EXPLANATION

Name: ________________________________ Date: _______________ Teacher: ___________________ Gender _____________

1. What were your previous rankings? Model A: ______________ Model B: ______________

2. Provide a reason for three of the arrows you have drawn. Write your reasons for the three most interesting or important arrows.

A. Write the number of the evidence you are writing about.
B. Circle the appropriate word (strongly supports | supports | contradicts | has nothing to do with).
C. Write which model you are writing about.
D. Then write your reason.

1. Evidence # ____ strongly supports | supports | contradicts | has nothing to do with Model _____ because:

2. Evidence # ____ strongly supports | supports | contradicts | has nothing to do with Model _____ because:

3. Evidence # ____ strongly supports | supports | contradicts | has nothing to do with Model _____ because:

3. Circle the plausibility of each model. [Make two circles, one for each model.]

	Greatly implausible (or even impossible)									Highly plausible
Model A	1	2	3	4	5	6	7	8	9	10
Model B	1	2	3	4	5	6	7	8	9	10

4. For the model you selected as most plausible, explain why you think so

APPENDIX G

SSI EXPLANATION TASK

Name: ______________________________ Date: _______________ Teacher: ______________________ Period: ____________

1. What were your previous rankings? Model A: ______________ Model B: ______________

2. Provide a reason that you choose three evidence and models.

A. Write the number of the evidence you are writing about.
B. Circle the appropriate word (strongly supports | supports | contradicts | has nothing to do with).
C. Write which model you are writing about.
D. Then write your reason.

1. Evidence # ____ strongly supports | supports | contradicts | has nothing to do with Model _____ because:

2. Evidence # ____ strongly supports | supports | contradicts | has nothing to do with Model _____ because:

3. Evidence # ____ strongly supports | supports | contradicts | has nothing to do with Model _____ because:

3. Circle the plausibility of each model. [Make two circles, one for each model.]

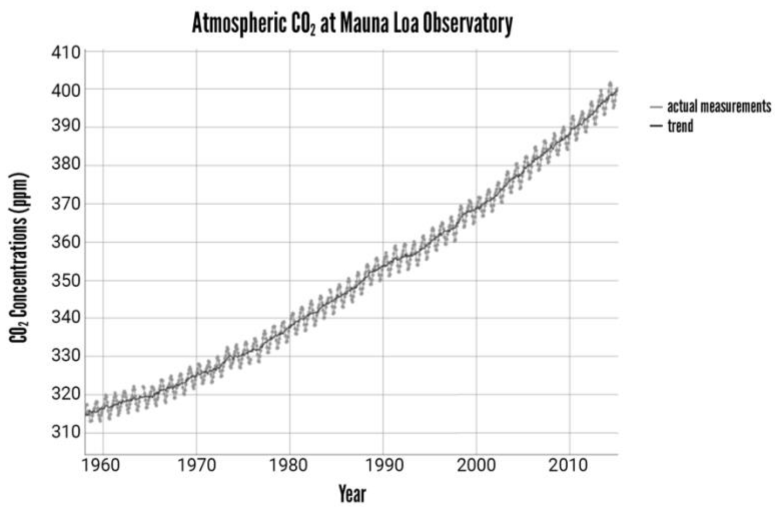
	Greatly implausible (or even impossible)									Highly plausible
Model A	1	2	3	4	5	6	7	8	9	10
Model B	1	2	3	4	5	6	7	8	9	10

4. For the model you selected as most plausible, explain why you think so.

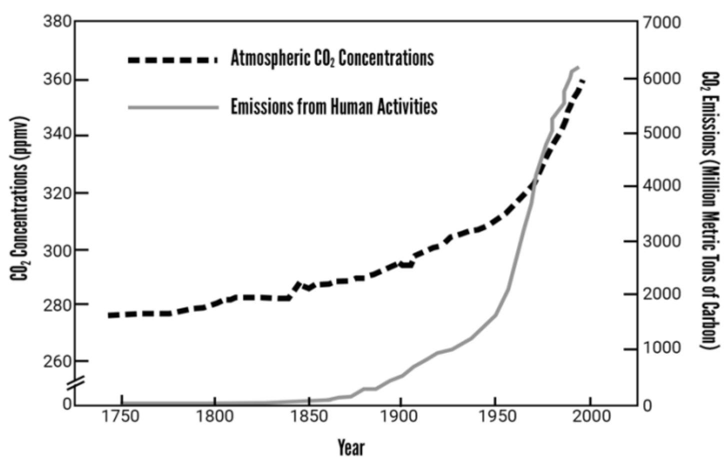
APPENDIX H

CLIMATE CHANGE EVIDENCE TEXT

Evidence #1: Atmospheric greenhouse gas concentrations have been rising for the past 50 years. Human activities have led to greater releases of greenhouse gases. Temperatures have also been rising during these past 50 years.

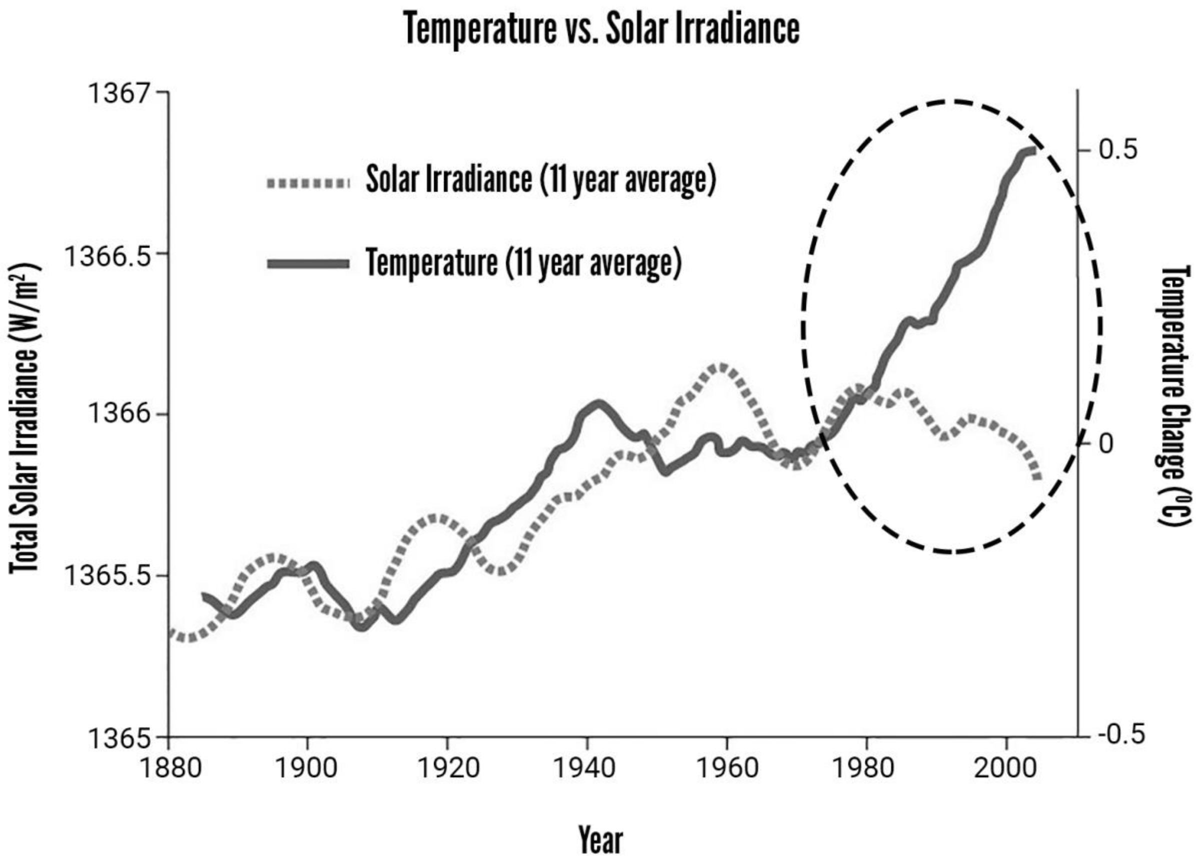


The graph above shows carbon dioxide levels in the atmosphere. The symbol for carbon dioxide is CO2. These levels have been increasing. CO2 in the atmosphere absorbs infrared energy emitted by Earth. People call CO2 a greenhouse gas because it keeps some of Earth's energy from escaping to space.



This graph above shows increasing releases of CO2 by the human activity of burning fossil fuels, including coal, gasoline, natural gas, and wood. Burning fossil fuels releases CO2 into the atmosphere.

Evidence #2: Solar activity has decreased since 1970. Lower activity means that Earth has received less of the Sun’s energy. However, Earth’s temperature has continued to rise.



This graph shows solar activity levels. The Sun’s brightness is one way to measure solar activity. The dashed line shows the Sun’s brightness. Since 1970, the Sun’s brightness has been decreasing. The solid line on the graph shows Earth’s temperature. The graph shows that temperatures are increasing while solar activity is decreasing. The region outlined by the dash-dot oval shows where solar activity is decreasing, and temperature is increasing.

Evidence #3: Satellites are measuring more of Earth's energy being absorbed by greenhouse gases.

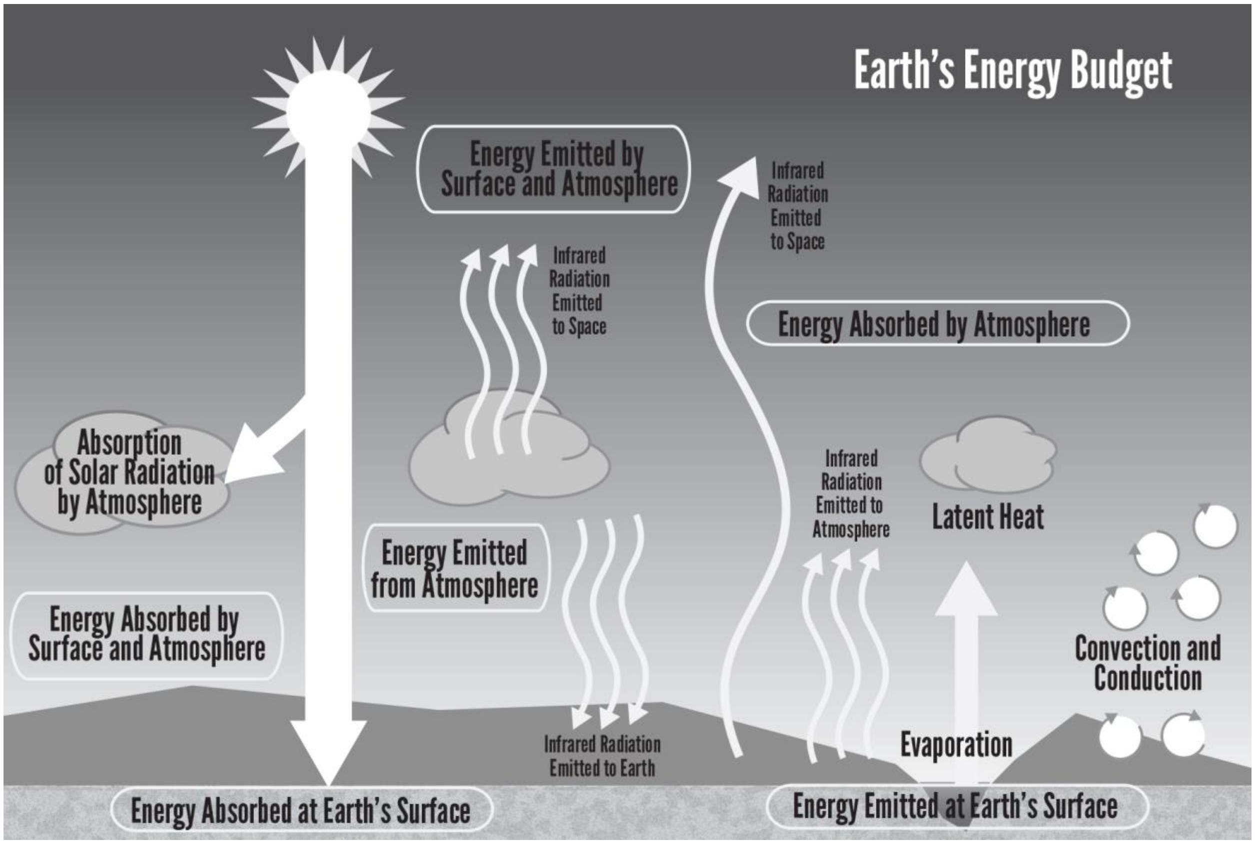
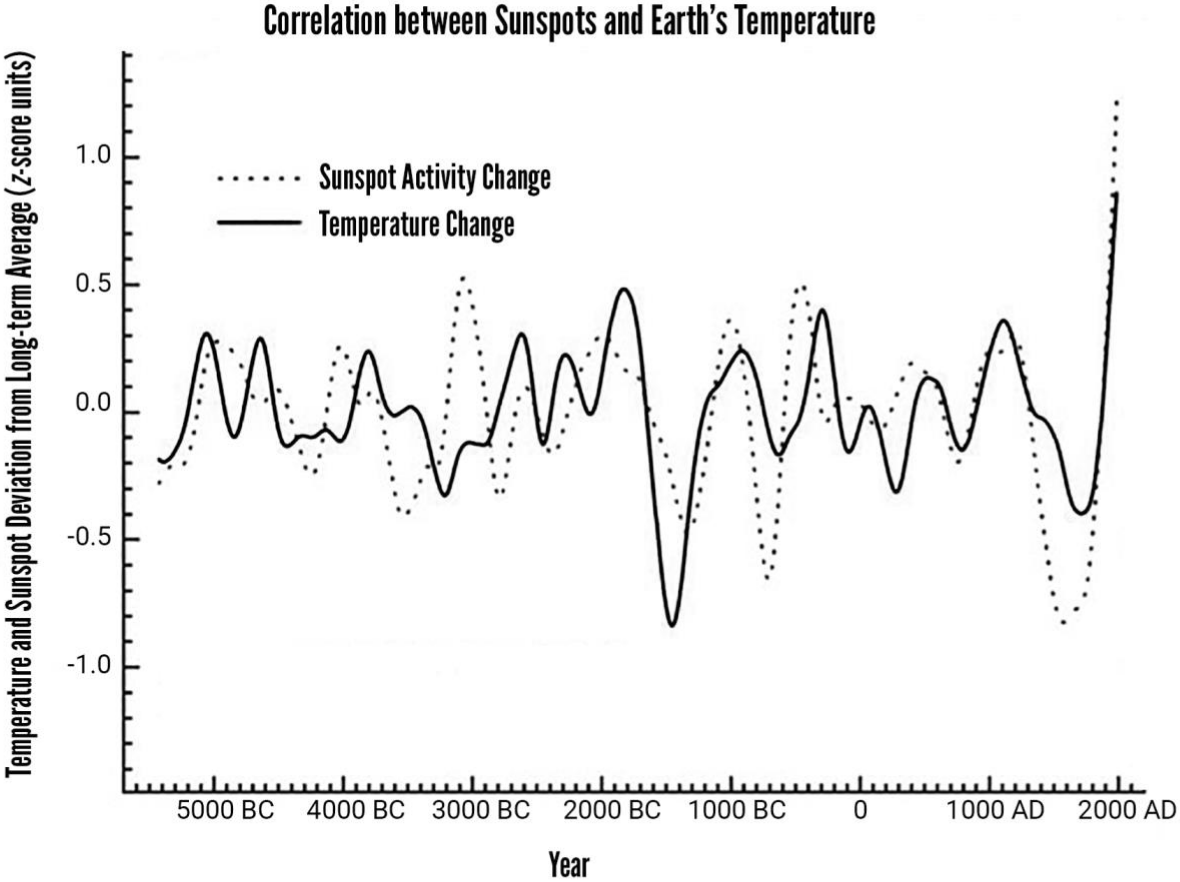


figure above shows Earth's energy budget. Earth absorbs about half of the Sun's energy. Most of the Sun's energy comes to Earth as visible light. Earth reradiates this absorbed energy as invisible light called infrared. Some of this infrared energy is absorbed by the atmosphere and sent back to Earth. Some escapes into space. Over time, NASA satellites orbiting Earth have recorded less infrared energy leaving Earth's atmosphere.

Evidence #4: Increases and decreases in global temperatures closely matched increases and decreases in solar activity before the industrial revolution.



This graph shows sunspot activity and temperature. Sunspot activity is the dashed line. Solar activity increases when the Sun has more sunspots. The solid line shows temperature. The shapes of the sunspot and temperature curves match closely. Peaks in the temperature are near peaks in sunspot activity. Dips in temperature are near dips in sunspot activity.

These data show sunspot activity and temperature for the past 9000 years. These data are based on evidence collected from tree rings. Some of the tree rings are from trees that are still living. Some of the trees rings are from ancient trees that have died.

APPENDIX I

WETLANDS EVIDENCE TEXTS

Evidence #1: Wetlands play a role in the global cycles of carbon, nitrogen, and sulfur. Wetlands change these nutrients into different forms necessary to continue their global cycles.

Chemicals in water can collect in wetlands, where processes change these chemicals into different forms. In addition to their role in the continuation of these globally important chemical cycles, wetlands also play a vital role in cleaning our water by removing hazardous chemicals, materials, and nutrients that can lead to harmful algal blooms.

In the case of the nitrogen cycle, 70-90% of all the dissolved nitrogen that passes through a wetland is actually removed from the water. The removed nitrogen is cycled back into the atmosphere in a step-by-step process. In the case of the carbon cycle, carbon is stored in wetlands so long as the wetlands remain wet. The breakdown of dead plant material occurs faster in a dry wetland. Therefore, carbon dioxide is released into the atmosphere. In the case of the sulfur cycle, one form of sulfur is changed into another that either stays in the wetland or goes into the atmosphere.

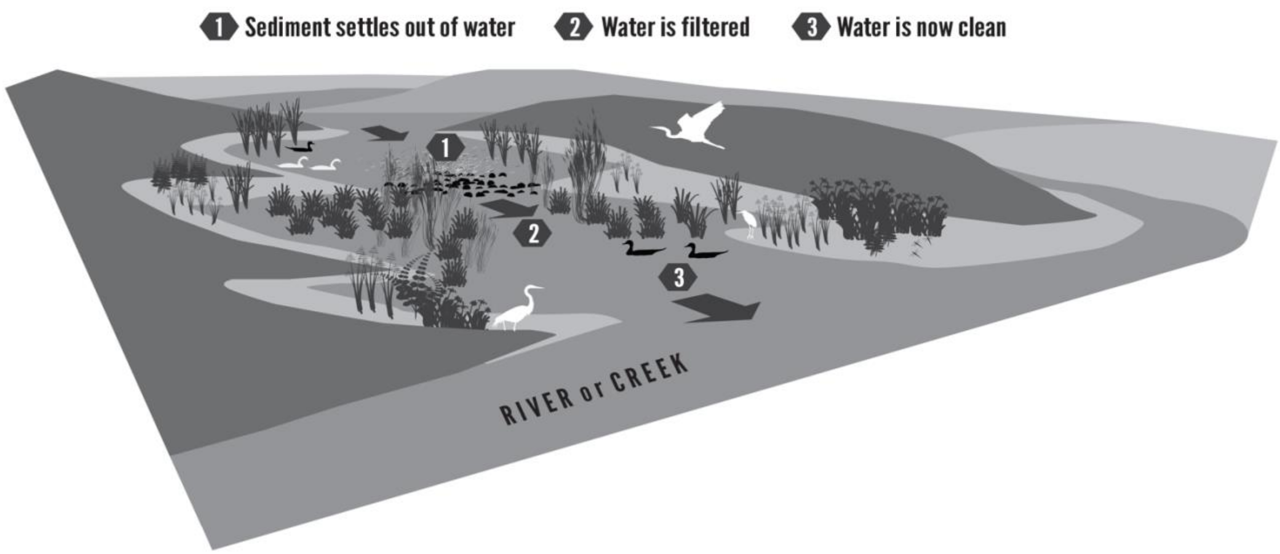


Figure 1. (1) Water enters the wetland, allowing for litter, sediment and other pollutants to settle to the bottom. (2) Water is filtered by micro-organisms and algae that grow on the plants. This removes nutrients from the water, especially nitrogen, to help reduce algal blooms in the nearby bay. (3) After water has spent about three days in the wetland, cleaner water is released back into the creek and water levels return to normal. Credit: Wright Seneres

As water flows into a wetland, nutrients are either transformed into less toxic chemicals or removed. Plants in the wetlands can absorb the transformed nutrients. Also, any solid particles suspended in the water will settle out. When nutrients and solid particles are removed, the water becomes cleaner. Wetlands are usually in flat areas where anything in the water has a chance to settle on the plants or in the soil of the wetlands.

Evidence #2: Flooding is a natural occurrence in low-lying areas and wetlands are places where floodwaters can collect.

Wetlands collect rainwater that falls in populated and unpopulated areas. Because wetlands store large amounts of water, they act as overflow areas for rivers during times of peak flow and can prevent populated areas from being flooded. Floodwaters bring nutrients and sediments from other areas that then settles in farms, towns, and cities. Natural flooding can contribute to the livelihoods of those who live nearby, especially those who depend on wetlands for agriculture and other economic benefits. Close to 2 billion people live in heavily populated areas in risk of flooding. If wetlands are damaged or reduced, there is a greater chance that these regions will flood, affecting lives and property. However, sometimes flooded wetlands can lead to harm when insects that cause diseases such as West Nile virus breed in the floodwaters.

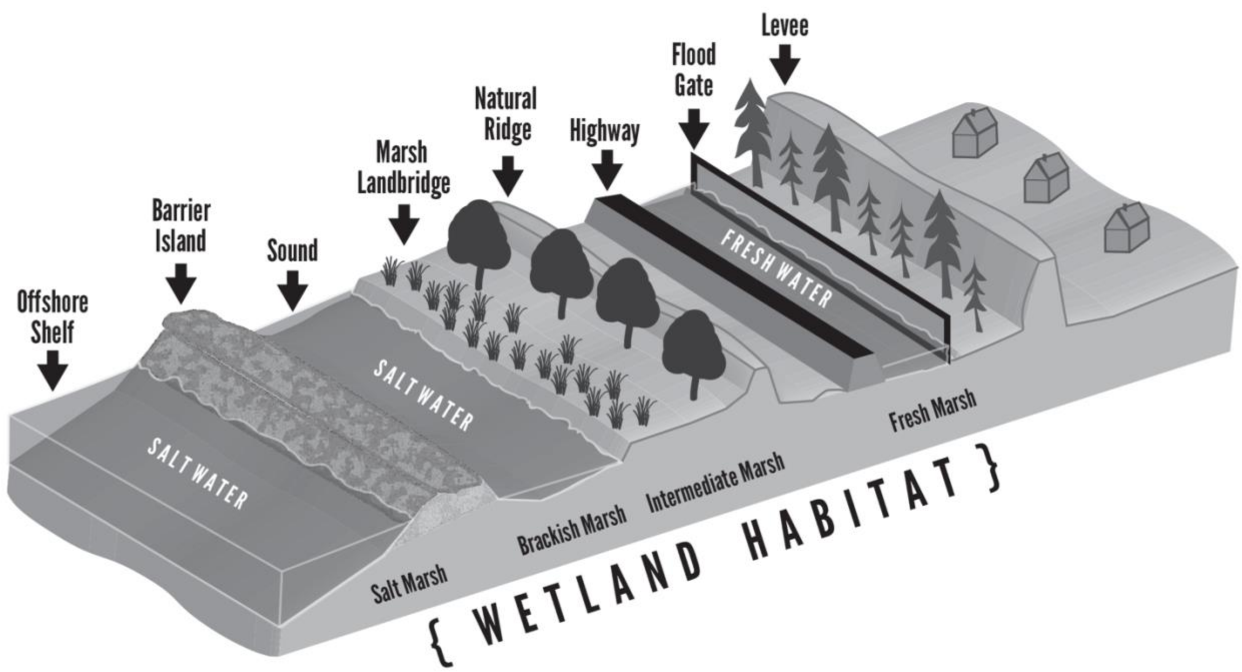


Figure 1. Coastal wetlands offer a first line of defense against hurricane storm surge. Credit: Wright Seneres

Evidence #3: Wetlands contribute 70 percent of global atmospheric methane from natural sources.

Even though methane does not remain in the atmosphere for a long time, it is a stronger greenhouse gas than carbon dioxide. This means that methane has a greater potential to contribute to global warming. Methane comes from natural and manmade sources. About 70% of the natural methane comes from wetlands globally. Water levels and soil temperatures affect the amount of methane released. When water levels fluctuate in warm areas, more methane is released. In polar regions, more methane is released during warmer summers. Scientists are actively working to better understand the role of wetlands in the production of atmospheric methane. The figure below shows the contribution of wetlands as a source of methane compared to other natural (shown as shaded) and human-caused (shown as white) sources.

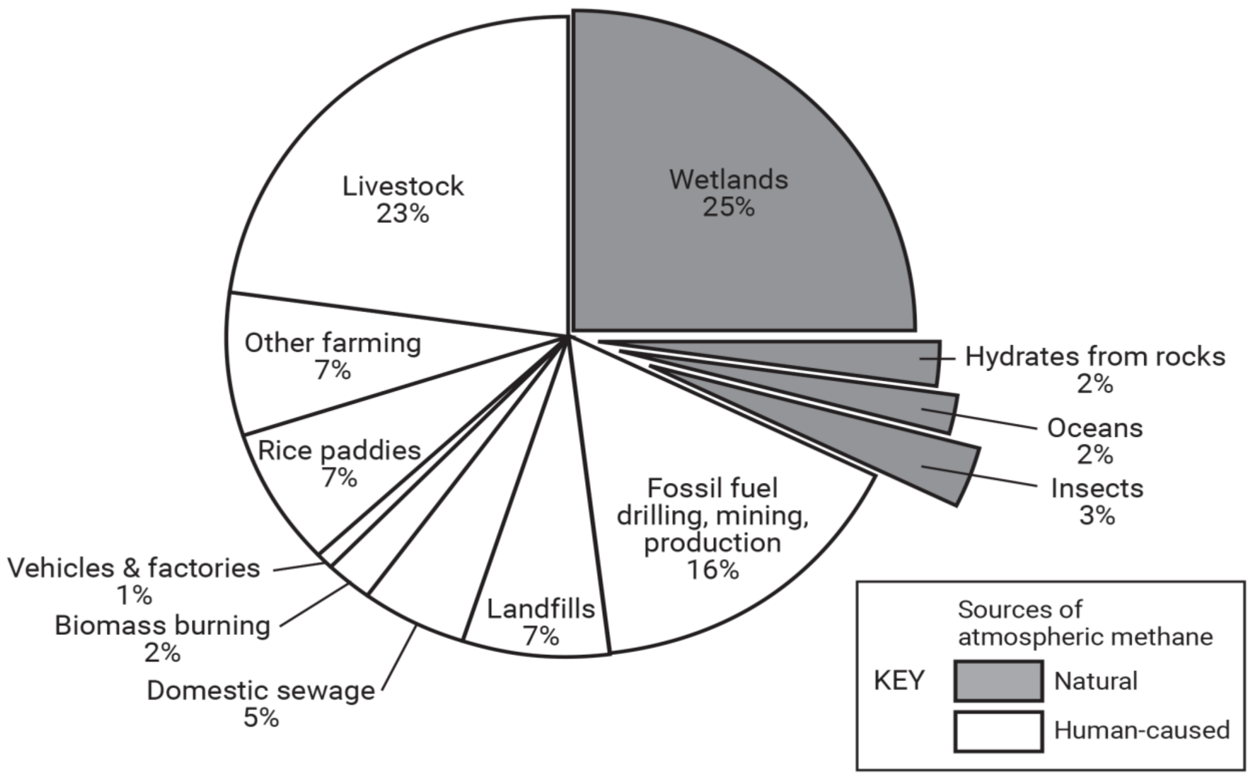


Figure 1: Natural (shown as shaded) and human-caused (shown as white) sources of atmospheric methane. Credit: Wright Seneres Reference: http://www.scientificamerican.com/article.cfm?id=methane-emissions-wetlands-tropics

Evidence #4: Many wetlands are located in rapidly developing areas of the country.

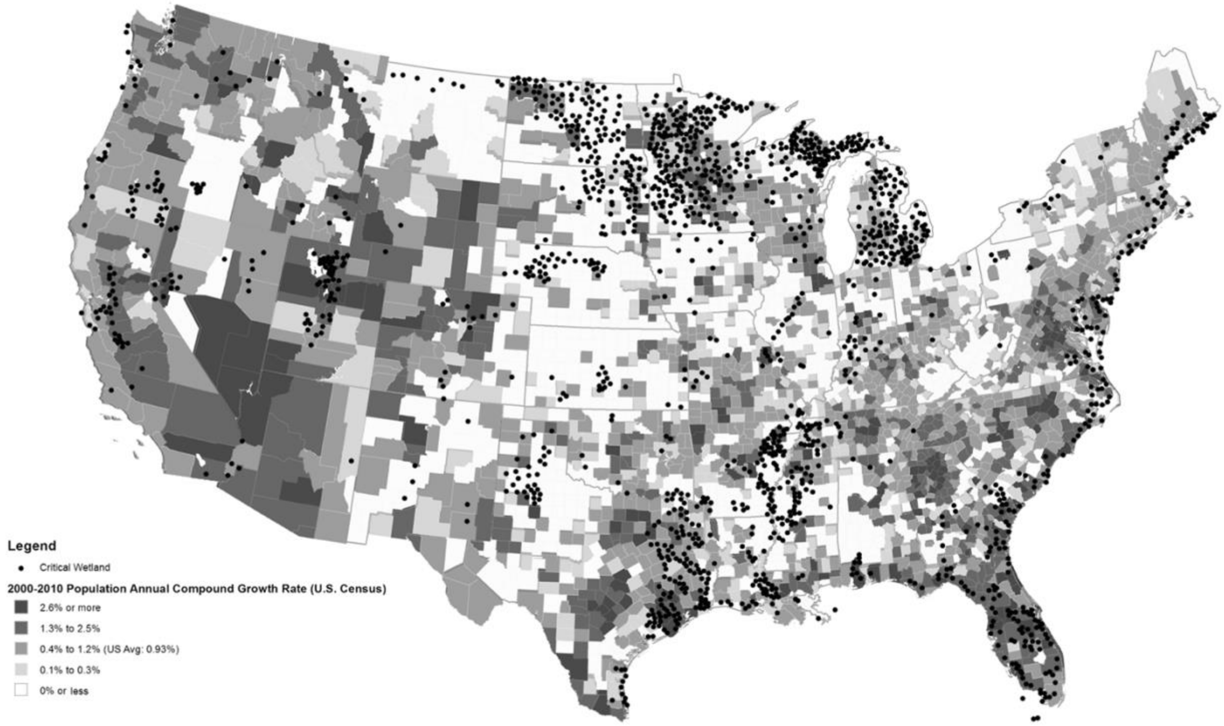


Figure 1. Critical wetlands (black dots) within the United States. Credit: Wright Seneres

Figure 1 above shows the locations of critical wetlands in the United States and areas of population growth. Approximately 75% of all wetlands in the United States are privately owned, and yet these landowners are limited with what they can do with their property. Five U.S. government agencies provide definitions of the various types of wetlands and they also regulate what can and cannot be done with the property. Unless a permit is granted, dredging and filling in wetlands is not permitted.

States enforce these regulations to different degrees. Compare the areas of population growth with that of wetlands (Figure 1). As populations increase, improved infrastructure like roads and bridges are necessary to move people from one location to another. The need for additional housing also makes it necessary to build in less than desirable areas like wetlands. If developers follow the regulations and promise to protect wetlands, then they should be allowed to build on wetlands.

APPENDIX J

CLIMATE CHANGE KNOWLEDGE SURVEY

Name_________________Gender_____Date_________Teacher_____________Period_____

Below are statements about climate change. Rate the degree to which you think that climate scientists agree with these statements.

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1. The Sun is the main source of energy for Earth's climate.	A	B	C	D	E
2. We cannot know about ancient climate change.	A	B	C	D	E
3. Burning of fossil fuels produces greenhouse gases.	A	B	C	D	E
4. Greenhouse gases absorb some of the energy emitted by Earth's surface.	A	B	C	D	E
5. Earth's climate is currently changing.	A	B	C	D	E

APPENDIX K

WETLANDS KNOWLEDGE SURVEY

Name__________________Gender____Date_________Teacher______________Period_____

Below are statements about wetlands. Rate the degree to which you think that *environmental scientists* agree with these statements.

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1. Wetlands occur naturally on every continent.	A	B	C	D	E
2. Loss of wetlands will have little impact on human welfare.	A	B	C	D	E
3. Frogs need wetland habitats in which to reproduce and feed.	A	B	C	D	E
4. Draining of some wetlands can result in release of carbon into the atmosphere, which could increase global warming.	A	B	C	D	E
5. Wetlands cause sudden and damaging floods downstream.	A	B	C	D	E

APPENDIX L

OPEN-ENDED QUESTION SURVEY ABOUT SSI-BASED LEARNING

The Title of Socioscientific Issue Topic:_________Teacher:____Age:______ Gender:____

Please explain all questions as you can possible.

1. What kind of experience did you have used a socio-scientific issue-based learning activity?
2. Would you suggest this activity to other friends? Why?
3. What were your favorite features of this activity?
4. What were some difficulties that you experienced in using this activity? (Please answer this question without technology issue)
5. How did this activity help you understand science?
6. What kinds of contributions did your teachers and classmates make to your learning?
7. If you were a science teacher, how would you design your ‘dream’ science classroom?
8. Would you describe yourself or your family as a “science person?
9. How does your family support you to be a successful student in the science classrooms?
10. What career do you plan pursuing?
11. How did you choose this career path?
12. How might science be related to this career?

APPENDIX M

TEACHER INTERVIEW PROTOCOL

Date:__________ Interview start and end time:__________________________

Part 1. Background Information

1. What grade level(s) and subjects do you teach?
2. How long have you been teaching?
3. Can you describe your classroom diversity (i.e., socioeconomic status, achievement, gender)?
4. When you were a child, did you want to be a science teacher?
5. How did you decide to be a science teacher?
6. How do you describe your favorite science teacher in your high school?
7. How effective was your pre-service program in preparing you to be a science teacher?

Part 2. Teaching

1. Could you please describe the teaching techniques or strategies that are most effective for you?
2. How did you decide to use those strategies?
3. How do you create relevant connections between instructional materials and students' lives?
4. How do you evaluate your student performances?

Part 3. SSI-Based Science Teaching

1. How comfortable do you feel using the MEL activity?
2. What features of the MEL activity do you particularly like?

3. What challenges have you experienced during the MEL activity?
4. How would you re-design the MEL activity for reducing teaching and learning challenges?
5. Do you think that your students like this activity? Why?
6. Do you think students found this lesson meaningful and relevant to the real world? Why?
7. Do you want to use the MEL activity when you teach? Why or why not?
8. Do you want to use SSI-based instructions for evaluating students' learning process? Why?

Part 4. Gender gap

1. What do you think about the gender gap in science education?
2. What are the main reasons for this gender gap in science fields?
3. Did you realize the gender gap in your classrooms? When?
4. Do you notice a difference between female and male students' interests in science?
5. What challenges have you faced in terms of engaging female students in science?
6. What do you think about SSI-based instruction's effectiveness in gender equity?
7. Do you think female students' interest in SSI-based science classrooms? Why?

Part 5. Professional Development

1. Have you participated in any professional development for SSI-based learning?
2. What kinds of professional development formats are most helpful to you?

APPENDIX N

INSTITUTIONAL REVIEW BOARD (IRB) APPROVAL

Temple University
Office of the Vice President for Research

Research Integrity & Compliance
Student Faculty Center
3340 N. Broad Street, Suite 304
Philadelphia PA 19140

Institutional Review Board
Phone: (215) 707-3390
Fax: (215) 707-9100
e-mail: irb@temple.edu

Approval for a Project Involving Human Subjects Research that is Approved as Exempt

Date: 19-Feb-2021

Protocol Number:	27874
PI:	HAN, INSOOK
Review Type:	EXEMPT
Approved On:	19-Feb-2021
Risk:	Minimal risk
Committee:	A2
Sponsor:	NO EXTERNAL SPONSOR
Project Title:	The Examination of Female Students' Experiences in Socioscientific Issues-Based Science Learning

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The IRB approved the protocol 27874.

The study was approved under Exempt review. The IRB determined that the research **does not require a continuing review**, consequently there is not an IRB approval period.

As this research was approved as Exempt, the IRB will not stamp the consent or assent form(s).

Note that all applicable Institutional approvals must also be secured before study implementation. These approvals include, but are not limited to, Medical Radiation Committee ("MRC"); Radiation Safety Committee ("RSC"); Institutional Biosafety Committee ("IBC"); and Temple University Survey Coordinating Committee ("TUSCC"). Please visit these Committees' websites for further information.

Finally, in conducting this research, you are obligated to submit the following:

- **Modifications - Any changes to the research that may change the Exempt status of this study must be reviewed and approved by the IRB prior to implementation.** Examples of such changes are: including new, sensitive questions to a survey or interview, changing data collection such that de-identified data will now be identifiable, including an intervention in the methods, changing variables to be collected from medical charts, decreasing confidentiality measures, including minors or adults lacking capacity to consent as subjects when previously only adults with capacity to consent were to be enrolled, no longer collecting signed HIPAA Authorization, etc. Please reach out to the IRB Staff with any questions about if a change to the study warrants a Modification.
- **Reportable New Information** - Using the Reportable New Information e-form, report new information items such as those described in HRP-071 Policy - Prompt Reporting Requirements to the IRB **within 5 days**.
- **Closure report** - Using a closure e-form, submit when the study is permanently closed to enrollment; all subjects have completed all protocol related interventions and interactions; collection of private identifiable information is complete; and analysis of private identifiable information is complete.

For the complete list of investigator responsibilities, please see the HRP–070 Policy – Investigator Obligations, the Investigator Manual (HRP-910), and other Policies and Procedures found on the Temple University IRB website: https://research.temple.edu/irb-forms-standard-operating-procedures.

Please contact the IRB at (215) 707-3390 if you have any questions.

If you would like to tell us how we are doing, please complete this 5-minute Satisfaction Survey: https://forms.gle/9EcgYGDEEANnvMw37