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HOW COLLABORATIVE LEARNING AFFECTS STUDENT PERCEPTION AND COMPREHENSION OF ELECTROMAGNETIC RADIATION IN AN INTRODUCTORY ASTRONOMY CLASS

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by

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(Under the direction of Donna Governor)

ABSTRACT

This research explores student perception of collaborative learning and comprehension of electromagnetic radiation in a university level introductory astronomy class. Collaborative learning is an instructional strategy in which small groups of students complete a common task such as answering a question, discussing a concept, creating a presentation, or conducting an experiment. Collaborative learning changes students' and teachers' roles in classrooms by shifting the focus from the teacher to the student-centered collaborative group. Collaborative learning may support students' comprehension of the course material through peer discussion and input, in order to construct knowledge with the help of their peers. This research seeks to explore student perception of collaborative learning in an introductory astronomy class through case study. Also, student comprehension of electromagnetic radiation is assessed by pretest and posttest. A review of the literature shows that while there have been extensive studies on collaborative learning, the effects of collaborative learning in the discipline of astronomy at the university level have not been widely researched. The analysis of the quantitative data supports collaborative learning as a means of improving student comprehension. Observation of student

engagement in collaborative learning as well as participant interviews indicate that students generally hold a positive perception of working in a small collaborative group environment, but they found collaborative interaction in a large expert group to be problematic, stressful, and detrimental to the collaborative learning process.

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CHAPTER ONE

INTRODUCTION

In a university-level introductory astronomy class, a wide variety of topics, including the structure and formation of the solar system, planetary science, stellar evolution, the Big Bang, expansion of the universe and life in the universe, have been traditionally presented to students. After completing an introductory astronomy course, students have been expected to understand concepts such as their location in the universe, their connection to the Big Bang and the stellar origin of the elements, all of which depend on an understanding of the electromagnetic radiation. Astronomy is an enormous and incremental topic of which students must first master the basic terms, theories and laws. Then they must apply such knowledge to specific concepts in astronomy.

Statement of the Problem

There has been a general consensus among many astronomy educators that students' conceptual understanding of astronomy was flawed and the method of astronomy course delivery should have been adjusted (Bailey & Slater, 2003). Bailey and Slater (2003) warned that scientific literacy among Americans was in decline and students were ill prepared for the scientific and technical jobs that needed to be filled. Many introductory astronomy students enrolled to satisfy their college science requirement. As such, Bailey and Slater suggested educators engage in educational research so that they may find the most effective way to motivate and inspire their students and help them to become excited about science.

The direct instruction method was commonly used in college level astronomy courses (Williamson & Willoughby, 2012). This type of content delivery is instructor based, meaning that the direction of instruction is guided primarily by the instructor (Fink, 2013). Since direct instruction is instructor-based, students may have been reluctant to engage the instructor in order to avoid a negative instructor response, or students may not have found an opportunity to contribute (Roehling et al., 2010; Liu & Littlewood, 1997). Based on this inherent lack of interaction, the instructor may have been unaware of any disconnect that may have existed between instructor and student. Johnson and Johnson (1986) explained that the problem with lectures is that "information passes from the notes of the professor to the notes of the student without passing through the mind of either" (p.10). As such, students often memorized astronomy facts associated with the topics, rather than comprehending the material; which has been an impractical approach to learning astronomy (Marché, 2001) because learning astronomical concepts required students to make connections between various astronomical phenomena in order to understand how the universe is arranged and how parts interact with each other (Retrê et al., 2019). One example of a concept that requires a level of comprehension beyond simple recall is how cosmological redshift yielded the age of the Universe. Such knowledge has been built upon progressively understanding multiple concepts and then applying layers of knowledge to answer related questions, as demonstrated in the redshift survey work of Colless et al. (2001).

The concepts necessary to understand the expansion of the Universe include the mechanism of red-shifted light as measured by spectroscopic analysis. Using this knowledge, the redshift of spectral lines has been used to measure the recessional velocity of distant galaxies. Then, using Hubble's Law, astronomers calculated the distance to receding galaxies. Hubble's Law states that redshifted galaxies move away from the observer at approximately 75 km/sec/Mpc (Hubble's Constant). Finally, by combining an understanding of spectroscopy, redshift of electromagnetic radiation and Hubble's Law, students have usually been expected to calculate and explain the age of the Universe. Therefore, students needed to learn and apply a combination of astronomy concepts in order to complete more difficult tasks, such as measuring the mass of a body based on the orbital properties of the body's satellites or determining the distance to galaxies based on their spectral redshift (OpenStax, 2016).

Theoretical Framework

This research was theoretically grounded in social constructivism. Social constructivism was an extension of Dewey's pragmatism, in the sense that knowledge is constructed by the learner. Social constructivism required the addition of a social component to constructivism, meaning that learning was constructed through interaction between people (Kozulin et al., 2005). Vygotsky was credited with establishing the tradition of social constructivism. Vygotsky's theory included mediation of higher mental processes, in which learners interacted with people or nature. The theory also included the zone of proximal development (ZPD) (Kozulin et al., 2005). The ZPD was defined as: "The distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers" (Vygotsky, 1978, p. 97). Specifically, the ZPD was the area between a student's independent capabilities and a student's capabilities with assistance. ZPD theorized that all students in a group should be able to perform at the level of its most competent members. Smagorinsky (2018) cautioned practitioners against a reductionist interpretation of Vygotsky's ZPD because, according to Smagorinsky, ZPD did not merely suggest students learn with assistance, but was a method of developing a student's ability to accomplish progressively difficult tasks, independent of others. ZPD was not concerned with short-term achievement but was concerned with long-term human developmental progress which resulted in the development of students' individual ability.

Collaborative learning was rooted in Vygotsky's (1978) zone of proximal development (ZPD) in that collaborative learning groups were established to allow students to work with more qualified peers. Collaborative learning was a teaching method in which students work together towards a common goal. Ideally, students would take turns being the most qualified among their peers, based on their level of interest or knowledge related to a particular topic. The method was appropriate for a multitude of tasks of various levels of complexity. Sometimes collaborative groups divided tasks and assigned parts to be completed by individuals, whereas other collaborative groups completed tasks collectively through discussion or discourse (Knight & Wood, 2005). To an extent, collaborative learning supported student-centered instruction. Collaborative learners participated in their own learning and constructed knowledge with the assistance of their group, rather than passively consuming information as it was presented by an instructor, as a member of an audience would (Volpe, 1984). For a passive observer in a direct instruction approach, such as a student in a lecture, it was not necessary to synthesize and apply information or to "cognitively restructure" (Webb, 1982, p. 428) information. However, synthesis and application of new knowledge was necessary for a member of a collaborative learning group tasked with learning and interacting with other members.

Purpose of the Study

The purpose of this study was to examine student perception of collaborative group learning and comprehension of topic of electromagnetic radiation as explored in an astronomy class. While engaging in collaborative learning, students learned and synthesized information as a result of interacting with peers who were in the process of constructing an understanding of a specific concept. Collaborative learning developed the construction of knowledge as an alternative for students to merely accepting a singular explanation from their instructor. As such, collaborative learning was active and replaced the students' traditional passive learning role during direct instruction (Cerbin, 2018; Rau & Heyl, 1990). This research sought to document student comprehension and perception of collaborative learning as a result of participating in collaborative learning groups and to facilitate synthesis of astronomical concepts such as the characteristics of light, and the analysis of light.

Research Questions

The following research questions guided this study:

1. What are students' perceptions of collaborative group learning?
2. What are the effects of collaborative learning on student comprehension of concepts related to electromagnetic radiation?

Significance of the Study

A review of the literature revealed that while there have been extensive studies on collaborative learning, the effects of collaborative learning in the discipline of astronomy at the university level have not been widely researched. Skala et al. (2000) examined the effects of collaborative in a university astronomy class but relied on focus groups to do so. This research sought to answer specific questions about collaborative learning effects on student perceptions through interviews and observations as well as effects on comprehension by means of assessment. These research questions were intended to develop theory grounded in shared student experience to inform researchers and practitioners interested in engaging students in collaborative learning.

Definition of Terms

The following definitions of terms were used specifically for the purposes of this study:

Direct instruction is the traditional method of instructor and student interaction in a university level introductory astronomy class. In direct instruction, the instructor speaks to the class and students receive knowledge as a large group (Knight & Wood, 2005; Webb, 1985).

Collaborative learning is an instructional strategy in which students work in groups to study, solve a problem or complete a task. While engaged in collaborative learning, students have the opportunity to explore concepts and construct knowledge based on their own analysis of the information presented to them as well as the analysis of their peers. This research is an exploration of collaborative learning as a means for students to study electromagnetic radiation.

Electromagnetic radiation is often simply referred to as light. Although visible light is part of the electromagnetic spectrum, radio, microwave, infrared, ultraviolet, x-ray and gamma ray are all electromagnetic radiation. All of these types of electromagnetic radiation are observed by astronomers in order to help them understand the nature of the universe in which we live (OpenStax, 2016).

CHAPTER TWO

REVIEW OF THE LITERATURE

The purpose of this study was to examine student perception of collaborative group learning and comprehension of topics explored in an astronomy class. The research questions guiding this study were:

1. What are students' perceptions of collaborative group learning?
2. What are the effects of collaborative learning on student comprehension of concepts related to electromagnetic radiation?

This chapter presents a review of the research literature pertaining to the purpose and significance of this research. Theories utilized for the purpose of this study are presented first, such as the importance of electromagnetic radiation in astronomy, and social constructivism. Then the focus shifts to the relevant literature of collaborative learning within higher education. The information provided here seeks to inform and contextualize the application of collaborative learning to a university astronomy class.

Importance of Electromagnetic Radiation in Astronomy

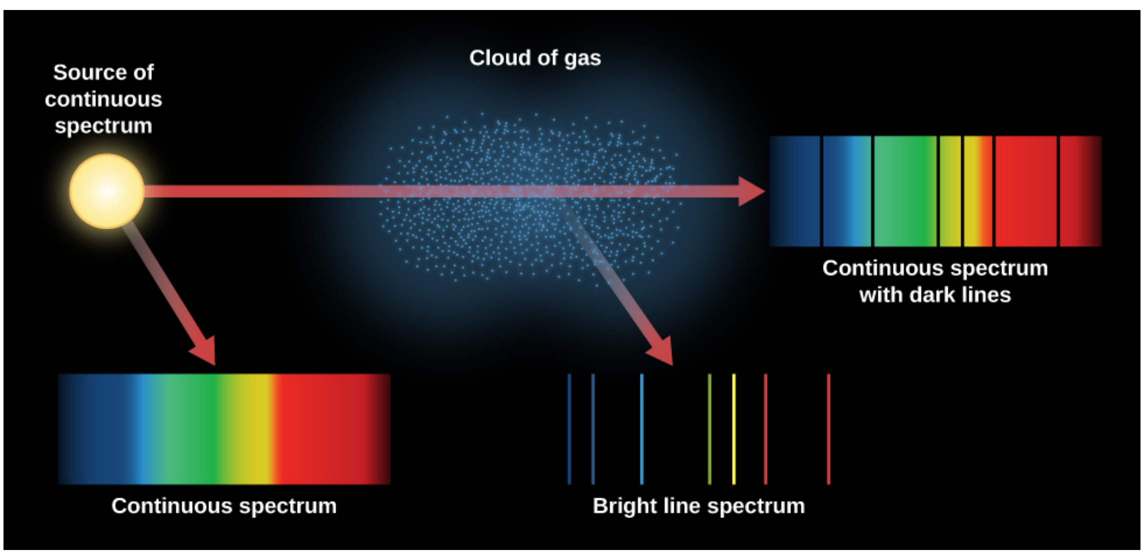
Electromagnetic radiation was important to the study of astronomy because it is the primary source of astronomical information from the Universe. The earliest astronomical observations of visible light were made with the unaided eye. Visible light is a form of electromagnetic radiation and is part of the electromagnetic spectrum. However, the electromagnetic spectrum also includes radio, microwave, infrared, visible, ultraviolet, x-ray and gamma ray radiation, all of which are different wavelengths of light. In the context of electromagnetism, radiation is energy in motion. Electromagnetic radiation is typically produced by accelerating charges or by the transitions of electrons between quantum states. (OpenStax, 2016). Different wavelengths of electromagnetic radiation allowed astronomers to peer through various intervening layers of matter and light to uncover information that would remain otherwise obscured. Astronomers even required electromagnetic radiation to observe gravitational interactions. Further, knowledge of the nature and dynamics of electromagnetic radiation was foundational to the comprehension of data resulting from multi-wavelength astronomy (Retrê et al., 2019).

In order for students to have applied knowledge of electromagnetic radiation to concepts in astronomy, an understanding of the behavior of light was required. Students should have understood that the peak wavelength of the light emitted and energy output from stars may have been determined by temperature. Finally, students should have comprehended that the Doppler Effect is a phenomenon in which approaching waves are closer together (blueshift) and receding waves spread apart (redshift). It should have been clear to students that the atmosphere of the Earth blocks most electromagnetic radiation and allows only visible, some radio, near infrared and very near UV wavelengths of light to pass through to the Earth's surface. The transmission of visible light and radio wavelengths allowed astronomers to make observations from Earth-based observatories. The atmosphere's opacity was the reason that scientists need space-based telescopes to observe specific objects at other wavelengths, such as x-ray, gamma ray, ultraviolet and infrared. Astronomers observed objects in these wavelength regimes to study their different physical properties or to see objects that are obscured by dust or gas. All of these concepts have been an important part of most entry level astronomy courses since so much of astronomy was based on a fundamental understanding of the nature of light.

Spectroscopy, another concept in astronomy based on an understanding of the electromagnetic spectrum, is the analysis of chromatically dispersed light. It allowed astronomers to identify the heated element or molecule from which it emanated. Also, spectroscopy was used to reveal the composition of cool gas that light passes through during its journey to the observer. Therefore, as light passed through cold dark space, astronomers could detect the elements present in the intervening space. Kirchhoff's law suggested that since light was produced by electron transitions, every element emitted specific identifying wavelengths of light, indicative of the light's element of origin. Conversely, cool elements in intervening space absorbed light of the same wavelength that they would also emit, if heated. Kirchhoff referred to these as emission and absorption lines. Spectroscopy allowed astronomers to determine the composition of astronomical objects such as stars, galaxies, nebulae, and stellar and planetary atmospheres. Continuous spectrum is light from a hot glowing object such as a star. (OpenStax, 2016). See Figure 1.

Figure 1

Types of Spectra



Note. This figure is an illustration of continuous spectrum emanating from a hot luminous source, a bright line emission spectrum, and a dark line absorption spectrum. Reprinted from *OpenStax Astronomy*, Fraknoi, A. Morrison, D. and Wolf, S. C., 2016, https://openstax.org/books/astronomy/pages/5-5-formation-of-spectral-lines. Copyright 2013 by OpenStax- Rice University. Reprinted with permission.

After students develop a clear understanding of spectroscopy, they have been expected to apply their knowledge to understand the radial motion of astronomical objects. Applying the Doppler Effect to spectroscopy allowed astronomers to measure the radial velocity of an object and determine if the object was approaching or receeding from the observer. Spectral lines shifted in the direction of shorter wavelengths of light; when approaching this was referred to as blue shift. Conversely, spectral lines shifted in the direction of longer wavelengths of light, or redshift, when leaving the observer. The amount of the shift was directly proportional to the velocity of the object. Combining spectral analysis of emission or absorption lines with the Doppler effect, astronomers were able to measure the velocity of stars and galaxies and the cosmological expansion of the universe (OpenStax, 2016). Because of the advanced and overlapping concepts presented here, knowledge of electromagnetic radiation was paramount to the pursuit of basic astronomical knowledge in any university level astronomy course.

Social Constructivism

Constructivism was the theory of learning in which the learner is an active participant in the learning process, rather than a recipient of information (Fosnot, 2013). Constructivism was based upon the early 20th century work in cognitive science and psychology of Vygotsky and Piaget. In the constructivist view of learning, learners constructed knowledge of the environment based on experiences to which they have been exposed. This view was in contrast to the objectivist notion that information exists independently of the learner and that learning was an act of accessing knowledge (Bhattacharya, 2017).

Unlike Piaget, who considered learning as a biological and sociological process, Lev Vygotsky studied learning as a social developmental process. Kozulin et al. (2005) discussed

Vygotsky's social constructivism theory in three divisions. The first is mediation of children's "higher mental processes" (p. 65) through human interaction, or through "symbolic" (p. 23) interaction, meaning through the use of symbols. Vygotsky's theory stated that "language, signs and symbols" (p. 65), introduced by adults, mediated children's higher mental processes (Kozulin et al., 2005). Vygotsky's (1978) theory also allowed for symbols to mediate the cognitive development of children. Symbols can be words, letters, numbers, counting of fingers or other objects introduced to the child by an adult. Symbols can also be objects or representations, which have been previously introduced to the child by an adult.

The second part of Vygotsky's theory explains "psychological tools" (p. 29) (Kozulin et al., 2005). Kozulin et al. (2005) explained that Vygotsky's psychological tools resulted in "cognitive education" (p. 29) which was the cognitive nourishment provided by parents through mediation during early cognitive development.

The third component is Vygotsky's Zone of Proximal Development (ZPD) (Kozulin et al., 2005, p. 17). ZPD was the metaphorical distance between the limit of a child's cognitive ability and the ability of the child as a result of adult mediation. ZPD described the change in a child's ability with the help of a more qualified individual. Vygotsky's theory was, in part, the basis for social constructivism. As such, Vygotsky attributed the act of learning to a child's self-constructed interpretation of its environment but the cognitive ability to construct understanding was mediated by the parent or peer (Vygotsky, 1978).

Collaborative Learning

Collaborative learning was an educational method, grounded in Vygotsky's Social Constructivism, in which groups of students worked together to achieve a common goal or task. According to Vygotsky's (1978) ZPD, a student could learn more with peers than individually.

By extension, through collaborative learning, all of the members of a group should have effectively performed at the proficiency level of the most qualified member of the group. More knowledgeable students helped less knowledgeable students to perform at a higher level and in turn, improved their own understanding by engaging in discussion and instruction.

In collaborative learning groups, the goal was for students to complete a common task. Students constructed knowledge while negotiating and rethinking their ideas based on input from other students. Collaborative learning also enabled students to experience course content through the constructs of their peers. Ideally, during collaborative learning, an instructor would only act as an observer. However, simply observing was not always practical, and the instructor's role often evolved into that of facilitator of the student learning process (Boud et al., 2014; Bruffee, 1999). At times, the class instructor had to intervene in the student group in order to serve as a catalyst for the collaborative learning process because students may have needed encouragement or direction. Additionally, the class instructor may have needed to intervene to keep the student group on task, or to serve as a mediator and facilitator for purposes of dispute resolution. The instructor also guided collaborative groups to utilize data that is based on scientific consensus rather than erroneous information. As the instructor had to perform several functions to support multiple collaborative groups, the instructor physically moved among the groups to provide assistance. Mobility of the instructor in itself was a departure from instructors' traditional position as the focus of the class (Lasry et al., 2014).

Bruffee (1999) found that in practice, collaborative learning could appear chaotic at times. Students become engaged in discussion and debate in an effort to construct their own individual understanding of subject matter. They may have also challenged and negotiated the collectively constructed understanding shared by the group, and some students may have rejected a group consensus in favor of their own construct. Because this behavior was atypical in a teacher-centered classroom, it may have been misconstrued by an observer as students being disengaged, or off task. The nature of group activity, as opposed to individual activity, may have appeared to be a class in disorder, when in fact students were learning at a higher level. As such, student interaction appeared to improve student performance (Boud et al., 2014; Panitz & Panitz 1998). Furthermore, when students explained concepts to each other or had concepts explained by a peer, there was a positive impact on student achievement (Xu et al., 2015; Prince, 2004). Students assisted their peers in collaborative learning environments, which correlated to improved student achievement. However, receiving help did not necessarily lead to improved student achievement (Hoogerheide et al., 2016; Webb, 1985). Webb found that receiving help from peers was only beneficial when students who need assistance asked for the help of their peers.

The individual ability of students and the collective ability of the group affected the benefit of both giving and receiving help. Collaborative learning can be more effective than direct instruction, as reciting information is less beneficial than teaching or relating information to a peer (Cerbin, 2018). Jackson et al. (2018) suggested that learning together in a collaborative group not only improved understanding and problem-solving skills but also prepared students to work with others in their professional lives.

Bruffee (1999) and Czajka and McConnell (2019) suggested that institutions of higher education that rely on direct instruction should reconsider the way that students were taught due to research that shows other methods were more effective at enhancing learning. Bruffee explained that knowledge and learning were a communal construct and proposed that learning should occur in groups of students which he named “learning communities” (p. 5). In these communities, students discussed ideas from their individual points of reference and therefore created more meaningful knowledge than if constructed from a single frame of reference. McCabe and Lummis (2018) noted that undergraduate students often assembled into groups outside of class in order to study collaboratively. Even though most students seemed to prefer to study alone, they would often form social groups to improve their individual learning outcomes. Activities in these self-formed study groups included discussions among high performing students. Lower performing students occupied their time during study sessions by quizzing, studying questions, and making flashcards (McCabe & Lummis, 2018). This research suggested that when high performing and lower performing students form a collaborative learning group, all group members had the opportunity to benefit from group discussion.

West and Williams (2017) defined "learning communities" (p.1570) as a group of learners who have access to each other. Learners who were physically present in the same classroom had access to other learners, but access could be extended virtually when learners shared a digital presence, such as an online environment. Second, West and Williams (2017) indicated that a community implied a relationship and identified principles of effective learning communities. Members of a community must have trusted other members in order to foster communication and collaboration. Also, communities could not be forced together; instead they must have been built by the members and based on interactions. Third, members of a community must have had a sense of belonging. They should have felt like part of the group and felt that they were connected to other group members by similarities among members of the community. Fourth, there should have been a sense of interdependence within the community. Members should have been able to depend on each other and feel as if they mattered as an important part of the community. Fifth, there must have been trust within the community. Additionally, there should have been faith in the community's focus on the individual members' needs, as well as the collective needs of the community. Finally, a community should have shared a vision so that the goals of the group were clearly articulated, and all members were working toward the construction of the knowledge of all group members. In the absence of such a group goal, less capable students may have not had the opportunity to benefit from the guidance of peers in collaborative learning groups (Graesser et al., 2018).

If instruction was to become supportive of a collaborative, student centered process, the interaction and therefore the relationship between teacher and student should have changed in order to facilitate the collaborative learning (Bruffee, 1999). To the same end, Czajka and McConnell (2019) recommended that college faculty should have implemented a student-centered approach that includes collaboration with peers. Students possess common traits, such as language, interests and abilities. The fact that the students were engaged in the pursuit of higher education was an indicator that the students may have wised to join the community of their discipline of study and it was helpful for them to do so in a group (Bruffee, 1999).

Bruffee (1999) also wrote about consensus groups, where a group of students discussed an assigned topic and tried to reach consensus, after which an elected spokesperson from each group shared the group results in a session with the whole class. Using this strategy, the teacher facilitated the discussion of differences and similarities in the reports from the student groups and mediated the accepted understanding of the discipline community. The teacher explained how the student reports aligned with the accepted views within the discipline. Knight and Wood (2005) shared Bruffee's approach to facilitating group consensus. In their research of collaborative learning, Knight, and Wood devoted much of their class instruction time to group discussion of topics in a Freshman English class to help the participants reach a consensus regarding topics explored during collaborative learning sessions. Skala et al. (2000) did not require consensus in their work with collaborative learning groups, and students were free to maintain their individual opinion. In the Skala et al. study students were free to disagree with their group so that they constructed independent knowledge with the help of peers, rather than completely assuming the constructs of the other group members.

Research suggested that collaborative learning increased student performance, comprehension and involvement and were student centered (Tal & Tsaushu, 2018; Rau & Heyl, 1990). In traditional classes utilizing direct instruction methods, a teacher typically instructed and solicited questions and responses from students, to which most students did not feel obligated to respond. As such, the result was that one teacher and only a few students ended up discussing any given topic. While in a classroom where students were in collaborative learning groups, members compared ideas, asked questions and answered questions in order to achieve a group goal. In such a classroom, students actively engaging in learning through participation tended to perform better than their peers (Freeman et al., 2014). In collaborative learning groups, there was more student participation and discussion than in direct instruction, so that more students benefited from the classroom experience.

Rau and Heyl (1990) discussed the importance of group size and selection in utilizing collaborative learning groups, and they recommended four to five students work together. This was based in part on the concern that small groups lacked diversity of knowledge and experience and that groups of three may have excluded one student. In groups larger than five students a student could become disengaged without bringing group activity to a halt; therefore, larger groups may have hindered learning by not engaging all members. Knight and Wood (2005) preferred three to four students in a group in order to evenly distribute students of high, low and medium achievement. In their study, static groups were assigned at the beginning of the semester based on performance in a prerequisite class attempting to assign groups with an “A” student, two “B” students and a “C” student while maintaining an even gender representation among groups. Skala et al. (2000) instructed participants to form pairs and then pairs joined to create learning groups of four students. Rau and Heyl (1990) randomly selected groups to encourage a diverse mix of students within the groups. Rau and Heyl (1990) also recommended that students trade roles, such as recorder or discussion leader, within their group from time to time so that the group would not be dominated by certain students. In Rau and Heyl’s (1990) classrooms, students were required to submit written work that was intended to prepare them for the group assignment. If they did not, they could participate in the group discussion but received no grade. This grade consequence prevented students from gaining from the group work without understanding or providing input. Each group submitted a written report that was collaboratively constructed by the group. Rau and Heyl (1990) suggested that all students should have a voice during group interaction if collaboration is to occur. Pang et al. (2018) found that social interaction was necessary before the process of collaboration began. Simply putting students into groups was insufficient; in order to benefit students, educators must have initiated the process of collaboration by starting a dialogue among the group members or by asking questions of the group to maximize student learning.

Student Perceptions of Collaborative Learning

Some students found the study of astronomy to be irrelevant and viewed astronomy as a long list of facts to remember and then recite (Skala et al., 2000). Also, many students in a direct instruction environment were merely passive learners, meaning that they received information from their instructor without engaging in the process of applying or synthesizing concepts

(Cerbin, 2018; Rau & Heyl, 1990). Introductory astronomy classes were often the final science class in the academic career of a non-science major and may have shaped students' lifelong perceptions of science (Wittman, 2009; Skala et al., 2000). To improve the student perception of relevance and change the tendency of students to memorize facts, collaborative learning may have been employed. Participation in collaborative learning required synthesis of concepts and therefore contextualization by the students, rather than the passive role students experienced during direct instruction.

To encourage the cooperation and participation among group members, collaborative groups should have had both individual and group goals (Kleingeld et al., 2011; Slavin, 1989). Achievement of the group goal, which was that all members constructed knowledge, was a means to improve student perception of the study of astronomy. Skala et al. (2000) devised a novel assessment practice. Students completed quizzes individually and then were allowed to attempt an identical assessment with the help of their collaborative group. The scores of the two assessments were then averaged, resulting in a student assessment grade that included an individual and group component, encouraging the co-construction of knowledge (Skala et al., 2000).

Skala et al. (2000) found that student participants of focus groups were concerned with the composition and formation of groups and how they are regulated. Wang & Lin (2007) found that the composition of collaborative learning groups and the ability of the individual group members were indicators of overall group effectiveness. Participants in research conducted by Skala et al., (2000) suggested regulation, because when students self-assembled into groups they tended to choose either students that were familiar to them, random students, or a mix of the two. For instance, students would pair with a familiar student and then join another random pair of students; the result being that most students were in mixed groups. Skala et al. (2000) noted that due to poor attendance, groups were often incomplete or had to merge with other groups. Skala et al. (2000) reported that random groups were the most problematic in terms of attendance and cooperation. The familiar groups were the most successful at working together and had the least complaints about working in groups

The second issue that arose from Skala et al.'s (2000) focus group research on the use of collaborative learning was that students felt that the group roles should be less structured. Each group was to have a "leader, recorder explorer and skeptic" (P. 190) and the students were to take turns in each of these roles. Many groups disregarded some of the roles because of time constraints or because they disagreed with the need to have roles. Skala et al. said that all groups used the role of recorder and some used the role of leader, but often they did not understand or find a need for the explorer or skeptic, which were assigned roles in their collaborative groups. DiMarco and Luzzatto (2010) offered that during the initial assignment or selection of collaborative learning groups, instructors should help groups create their own structure in order to equitably distribute work among the group members. In Knight and Wood's (2005) collaborative learning study, students were allowed to self-assemble into unstructured groups.

The third issue from Skala et al. (2000) focus group study was whether students felt that the collaborative learning groups helped them learn the material. The results of the study showed that all of the students in the focus group, which was over 33 percent of the class, agreed that they learned better in the collaborative groups. Some students appreciated the "hands-on" (p. 190) approach while others found benefit in the discussion of concepts with others. Research by Christensen et al. (2013) supported this finding that hands-on activities contribute to a persistent construct of knowledge.

In a review of the focus groups' transcript data, Skala et al. (2000) found that groups reported often only having three members present and that some students actually preferred working in groups of three. Skala et al. (2000) expressed concern about attendance for groups of this size, and its negative effects on student learning and collaborative learning groups throughout their paper. Skala et al. (2000) noted that due to poor attendance, groups often did work with only three students present, suggesting that the optimal number of group participants might have been reconsidered. In a study by Clarke et al. (2017) exploring the effect of collaborative group size in kindergarten math, they found that there was no statistical difference in individual performance among groups of two or groups of five.

Absenteeism caused a variable collaborative group size. Koppenhaver (2006) suggested implementing an attendance grade policy in courses that use a collaborative learning structure. Koppenhaver found that poor student attendance was not only detrimental to the individual student but had a profound impact on the performance to the other members of their collaborative group.

This research acknowledged the need for the synthesis of information presented in a university introductory astronomy class as opposed to memorization of facts. Whereas Skala et al. (2000) approached the need for synthesis by assigning group work, this research engaged collaborative learning groups in constructing knowledge, based on course content with the interaction of peers. Also, this research explored the student experience of collaborative learning based on observations and individual student interviews, as well as pretest and posttest, rather than relying on focus groups as did Skala et al. (2000).

Kumi-Yeboah et al. (2017) studied student perception of collaborative learning in a graduate level, special education, online course. The participants were a group of twenty culturally diverse minority graduate education students. Kumi-Yeboah et al. (2017) found that the cohort's perception of the collaborative learning experience was positive. Participants indicated that collaborative learning activities helped them to construct knowledge through communication and interaction. Also, the participants expressed the benefit of working in a diverse group due to the collectively wide range of experiences represented in such a group. Further, they preferred learning in small groups because their contributions made a greater impact on the learning experience than when working as a larger group, and there was more accountability for individual performance.

Collaborative Learning on Comprehension

Fielding and Pearson (1994) examined comprehension and cognition in collaborative learning groups and found that social interaction of the group influenced both. Fielding and Pearson (1994) focused on reading and comprehension as mediated by collaborative groups and the effects of mediation on synthesis of information. Fielding and Pearson (1994) found that "students gain access to one another's thinking process" (n.p.) in collaborative groups and that "comprehension is a process in which students construct knowledge, make inferences and evaluate rather than memorizing information" (n.p.).

Collaborative learning provides students an opportunity to discuss, be responsible for their learning, and to think critically (Totten et al., 1991). Bellaera et al. (2016) found a causal connection between critical thinking and comprehension. In a collaborative learning group, students have the opportunity to act as both teacher and student which should initiate critical thinking. Students giving and receiving explanations, rather than just answers, improved their achievement (Webb, 1985).

Moore and Quinn (1994) demonstrated that during direct instruction, students were not always engaged and “on task” (p. 42). Employing collaborative methods, such as applying learned information or teaching groupmates and the ability to apply learned information to new tasks, was called “transfer” (p. 49). Moore and Quinn asserted that transfer is the overarching goal of teaching and learning. Studies have shown that information learned by reading or by lecture was insufficient and students should have actively learned and been able to transfer their new knowledge (National Research Council, 2000).

Knight and Wood (2005) conducted a study to measure the effects of collaborative learning on the content knowledge of their undergraduate biology students. Pretest and posttests, as well as homework and in-class formative assessment were used to determine the level of student conceptual understanding as compared to a control section where collaborative learning strategies were not employed. Biology student performance on the pretest was similar regardless of group, but the students who engaged in collaborative group learning activities scored an average of nine percent higher on the posttest. In group work sessions, Knight and Wood (2005) described three observed scenarios and found each to be acceptable. In the first scenario, students worked together and discussed the questions. In the second scenario, students divided their work and then shared the answers with each other. Dividing assignments among members of a collaborative group enabled each student to become knowledgeable about aspects of a specific topic, and then co-constructed knowledge by relating what they have learned to their peers (Hicks & Howkins, 2015). In the third scenario, some students did the work and other students just received answers. Although Knight and Wood (2005) did not express a preference among the three scenarios, in the third scenario the students who only received answers were not engaged in the collaborative process and were task oriented. Oliveira et al. (2014) suggested that a task-oriented goal, rather than group-oriented goal, in a collaborative environment could lead to low cognitive engagement among group members.

Knight and Wood's (2005) experiment received mixed reactions from students. Some students realized value in the group interaction and others did not. Overall, survey responses indicate that the majority of students felt that "significant learning took place during class" (p. 304). Knight & Wood (2005) recommend replacing some lecture content with collaborative activities because their students experienced "learning gains" (p.298) and improved conceptual understanding from engaging in collaborative learning. Knight and Wood (2005) experimented with an interactive approach to instruction in an upper-division developmental biology lecture course. The interactive approach included collaborative solving and student in-class participation in order to improve students' conceptual understanding of topics in biology. Students were instructed to assemble into groups of three to four and remain in the same group in their lecture and lab sections for the entire semester. Students were assessed individually on their content knowledge throughout the class meetings using "clickers." When the assessment revealed disagreement among the class, students were asked to discuss the answers in their collaborative groups, and they were assessed again. Freeman et al. (2014) found that students who are engaged in the process of active learning show improved performance over students taught by direct instruction. Therefore, students engaged in the active process of collaboration showed improved performance and comprehension (Fink, 2013). Fink (2013) found that direct instruction was ineffective. Fink reported that students performed poorly on open book and open note conceptual assessments directly following lectures. Student performance declined substantially on the same assessment after two weeks. Fink recommended that educators change the way that they teach to include engaging students in problem solving exercises, development student curiosity, and the application of course content.

Collaborative Learning in Astronomy

Misconceptions may have occured when people applied sound logic to a topic that they misunderstood or partially understood (Hammer, 1996). Misconceptions could have also been constructed when people learned new information and then adjusted their conceptual understanding in such a way that attempted to reconcile the new concept with prior knowledge (Vosniadou, 1994). Hammer (1996) defined misconceptions as “strongly held cognitive structures” (p. 1318) which affect understanding and must be eliminated. Students often had misconceptions about fundamental topics in astronomy and such misconceptions were compounded when students based increasingly complex constructs upon them (Chi, 2005; Williamson & Willoughby, 2012). The study of electromagnetism in astronomy has been one such concept.

Remembering and recalling concepts was the lowest cognitive level within Bloom’s taxonomy (Bloom, 1956). Johnson and Johnson (1986) stated that collaborative learners must think on higher levels and exhibited improved information retention. Collaborative learning may have been an effective mechanism to initiate a higher level of learning in an astronomy class. Joyce et al. (1987) showed that humans learned best when they collaborated with others while learning new information. McConnell et al. (2017) found that the achievement gap was reduced when STEM students worked collaboratively.

Engaging students in collaborative group activities allowed students to receive feedback from their peers and articulate their understanding of a topic, which may have improved comprehension and addressed misconceptions, such as those that occur in astronomy, with the help of their peers and their instructor (Kozulin et al., 2005). Also, collaborative learning built student confidence, which enabled students to attempt more challenging tasks (Bruffee, 1999). Adding the collaborative component to the construction of knowledge required students to explore and synthesize the information delivered through direct instruction.

Due to the volume of information that is typically learned during the course of a semester in an astronomy course, students may have had difficulty retaining and comprehending the large amount of verbal information presented to them through direct instruction. Among students in a lecture, attention waned over time (Risco et al., 2012). Wilson & Korn (2002) showed that students' attention span during direct instruction lasted approximately ten to fifteen minutes, after which their attention waned and retention of information decreased.

Summary

Learning about astronomy required students to reconstruct prior knowledge and to abandon misconceptions in order to master the concepts. From the front of the class, where the instructor was typically located during direct instruction in a traditional astronomy course, it could have been challenging to assess and address students conceptual understanding of new topics and how new information is interwoven with prior knowledge. In this research, collaborative learning was a measure by which student learning could be facilitated through the assistance of peers as well as multiple instructional tools, such as books, models and hands-on components.

Although the perception of collaborative learning and comprehension of topics explored in an introductory university astronomy class have not been extensively researched, there have been studies of collaborative learning that are specific to the discipline of astronomy that indicated collaborative learning improved students' achievement and understanding of topics in astronomy. Hudgins et al. (2006) and Skala et al. (2000) showed that collaborative learning was an effective teaching strategy to improve student achievement in astronomy. Hudgins et al. (2006) explored the introduction of group ranking tasks in which students were assigned the task of arranging several pictures in the correct order to demonstrate a sequence of events or specific outcome. For example, students were asked to arrange depictions of stages of solar system formation into the correct sequence. Students were also asked to rank stages of stellar evolution. Hudgins et al. (2006) used group ranking tasks, in which students assigned a numerical ranking to illustrations of astronomical objects or processes to indicate sequence of events, distances or size, as a means of improving student understanding in a college astronomy lecture class. Skala et al. (2000) engaged students in collaborative learning groups of three to four students in which the students were assigned open-ended projects to supplement a typical astronomy lecture section. Skala et al. (2000) found that students perceived their ability to learn improved as a result of working in collaborative groups. Hudgins et al. and Skala et al. concluded that collaborative learning can improve student perception of their own ability to learn as well as their performance in an astronomy class. Research by Hudgins, et.al. (2006) and others formed the foundation for this research to investigate the use of collaborative learning groups in an introductory level astronomy course.

Conclusion

The literature presented has established the importance of electromagnetic radiation as it pertained to astronomical inquiry and has also explored the theoretical vantage point of this research, which was conducted through the lens of social constructivism. The proposed intervention was collaborative learning, which stemmed from social constructivism in the sense that collaborative learning is a practice through which people learn socially. Additionally, collaborative learning research showed that group learning improved student comprehension and can be more effective than direct instruction. Collaborative learning is student centered and a form of active learning. Although the topic of collaborative learning has not been widely studied as applied to astronomy, the research indicated that collaborative learning could be beneficial to astronomy students, improving student perception of learning astronomy by allowing the opportunity to co-construct knowledge, rather than memorizing facts.

CHAPTER THREE

METHODOLOGY

The purpose of this study was to examine student perception of collaborative group learning and its effects on comprehension of concepts related to electromagnetic radiation in an introductory astronomy class at the college level. The following research questions guided the study:

1. What are students' perceptions, attitudes and opinions of collaborative group learning in an astronomy class?
2. What are the effects of collaborative learning on students' comprehension of concepts related to electromagnetic radiation?

It was hypothesized that engagement in collaborative learning groups would have a positive impact on perceptions, attitudes and opinions of students, and improve comprehension. These positive impacts would result in higher assessment scores among the intervention group than the control group. This methodology is organized into the following sections: study design, data sources, data collection, data analysis, ethical considerations, and assumptions, limitations, and delimitations.

Study Design

The ideals of constructivism were evidenced by the realization that students construct their own knowledge rather than integrating pre-existing knowledge. Students working together to extend the learning ability of the group members was a direct representation of Vygotsky's (1978) principles of social constructivism through collaborative learning. Vygotsky considered learning to be a social interaction, as is the case when a parent assists a child in the construction of knowledge. Vygotsky considered construction of knowledge to be development. By extension, students learning through social interaction with their peers should also experience developmental gains.

This research was a mixed method design and relied on case study design from the standpoint of this researcher's social constructivist worldview. Mixed methods is a term that refers to the methodological approach of conducting research using a quantitative as well as a qualitative approach. Mixed methods are appropriate when qualitative and quantitative data can be mutually supportive, meaning that a combination of the two methods answer research questions more completely than would be possible using a single method (Mertler, 2016).

Case study is an approach in which the researcher attempted to understand an issue or problem by observing a case or a "*bounded system*" (Creswell, 2007, p.73). In this study, the case was the students of a lecture course section. This case study involved three sources of data (observations, interviews and assessment results) from which this researcher sought to not only assess student comprehension gain but also to gain insight to student perception of the collaborative learning method. Yin (2009) found that case study is appropriate for answering *how* questions such as those guiding this research and for understanding the characteristics of collaborative learning.

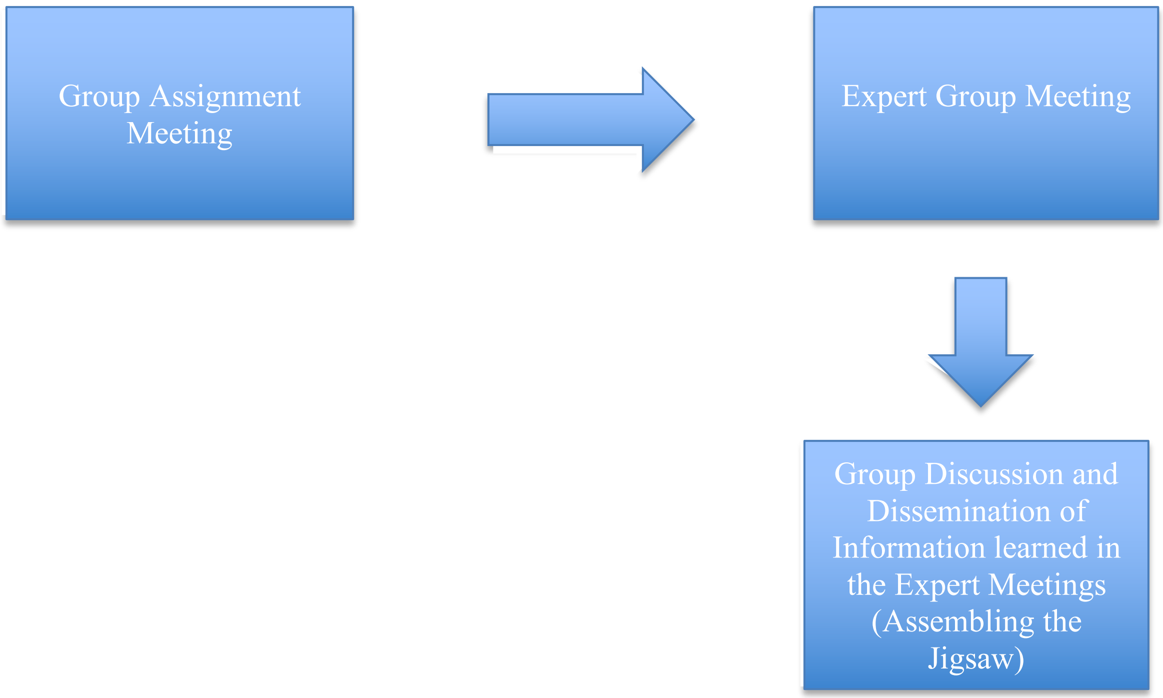
Method

In this research, collaboration began with group selection. Rau and Hay (1990) indicated that collaborative learning groups should be organized to include diversity in gender, ability, skills, and interests. Also, groups should have consisted of male and female students and students of various ethnicities and nationalities when possible. Further, while too few students in a group may have result in homogeneity of experience and prior knowledge, too large of a group could have lead to communication problems. In the grouping strategy used for this study, participants first selected a partner with whom they were familiar, and then two pairs of partners joined to become a collaborative learning group of four.

This intervention for this research was based on the *Jigsaw* methods described by Slavin (1989). The *Jigsaw* method was an appropriate method for this research because it was designed to initiate collaboration and co-construction of knowledge. Slavin explained that the *Jigsaw* method was an approach in which a member of each collaborative learning group met to become an expert on a sub-topic. Students then returned to their respective groups as experts to share what they have learned. When all group members have communicated their subtopic, the group could construct knowledge of the entire topic introduced by parts. For example, in this research each group member investigated a different aspect of electromagnetic radiation and reported their findings to their respective collaborative group. In this respect, every member had a responsibility and their peers relied on the participation of all members. Electromagnetic radiation was divided into subtopics to be discussed in expert groups. The subtopics for this unit were the speed of light and the relationship with wavelength and frequency, the formation of spectral lines, the inverse square law, and the divisions of the electromagnetic spectrum. Students within each learning group assigned members to each expert group. After which collaborative groups reconvened and then constructed knowledge based on information shared by the experts. See Figure *2*.

Figure 2

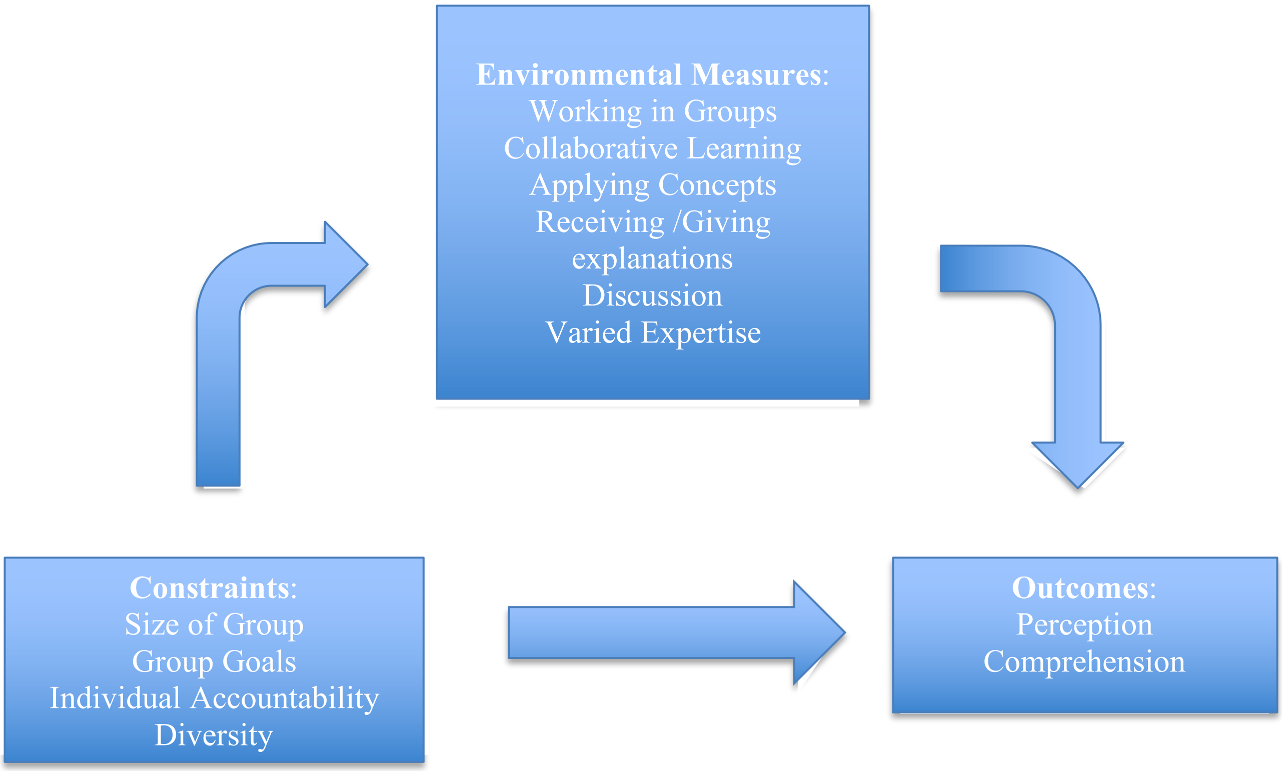
Jigsaw Method



Chinn et al. (2000) reported that discourse can improve the quality of group interaction through the process of students reaching a conclusion and then constructing an argument to support their conclusion. Discourse is often embedded in collaborative activities. In this regard, discourse was encouraged among members of the group by introducing concepts that are open to individual interpretation. At other times, discourse was encouraged between groups to initiate intergroup collaboration. Ideally, students construct knowledge based on the course material, and then present and defend their knowledge within the group. The group should then attempt to negotiate a collective understanding through discussion, which members can individually agree with or choose not to agree with (Skala et al., 2000).

Figure 3

Study Design



The environmental measures in this research project were the conditions that the participants experienced through collaborative group learning. In the Figure 3 flowchart, environmental measures are connected to the framework by two arrows. One arrow indicates that the constraints dictate the environmental measures. The second arrow connected to environmental measures in Figure 3 points from environmental measure to outcomes, indicating that the outcomes are consequences of environmental measures. In this study, the participants will be expected to collaborate in groups of four, as recommended by Rau and Heyl (1990), in which they constructed conceptual knowledge in astronomy based on group discussion and negotiation of information delivered by expert peers (i.e., *Jigsaw* method). The participants participated collaboratively, meaning that they engaged in discussion about topics in astronomy as a means of co-constructing knowledge and completing assignments. Participants applied concepts in their expert groups, and again while instructing their own collaborative group on their expert topic. Participants had the opportunity to both give and receive explanations. Giving and receiving explanations among group members allows participants to access and benefit from the thinking processes of their peers (Fielding & Pearson, 1994). Collaborative groups engaged in discussions to negotiate and perfect their constructed knowledge. Each participant brought to the group unique prior knowledge and life experiences and therefore offer varied expertise to the collaborative group.

The constraints applied in this study were the group size, group goals, individual accountability and diversity. The overarching and constant group goal was for all members to participate in and benefit from the co-construction of knowledge. Within the context of the collaborative group there were additional goals and assignments, but the purpose of this collaborative learning study was to elicit and study perception and comprehension rather than to merely complete a task or assignment. In addition to group goals, there was individual accountability as all group members were assessed individually, which resulted in a grade consequence for nonparticipation.

The final constraint applied to construction of collaborative learning groups was diversity of knowledge and experience, which is a key component of learning when relying on capable peer support in the construction of knowledge. Diversity lead to role shifting in a collaborative learning group, meaning that the most qualified member in a specific concept lead the learning of the less capable members of the group. If knowledge and ability was homogeneous among the group members, comprehension would halt, as suggested by Vygotsky (1978). In the study design flowchart in Figure 3*,* arrows point away from the constraints toward environmental measures as well as outcomes. The constraints represent the major considerations of this research in the context of student perception of collaborative learning and their effect on student comprehension. The constraints were the parameters put into place that directed this research.

The outcomes in this study were theoretically affected by both environmental measures and the constraints. Outcomes were represented by the final box on the flow chart of Figure 3. Arrows lead from both the constraints box and the environmental measures box to the outcomes box to show that constraints impacted outcomes directly or may have impacted environmental measures, which also affected outcomes. Perception and comprehension were equal areas of focus for this study. The perception variable was a representation of participants' impression of their experience in the collaborative learning group. Perception was documented through interviews and observations. Comprehension was a measure of the knowledge constructed in the collaborative learning interaction. Comprehension was measured with the pretest content assessment Light and Spectroscopy Concept Inventory (Bardar et al., 2007) and posttest questions within the course final exam.

Participants

This research occurred at a large university located in a major city in the southeastern United States attended by 45% black or African American, 23% white, 12% Latino, 9% Asian, 6% two or more races, 1% unknown race and 5% non-resident alien students (National Center for Education Statistics, 2020).

Audette (2017) offered six common methods of group selection. The first method is *Proximity Based* groups, in which students simply work with their neighbors. The second method is *Student Selected*, in which students constructed their own groups. Proximity Based and Student Selected methods of group selection often lead to homogeneous groupings. The third method was *Student Selected Groups With Limitations* in which the instructor placed limitations on group selection in order to evenly distribute ability among the class or to encourage diversity of group members. *Assigned Role* grouping occured when students were given a specific role, and then groups were assigned based on the need for each group to include every role filled (i.e., recorder, reader, or coordinator). *Randomly Assigned* groups were based on random selection, and the final method of grouping students is *Assigned Groups*, where groups were assembled by the instructor based on specific variables such as prior grades, or to facilitate diversity of group composition. This research relied on the *Student Selected Method* to facilitate diversity, but the student assistant helped with group selection for expediency and to protect non-consenting students. Diversity in partner selection was encouraged but limitations were unnecessary because of the rich diversity of the institution. Additionally, the Student Selected method allows students freedom to shift between roles as appropriate, based on students' degree of mastery among various topics. The groups were permanent but could be adjusted if necessary. If one member was absent, a member from another group would collaborate with two groups. If two group members were absent, the remaining members would join other groups. Groups could also be rearranged or dissolved if students dropped the course, decided not to participate in or withdraw from the research, or if participants could not work well with their group mates.

The participants in this study were students enrolled in a single Spring 2020 *Stellar and Galactic Astronomy* lecture section. There were approximately 40 participants. At the time of the study, the participants were in their second semester of introductory astronomy. As a result, many students had a basic familiarity with electromagnetic radiation as applicable to astronomical observation of the Solar System, which was the focus of the previous course.

Study Context

Since collaborative learning occurred in an astronomy lecture section, it was set in a lecture hall. The arrangement of furniture in the lecture hall was conducive to collaborative learning because the desks were movable, and students could physically assemble into groups. However, because students had difficulty transitioning the furniture from small groups into larger expert groups, some students chose to stand or sit on the floor.

Previously, this course has been structured around reading assignments supplemented with direct instruction and limited collaborative group interaction. Chapter review questions were assigned as homework and students often were instructed to assemble in work groups to collaborate on homework and occasionally collaborate on class questions. In this research, there was intentionally more student collaboration than in previous semesters, as proposed in the design of the study. Students spent several classes working in collaborative groups in order to master the topics of light and analysis of light. Students were provided with a handout to guide them through the expert and collaborative group engagement (see Appendix A).

Data Sources

In this research, the first question, “What are students’ perceptions of collaborative group learning?,” was approached from a qualitative stance. The data collected and interpreted to answer question one was through interview and observation. Interview and observation are qualitative methods (Charmaz, 2014). The second research question, “What are the effects of collaborative learning on student comprehension of concepts related to electromagnetic radiation?,” was assessed through pretest and posttest which is a quantitative method (Slater et al., 2015). The data collected from this assessment in regard to the research questions was analyzed by comparing assessment score gain between the intervention and control groups.

Qualitative Data

The qualitative portion of this research sought to examine student perception of the shared collaborative learning experience through interview and observation. Additionally, the observation data were intended to provide insight to student interaction and activity while learning in collaborative groups.

Observations

Observations were included in order to gain understanding of nuanced student communication and interaction. This research is grounded in the shared experience of the students. Observing student interactions, work, and use of time can provide unique insight into the activity of the participants that is more detailed than data that students may provide in an interview (Kawulich, 2005). Some groups required more instructor attention than others, making it difficult to reasonably guide all of the groups while conducting observations and journaling their behavior. Therefore, observation data were collected by an undergraduate student research assistant, which additionally helped to avoid instructor bias. The student assistant took observation notes of the following group behavior as it pertained to student comprehension and perception of the collaborative learning process. The student assistant was instructed to take general notes on collaborative learning group and expert group interactions. The research assistant was instructed to observe and note examples of student engagement, participation, interactions, peer teaching, discourse, disputes, resolution. Also, the assistant was to note examples of hierarchy and leadership structures that emerge throughout the collaborative learning process and any student utterances related to course content and materials. These loosely defined categories were used as a starting point for the observation process. An observation protocol was provided to the student assistant in which field notes were to be recorded while conducting observations, as recommended by Creswell (2007). The observer was free to make additional notes which may lead to altered or expanded categories within the observation protocol. (see Appendix B).

Student interactions were observed during collaborative group learning as well as in expert group meetings and journaled by the student assistant. As observations are intended to provide insight to the research questions, any student utterances or behavior related to the research questions were recorded.

Interviews

A major tool for addressing the research questions was the data collected in student interviews. Participant interviews were conducted after the end of the unit, with students having completed both the collaborative learning group activities and the pre- and posttest. To avoid any potential bias, the interviews were conducted by the student assistant and the data were not released to the researcher until the final grades were posted at the end of the semester. The interviews were designed to assess the students' perception, attitude, and opinions of the intervention, so logically the interview would follow the intervention.

The interview questions were open-ended to encourage students to share their experience of the collaborative learning group engagement. In a single session, participants were asked to answer "Grand Tour Questions" as recommended by Bhattacharya (2017, p. 132) that provided a general sense of the collaborative learning experience. Additionally, if there was a particular part of the experience that they wanted to talk about, the grand tour questions allowed respondents to do so. Next, participants answered "Mini Tour Questions" (Bhattacharya, 2017, p. 133) to encourage respondents to share specific information from their point of view. The mini tour questions are loosely structured so that responses that span the spectrum of possible participant experiences may emerge. The design allowed for triangulation of data with interview responses, observations and pretest/ posttest data to gain a better understanding of student perceptions, attitudes, opinions, and learning gain. Therefore, one of the mini tour questions asked the participant to link collaborative learning with their assessment performance. Since the interviews were anonymous, this question allowed the interviews to be tied to the assessment results while maintaining confidentiality. Finally, participants answered one "Structural Question" (Bhattacharya, 2017, p. 133) about the participants' favorite and least favorite topics covered, to determine if the preferred concepts were covered through direct instruction or through collaborative learning (see Appendix C for Interview Questions).

Participants were asked to volunteer to be interviewed by the research assistant through several emails and messages sent to the participants over a period of several weeks, encouraging them to participate in the interview portion of this research. Five students agreed to be interviewed during the term, with one of them waiting until after the semester ended. Due to university closure in response to the COVID-19 pandemic, face-to-face interviews were not possible. The research assistant interviewed the volunteers through video conferencing and made audio recordings which were transcribed manually and by using transcription software. This researcher listened to the audio recordings to verify the accuracy of the transcripts.

Student Assistant Training

In order to facilitate the data collection process, the student research assistant received training and experience in investigation, observation and interviewing methods. The research assistant read texts and papers on education research, coding, and interviewing specifically in the context of education research. Additionally, the research assistant reviewed previously coded transcripts in order to standardize the interviewing, observing and coding process. Additionally, all required CITI training was completed for protection of human subjects.

Quantitative Data

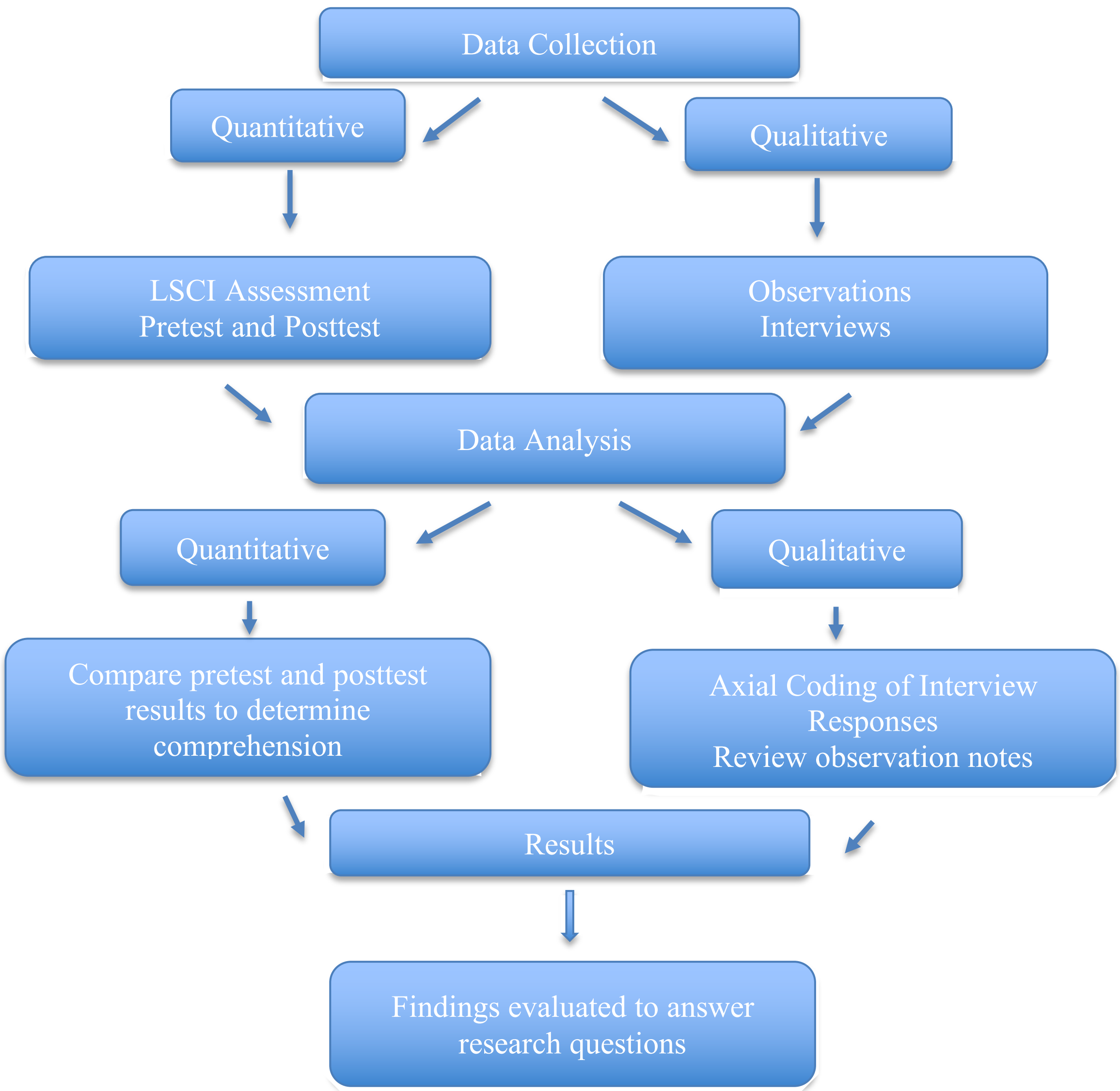
Learning gains were measured in a pre- and posttest qualitative design. The assessment covered electromagnetic radiation to assess the effectiveness of the collaborative learning group engagement on individual student comprehension.

Assessment Instrument

Light and Spectra Concept Inventory (LSCI) is the assessment that was used as a pretest to measure comprehension of electromagnetic radiation. The LSCI instrument is encrypted and password protected and may not be exported published or distributed. The LSCI was evaluated by the American Association of Physics Teachers (AAPT) which cited Bardar (2008). The AAPT PhysPort (2019) website indicates that the LSCI has been peer reviewed across multiple institutions by experts and undergone appropriate statistical analysis. Bardar et al. (2007) evaluated the difficulty of LSCI and eliminated questions that were deemed overly difficult. The updated version will be used in this research. Cronbach's alpha statistic of 0.77 indicated consistency. Bardar et al. (2007) found LSCI to be valid based on a review of textbooks and course syllabi. Peer review supported content validity. Concurrent validity was established by distinguishing, through LSCI results, populations of students who attended a course taught by direct instruction from those who engaged in active learning (Bardar et al., 2007). Due to COVID 19 protocol, students were unable to assemble to take the LSCI posttest. Therefore, this researcher and the professor of the control group section selected twenty questions from the test bank associated with the course textbook. Questions were selected to align with the questions of the LSCI assessment. The selected questions were added to the final exam of both the experiment and control section. The selected final exam questions were considered to be the posttest. In this research, students' pretest and posttest results were evaluated, the student gain score was calculated, and the average gain was normalized.

Figure 4

Data Collection and Analyses



Triangulation, which was the collection of data from more than one source using more than one method, strengthens the validity of research, meaning that the data collected is more likely to be a true reflection of the participants experience (Creswell, 2007). The sampling strategy of this research was to triangulate observations with assessments and interviews to allow for validity in research methodology. The population for observations and assessments included all enrolled students as part of regular course activities. Data were not collected regarding students who did not consent to participation in this research. Participants who took part in interviews were selected randomly and asked to participate on a voluntary basis.

Data Collection

This study was a mixed methods examination of student perception of collaborative learning and student comprehension of concepts relating to electromagnetic radiation in an undergraduate level astronomy class. As a regular part of instruction, students completed a pretest to assess their prior knowledge to use baseline data to compare with a posttest which was administered after the intervention. In the first week, students formed collaborative pairs and then collaborative pairs joined to form collaborative groups of four, in the approach used by Skala et al. (2000). The group goal of co-construction of knowledge for all participants was explained. It was explained to students during lecture that the collaborative learning groups should be outcome-oriented rather than completion-oriented.

In order to prepare students for collaborative learning using the *Jigsaw* method, there was a practice session in which students joined expert groups to discuss one current event and become experts on that event. Then students returned to their collaborative learning group to teach their peers about the event on which they have become an expert. Then intergroup discussion was encouraged in order to exchange ideas about of all of the current events. Thus, students had practiced the strategy and expectations were clear prior to data collection.

Once the students were comfortable with the process of collaborative learning and the *Jigsaw* method, students applied this strategy to the co-construction of knowledge within the instructional unit on electromagnetic radiation. A student from each collaborative learning group joined the appropriate expert group. Students were asked to read the text before class in order to be prepared to participate in the expert group. In the study of electromagnetic radiation, there were four expert topics based on the sections of the course textbook (OpenStax, 2016). One expert group studied the speed of light and the relationship between wavelength and frequency. The second group studied the formation of spectral lines. Group three studied the inverse square law. The fourth group covered the characteristics of the electromagnetic spectrum. Expert groups were allowed as much time as necessary to explore their subject. This researcher and research assistant circulated among the groups to help interpret the text if necessary. When every member of the expert groups mastered their topic, they returned to their collaborative group to teach and learn from their group mates. Finally, the topics were discussed among all members of the class.

In the second collaborative learning session, the collaborative learning groups studied the analysis of electromagnetic radiation. As with the topic of electromagnetic radiation, analysis was split into four subtopics to be explored in four expert groups. These included Kirchhoff's Laws, the Stefan-Boltzmann Law, Wien's Law and finally, the Doppler Effect. Kirchhoff's Laws govern the formation of spectral lines which allow for the identification of gas by light analysis. The Doppler Effect, as it applies to astronomy, is the perceived compression or expansion of light waves. Compression and expansion is a consequence of radial motion and allows for measurement of the relative radial velocity of the object emitting light. Stefan-Boltzmann Law allows for the measurement of energy based on temperature and Wien's Law allows for the calculation of temperature based on color (OpenStax, 2016). It should be noted that the concept of electromagnetic radiation is connected to all other topics in the study of astronomy.

Data Analyses

Interviews, using open-ended questions, were used to elicit detailed individual student descriptions of their shared collaborative learning experience. The study design and research questions informed the structure of the interview questions. This researcher sought to know how collaborative learning effects student perception and comprehension. Since the interview questions were loosely structured, respondents were free to elaborate on their account of the collaborative learning experience outside and beyond the scope of the interrogatories. Such elaboration could lead to future research questions and additional dimensions to this study.

The interview and observation data that was germane to the research question, "What are the effects of collaborative learning on student comprehension of concepts related to electromagnetic radiation?," were inductively coded using NVivo software. Interview transcripts and observation notes were open coded, or initially coded (Charmaz, 2014), using "verbatim coding" (Saldaña, 2016, p. 105). The initial coded information was categorized, axially, into nodes. The second round of coding was Structural Coding (Saldaña, 2016) which was based on the research questions and was conducted from a clean slate, meaning that it was independent of round one coding. The first and second round coding approaches led to overlapping codes (Saldaña, 2016). Any words or phrases that were germane to the research questions became codes. The third round of coding used Pattern Coding (Saldaña, 2016) in which the first and second round codes were combined into meaningful groups of codes that express common ideas or themes.

To address the second research question, "What are the effects of collaborative learning on student comprehension of concepts related to electromagnetic radiation?," the *Light and Spectra Concept Inventory* pretest and posttest was used to measure the effect of collaborative learning on student comprehension. Pretest and posttest results were compared by employing the descriptive statistical method prescribed by Slater et al. (2015) in which student gain and sample gain are calculated. Next, the average student gain was calculated, and normalized and the mean gain of the class was calculated. Using the inferential method prescribed by Slater et al. (2015), the pretest posttest gain results were compared to the pretest to posttest gain results from a non-related astronomy section in which direct instruction was the only delivery method. The direct instruction section, which was taught by a different instructor, served as a control group. Although the direct instruction section was considered the control group, there may be additional differences between the treatment and control group that affect student comprehension due to instructional decisions. An example of such a difference is length of time spent on the topic of light in which will be longer it the treatment group (Goodsell, 1992). The student assistant administered the pretest and posttest in the control section and collected and maintained informed consent from the control participants. The test scores were converted to a percentage score and the gain between the pretest and posttest of the control group and intervention were calculated. Then, the gains of the two groups were compared. A p value of less than 0.05 was considered to be statistically significant. (Slater et al., 2015). Aggregate results are reported while individual student results remain confidential.

Ethical Considerations

To comply with requirements for research involving behavior of human participants, all researchers who participated in this study completed the required CITI certifications. Further, implementation of this research received IRB approval from the research institutions. This research conformed to the requirements for exemption from 45 CFR part 46 requirements as outlined in 45 CFR 46.101 (b)(2) (U.S. Department of Health and Human Resources, 2019).

Participant names were not used so that interviews and observations were anonymous. Interviews were conducted and maintained by the student researcher. Individual student survey transcripts were only be available to the researcher after the semester ended and the final grades were posted. This procedure was intended to assure students that their participation was voluntary and in no way impacted their course grade. As such, students were encouraged to respond to interview questions honestly without the possibility of negative or positive repercussions. Any saved documentation was scanned and stored on the research institution's server.

Assumptions, Delimitations, and Limitations

The collaborative learning configuration used in this research was a narrow representation of a broad spectrum of possible collaborative learning groups (Bhattacharya, 2017). Guidance was balanced with students' need to develop their own personal constructs. To this end, student-centered learning could help students identify learning obstacles they face in class. Some obstacles students face can be a lack of resources and support, or even incorrect or incomplete prior knowledge (Vosniadou, 1994).

As both the researcher and the instructor for this course, it was important to circulate among the student groups to facilitate discussions and guide the collaborative process. As students develop competence as collaborative learners, less focus was spent guiding the groups and more time was spent providing support for mastery of course content. This research is not generalizable and is transferable specifically to astronomy education.

CHAPTER FOUR

RESULTS

In this *results* section, the qualitative and quantitative data were presented followed by descriptive analysis. The quantitative results were representative of the student gain between pretest and posttest, by group. The qualitative data were derived from classroom observation notes and codified interview transcripts.

Quantitative Data

This analysis focused on a control group of 31 participants and an intervention group of 33. The pretest and posttest gain of the control group was compared to that of the intervention group. The intervention group had a lower mean and median pretest score*,* than the control group did, and a higher posttest than the control group. The control group minimum and maximum scores = (7.7%, 46%) pretest, and (60%, 95%) posttest. The intervention group minimum and maximum scores = (0%, 46%) pretest, and (65%, 100%) posttest (see Table 1).

Table 1

Gain Comparison between Control and Intervention Groups

	Control Group		Intervention Group	
	Pretest%	Posttest%	Pretest%	Posttest%
Mean	27.2	85.3	20.9	91.7
Median	27.0	90.0	19.2	95.0
SD	8.4	9.4	10.2	9.2
Range	38.5	35.0	46.0	35.0
Min	7.7	60.0	0	65.0
Max	46.0	95.0	46.0	100.0

The variance in gain between the intervention group and control were found to be unequal, $F = .43$, $p = .01$; therefore, the data were analyzed using a t-test assuming unequal variances. The difference between intervention and control group gain scores was significant at the specified .05 level, *t-stat* = -3.97, $p = .0001$.

Qualitative Data

Observations

Observations were conducted over two consecutive class periods. The classroom accommodates a maximum of 40 students in individual desks. The participants formed seven home groups of four students. Each individual selected one of four topics to research in an expert group of six to eight students using a Collaborative Learning Assignment Sheet (Appendix A) as an activity guide. Students first met in their expert groups, then reassembled into their original home groups of four. The participants were observed working in both home and expert collaborative learning groups, using the observation protocol and worksheet (Appendix B) to record student interaction and utterances during collaborative learning sessions. The observations were collected by spending several minutes observing each group, two to four times per session. See Table 2.

Table 2

Expert Groups Observation Date: 5 March 2020

Group/Topic	Time	Instructor Activity	Student Activity	Observer Notes
1 Relationship between the Speed of Light, Wavelength & Frequency	3:07	Observing the entire class	Discussing questions to research	Individually researching/ working on various tech (Laptops, cellphones)
1	3:20	Answering questions on misconceptions of light	Students discussing misconceptions of light	Students in this group are discussing light interference.
1	3:25	Answering questions with group 4	Discussing all finding current in their group	Group 1 is the most actively participating group in the classroom, all group members w/ 1 exception are actively discussing their expert topic.
2 Formation of Spectral Lines	3:11	Answering individual questions with other groups	Researching topic individually	The entire group is conducted individual research, not interacting with each other and no discussion.
2	3:20	Answering group one questions on misconceptions of light	Very minor discussion going on with two group members	All members have been working individually for the majority of the time. Some members were online shopping, searching social media, it appeared that only two of the members were focused on getting information online through the textbook. Another member is just asking for the answer to assigned questions.
3 Inverse square law	3:01	Professor is observing class	All members working individually	All members working individually on laptops and cell phones
3	3:17	Answering questions with	Minimally discussing	All group members working individually,

Group/Topic	Time	Instructor Activity	Student Activity	Observer Notes
		group one	together	major utilization of cell phones in this group.
4 Parts of the electromagnetic spectrum (R, M, IR, V, UV, X, G)	3:15	Walking observing class	Discussing questions to answers	Group members are consistently working separately on questions
4	3:20	Answering Group 1 questions.	Not one person in this group is talking to each other	Half the group members are utilizing the online textbook.
4	3:25	Professor is answering individual questions	No discussion amongst each other.	This group required more time for expert group when asked by the professor if all group were ready to return to their home group. The other 3 groups were ready to return this was the only group requesting more time.

First Observation

In the first expert group collaborative learning session, group one was observed studying the relationship between the speed of light, frequency, and wavelength. The observer's notes indicated that most members were consistently engaged in research and collaboration. The observer also noted that the group members were actively engaged in discussion of their assigned topic while using their electronic devices to conduct research to support their construction of knowledge through discourse. The remaining expert groups did not collaborate during the process of constructing knowledge during the first observation. Therefore, their ability to learn through collaboration was severely limited. Group four seemed to work together initially; however, the observation record indicates that the participants in group two (formation of spectral lines) worked independently of their group mates throughout. The participants had little interaction and collaboration. Some members asked their peers for answers to questions on the worksheet rather than collaborating. Group three was observed twice as they studied the inverse square law. All of the group three participants initially seemed to be working individually using their cellphones and laptop computers. During the second check they were observed to interact minimally, meaning that they continued to work individually rather than as a group. Group four was observed three times as they studied the constituent bands of the electromagnetic spectrum. They initially discussed the answers to the questions on the worksheet with each other, after which there was no further communication as participants worked independently. Group four ultimately ran out of time and needed an extension. See Table 3.

Table 3

Expert Groups Observation Date: 10 March 2020

Group/Topic	Time	Instructor Activity	Student Activity	Observer Notes
1 Kirchhoff's Laws	3:00	Talking with group 1	Working Individually on different tech.	This group is having little to no discussion while setting up how they will research the questions. For instance, pulling up textbook on web page or cell phone
1	3:05	Individual Discussion	Working individually on different tech.	This group only discussed their topic when the professor was near, other than that no group participation.
1	3:14	Observing	2 students asking professor a question. And the other members continue	This group has preferred to ask their questions about the expert topic only with the professor. Without the professor present the

Group/Topic	Time	Instructor Activity	Student Activity	Observer Notes
			working individually.	group continues to work individually.
2 Stefan Boltzmann Law	3:05	Answering individual question	Discussing with each other the necessary questions	Two group members working together on laptop, discussing the visuals on Stefan Boltzmann Law. The other 5 members working individually
2	3:10	Currently answering group 1 question	Most members researching other things	This group continued the same pattern, two members actively engaged trying to understand the law, the rest of the group were not working on astronomy.
2	3:17	Observing	Working in pairs on answering the questions	This group of seven managed to work in pairs, with only 1 member working individually on non-astronomy work. They did not work as a group during my observation.
3 Wien’s Law	3:00	Discussing Spectroscopy diagram	Asking each other questions of each other on Wein’s Law that they already knew	Working individually on electronic devices.
3	3:08	Working with expert group 4	Individually Working on different tech.	While working in this group, to an observer, one could not tell there was a group. All desk are in original position and students continue working

Group/Topic	Time	Instructor Activity	Student Activity	Observer Notes
				individually and no discussion.
3	3:10	Answering group 1 questions	Asked a single question by one group member and directed it towards professor.	Students in this group continue to work individually in silence, the one question asked by a student was directed at the professor instead of other group members
3	3:15	Asking for questions	Working with textbook on visuals for Wien's Law.	Consistently working on material for Wien's Law, despite lack of discussion, this group has continuously been answering their questions on the material.
4 Doppler Effect	3:00	Answer questions with group 1	Discussing the doppler effect as it pertains to weather	Working together as a group (seven people), discussing the doppler effect and asking each other more detailed questions. This group has members that read the material (noticeably) before class.
4	3:04	Answering individual questions	As a group working to define the Doppler Effect	Very active group discussion on how to understand the doppler effect without utilizing any aspects of the definitions from the textbook or online resources.
4	3:08	Working with group 4 and using white board to	Speaking with professor on how to visually	Group actively discussing with professor on Doppler Effect

Group/Topic	Time	Instructor Activity	Student Activity	Observer Notes
		demonstrate visual doppler effect	represent the Doppler Effect	
4	3:18	Asking for any questions	Finishing their questions on expert topic	This group had an active discussion the entire time working in their expert group, they utilized shared visuals, and open discussion with the professor. This group was the most interactive with each other in the entire class.

Second Observation

In the second expert group collaborative learning session, group four was observed four times while studying the Doppler Effect. This group was observed to be engaged in the collaborative process and were the most active group in the collaborative learning session. They interacted as a group and with the professor. The observer noted that it was clear that they read the material beforehand. The participants were not only interested in answering questions, but they attempted to visually and verbally conceptualize the topic as they discussed methods of conveying knowledge to others.

Members of group two worked individually and in pairs. Group two was observed three times while learning about the Stefan Boltzmann Law. Initially, two members worked together while five members appeared to be disengaged. In the last observation, the research assistant indicated that all but one participant were interacting in collaborative pairs.

The disengaged groups in this session were one and three. As group number one studied Kirchhoff's Laws they were observed three times. The observer noted that the participants worked individually most of the time. Some participants asked the professor questions and then continued to work independently. Group three was observed four times while studying Wein's Law. The research assistant reported that there was no conversation within the group. The single question uttered was directed toward the professor. However, the group participants worked individually toward completing their task. Their work was not collaborative.

Table 4

Home Groups Observation Date: 10 March 2020

Home Group	Time	Instructor Activity	Student Activity	Observer Notes
A	3:25	Walking around Classroom	Discussing with each other, not the assignment	Group participating and talking amongst each other on current events not astronomy.
B	3:23	Walking around Classroom asking for questions	Discussions and teaching to each other	Three out of five group members are participating in discussion the other two are on cell phone social media or laptop shopping for shoes.
C	3:20	Answering Questions on Wien's Law with group A	Very interactive – All members participating	The group is very active in working on Stefan-Boltzmann, however the group members just asked one group member to relay to them only the important details
D	3:25	Briefly answering questions with group D	Active Group members. all members	This group is actively engaged in group discussion and exchanging photographs on material.
E	3:20	Answering questions on	Students are engaged in	The group members are actively exchanging

Home Group	Time	Instructor Activity	Student Activity	Observer Notes
		Wien's Law w/ Group A	discussing Kirchhoff Laws- All 4 members participating	notes and writing notes, so every member has the same notes. Each member is asking a question and actively engaged in the material. One group member asking for visuals and clarification to Kirchhoff
F	3:25	Actively answering questions	Students are active in this home group	All four members are diligently taking notes and asking questions in group discussions
G	3:27	Answering on white board a demonstration of material.	Active Group Members	Only half of the group members, two of four, are actively participating in group discussion

Observer Notes

Observer's notes on home groups	• March 10th is the only day the observer was able to observe the HOME group interaction. The class members seemed otherwise involved in discussing COVID-19 and the effect it would have on the class and school. • By 3:35 pm groups have ended discussion on material and are packing up to leave with the exception of Group E who stayed working together on group discussion until 3:45pm

Third Observation

The third observation took place the same day as the second observation. This was the portion of the activity where the home group was reunited, and the participants were to teach the other home group members about their expert topic. Each group was observed one time over a twenty-minute period. The observer noted that the participants were involved in discussing COVID-19. Students were occupied by speculation about the remainder of the course. This observation occurred during the final 25 minutes of class on the day before spring break, so most groups were anxious to leave. The observer reported that by 3:35pm all groups but one packed their belongings to leave with the exception of group E that engaged in collaboration until 3:45 which is the end of the lecture period. Due to the pandemic, this class meeting was the last time that this section met face-to-face.

Interview Coding

Five student interviews were conducted by the research assistant, after which the data were analyzed using NVivo coding. Seven terms were identified based on word frequency count. The term *information* was used 20 times in the context of "extracting information from people," for example. *Collaboration* was used to describe returning to home groups as in the statement, "coming back explaining to your group." *Expert* appeared in the word count every time that the term "expert group" was used, so the word count was reduced to account for such usage. An example of the use of *expert* is "I think that we are experts." *Helps* emerged as a code indicating the effectiveness of collaboration, as in the quote "saying it outloud helps me remember." *Concepts* and *conceptual* were classified as the same word. Concepts was used when students referred to subject matter such as "learn the concepts better." Students used the word *perspective* to indicate point-of-view as in the quote "from a different perspective." *Participation* emerged as a code that indicated engagement as in the quote "relying on other people to participate."
See Table 5.

Table 5

Round 1 Codes

Code	Frequency Count	Quote
information	20	extract information from people
collaboration	17	coming back explaining to your group
expert	16	I think that we are experts
helps	11	saying it out loud helps me remember
conceptual	5	learn the concepts better
perspective	4	different perspective
participation	4	relying on other people to participate

The second round of coding utilized a Structural Coding process (Saldaña, 2016), based on the research questions asked. Codes during this round were developed from a clean slate, meaning that it did not rely on the round one coding. The first round of coding was based on word frequency while the second round of coding was an examination of the interview responses developed by addressing the research questions. The first and second round coding approaches led to overlapping codes agreeing with the assertion that the interview responses have a relationship to the research questions (Saldaña, 2016). Any words or phrases that were germane to the research questions became codes.

Collaboration tied to the research question regarding the effects of collaborative learning on student perception. *Expert* was related to the research because collaboration in expert groups was part of the *Jigsaw* method aspect of the intervention. *Conceptual* tied to the comprehension aspect of the research. A student used the term conceptual in the context of comprehension: “good conceptual grasp.” Collaborative learning relies upon *Participation* which is engagement in group activities. *Chaotic* emerged as a code because it tied to the expert group meetings, which were an integral part of the intervention and described the condition of the expert group interactions: “expert groups were *chaotic*.” *Chaos* and *chaotic* were merged into a single code.

See Table 6.

Table 6

Round 2 Codes

Code	Definition from Codebook	Count	Quote
collaboration	Working together to complete a task or answer a question.	17	coming back explaining to your group
expert	Mastery	16	I think that we are experts
conceptual	Pertaining to the core concept of the topic	5	good conceptual grasp
participation	Engagement in group activities and construction of knowledge	4	relying on other people to participate
Chaotic	Disorganized poorly structured	2	expert groups were chaotic.
accountability	Consequence for action or lack of action	1	individual accountability

The third round of coding used Pattern Coding (Saldaña, 2016) in which the first and second round codes were combined into meaningful groups of codes that express common ideas or themes. The emergent themes were classified by *How students learned* and *What students learned*. In such a context, the codes *participation* and *accountability* were similar due to the contextual use of both words. Only one interviewee used the word *participate.* The interviewee was concerned that students who *participated* were *accountable* for all of the work and students who did not *participate* should be *accountable* for their disengagement. *Participate* and *accountability* therefore merged into one code, *accountability*. Also, the code *Expert* merged into *Collaboration*. Interviewees used the term *expert* to indicate the result of their collaboration in an expert group or to indicate their preparation and ability to engage in collaboration at the point that they returned to their collaborative group. The round one code *Helps* overlapped many other codes and was not included in round three. See Table 7.

Table 7

Round 3 Codes

How Students Learned	What Students Learned
Chaos	Information
Collaboration	Conceptual Knowledge
Participation	Perspective

Nested within the category *How Students Learned* were codes *Chaos, Collaboration, and Participation.* All five interviewees made comments that were coded *Collaboration.* One participant spoke of the collaborative nature of the expert groups: “I'm getting feedback from other people. And then like, seeing what they got from the lesson, and then me coming, and showing them what I got from the lesson.” Another student described the collaborative process that occurs after the initial awkwardness of convening in a large group: “We just get started doing our work and we all do what we need to do to get it done.” The third interviewee noted that the collaborative process while learning in a home group was connected to familiarity and trust: “When you come back home, you know, for me, it's good information, because I've kind of picked people like, for that reason that I think, you know, we'll try as hard as I do, of course.” The fourth participant was uncomfortable with the collaborative learning process but stated that when the topic was light, it was beneficial to have members of the home group who were experts on the topic: “My teammates drew pictures. So that kind of helped and it was kind of a quick and dirty explanation of that whole section of that chapter.” The final participant commented on the utility of conversation in collaborative learning: “I'd say it made more sense talking about it, rather than like me trying to study on my own. Actually, have a conversation, and make sure I fully grasp the topic. Bouncing ideas off others.” Additionally, proximity was included in the statement about collaboration: “When I placed myself next to people who I knew, knew what they were doing and knew the information did help me better.” These quotes exemplify the idea that knowledge is constructed with the help of a more knowledgeable individuals and through collaboration and discourse.

Statements from three of the five interviewees were coded as *Chaos*. In the statement, “I would say the expert groups were more I guess strenuous and trying to learn and know the concepts better of everything because it was so many people and everybody and everybody can’t sit together,” the word *strenuous* was uttered. The participant was concerned with the size of the group, physical arrangement and the ability of participants to work in concert. The second participant expressed concern about the *Chaos* of dependence on the knowledge of peers, class size, and time constraints: “It becomes awkward in a classroom like we had, because we lost a lot of time just getting organized. So, I didn't notice because the classroom was small, or because they got confused as to what group they were in or whatever. So, I think because the class is so short, we lose valuable time.” The third participant stated that “expert groups were chaotic.” Based on the context in which the terms “Chaos and Chaotic” are used in the student interviews, they do not appear to view Chaos in a positive light. The theme “Chaos” seems to be an obstacle to collaboration and, based on interview responses, is attributed to expert group size.

Four interview responses were coded as *Participation.* A participant stated repeatedly that in collaborative learning groups, members must rely on the participation and engagement of others: “Relying on other people to participate and kind of care as much as you care to get the information,” and “One or two people were really actively participating in the expert group out of the six and eight of people that were in there.” Another interviewee spoke of the social aspect of collaborative learning: “I've kind of picked people like, for that reason that I think, you know, we'll try as hard as I do, of course.” She also discussed the importance of participation and how the lack of participation, on the part of one student, may impact other students: “If they don't do it, then I won't know the answer. And then if we have a quiz or test on it, and someone didn't do that section.” The participant encountered engaged as well as disengaged group mates: “I have been in a group where somebody was just like not wanting to do anything and most somebody was relying on doing most of the work. For the most part everybody was working together and trying to get stuff done.” The third participant commented on the distribution of participation in collaborative learning groups: “In the team, there was some, some that worked a little harder than others.” The fourth participant to discuss participation also commented on distribution of participation: “Some people did all of the work and others did none of the work.” The interviewees indicate that they are dependent upon others to participate and contribute and that some of their peers were disengaged. The participants expressed that they are more comfortable and more collaboration occurs in home groups.

The code category “How Students Learned” revealed the students’ perceptions about *collaboration, chaos,* and *participation.* Interviewees indicate that some positive aspects of *collaboration* are feedback from peers, seeing things from the prospective of a peer, and conveying one’s own perspective with others. Proximity to a more knowledgeable peer was recognized as a benefit. Participants reported an initial awkwardness in the expert groups that subsided when work began. Home groups were described as familiar and a comfortable learning environment where peers engaged in conversation, collaboration and the co-construction of knowledge. The code *chaos* was based on interviewee perception that expert groups were strenuous, too large and participants did not work together at times. Due to the expert group size, time was wasted on bringing collaborative sessions to order. Also, depending on peers to be knowledgeable is a theme in *Chaos.* The fact that some students did not participate in collaboration was a reoccurring theme in the interviews, specifically in expert groups. Students generally expressed a negative perception of expert groups and a positive perception of their home groups. Home groups were self-selected and therefore composed of students who liked each other. Interviewees indicated that they were more willing to rely on and work hard for their home group members.

Nested within the theme *What Students Learned,* are the three codes, *Information, Conceptual Knowledge,* and *Perspective.* All five interviewees commented on information. The first interviewee statement overlapped with the participation code but also relayed the importance of *information* to the collaborative learning process: “I think sometimes it's a little hard because you're just relying on other people to participate and kind of care as much as you care to get the information.” The second interviewee spoke of the importance of the process of exchanging information: “So you have to kind of take the information from those who are willing to share because they just are sharing people,” and “You have to know how to extract information from people.” The third interviewee questioned the accuracy of the shared information: “So we did pass on the information whether it was accurate or not? We don't know. Right?” The third interviewee also enjoyed exchanging information in collaborative groups: “If we got all the information, it was really cool to cover and learn." The fourth interviewee successfully obtained information: "Okay, so I definitely took in information." The fifth interviewee spoke of the "grasping" of information or the construction of knowledge and the difficulty in relaying knowledge: "I had a hard time grasping the information and the telling someone what I learned because 15 percent of the time we didn't learn anything." Interviewees discussed the difficulty associated with the exchange of information as well as relying on the participation of their peers. There were concerns about the accuracy of information passed from one student to the next. An interview also revealed that some students had difficulty "grasping" information or constructing knowledge.

Two interviewees' comments were coded as *Conceptual,* indicating that the participants addressed conceptual knowledge through collaborative group learning. The first interviewee addressed conceptualization in the context of the construction of knowledge and the application of knowledge at a later time. The first interviewee stated: "We can conceptualize everything okay, but applying what we're learning to maybe like quizzes and tests is not." This student went on to add, "I don't know cuz we'll like, study so much. And then our test scores are always like I don't know, not like the greatest. It's just like, I guess that goes back to like, you know, you feel like you have a good conceptual grasp, but it doesn't translate." The second interviewee tried making flashcards to help with conceptualization and stated, "So, flash cards really helped us learn the concepts better and learn more quicker, I would say." Rather than constructing knowledge with peers, this participant used flash cards for the purpose of short-term memorization. The second interviewee did previously stipulate to the merits of collaborative learning as well as the value of examining topics from various points of view. This student was not reported to be working with flash cards by the research assistant and therefore it is unclear when he used the flashcards. Both interviewees claimed to possess conceptual knowledge, but the first interviewee expressed an inability to apply conceptual knowledge.

Two interviewee responses shared the code *Perspective.* Students construction of knowledge was framed by the perspective of their peers. One interviewee responded, “It gives you a chance to talk to other people and, you know, exchange what they might have thought about it, and just get a different perspective on the material.” Also, this interviewee noted that it is valuable to seek the perspective of a larger group, “meet new people and talk to other people and get their perspective on things. Because in our home group, you know, our friends, and we might talk and we might just go with the other person said, and not really give it too much thought about like details.” Another interviewee shared the same sentiment and added that perspective adds efficiency to collaborative learning: “I didn’t have to do as much work as I would without other people’s perspective it also helped me to do a different perspective on topic.” Interviewees indicated that there was a cognitive benefit to learning the perspectives of their peers, especially new perspectives. Additionally, gaining the perspectives of others resulted in less work for the interviewee.

The code category “What Students Learned” revealed that the interviewees relied on other students to provide information but were concerned about the accuracy of the shared information. Participants expressed difficulty in grasping concepts and constructing knowledge. Two interviewees claimed to possess conceptual mastery but reported an inability to apply core concepts. The interviewees reported that learning the subject matter from various points of view, in expert groups, helped them to comprehend material.

Summary

The quantitative data resulting from the pretest and posttest support the assertion that in this study, student comprehension was improved by engagement in collaborative learning. Participants who participated in the intervention of engaging in collaborative learning experienced a greater gain between pretest and posttest scores than the control group. The qualitative portion of the data illustrates student perceptions of the benefits of collaborative learning, as well as the obstacles specific to use of the *Jigsaw* method in this research. The data indicates that participants experienced some frustration with the chaotic nature of group work as well as the vulnerability associated with depending on others to participate. Despite some frustration, a reoccurring theme revealed by observations and interviews was student perception that learning was occurring as a result of collaboration in home groups as well as in expert groups through the examination of information from various perspectives. The interview participants not only shared their impressions of the collaborative learning process, but they also volunteered helpful analysis that may be used to improve collaboration for future cohorts.

CHAPTER FIVE

DISCUSSION

The purpose of this study was to examine student perception of collaborative group learning and comprehension of topics explored in an undergraduate level astronomy class. While engaging in collaborative learning, students learn and synthesize information as a result of interacting with peers who are in the process of constructing an understanding of a common concept. Collaborative learning provided an alternative to merely accepting a singular explanation from an instructor and requires student participation in the learning process. As such, collaborative learning is active and replaces the students' traditional passive learning role during direct instruction (Cerbin, 2018; Rau & Heyl, 1990). This research sought to document student comprehension of science content and perception of collaborative learning as a result of participating in the *Jigsaw* method of collaborative learning in groups. The learning outcome of this strategy was to facilitate synthesis of astronomical concepts such as the characteristics of light and the analysis of light through collaborative participation and active learning.

Summary of Findings

The study of astronomy is incremental, meaning that foundational topics must be mastered in order to apply them to more complex topics. There is a general consensus among many astronomy educators that students' conceptual understanding of astronomy is flawed, and the method of astronomy course delivery should be adjusted (Bailey & Slater, 2003). Currently, astronomy course delivery often relies upon direct instruction (LoPresto & Slater, 2016). Direct instruction, by definition, is a recitation of information by the instructor, rather that the construction of knowledge by students. Direct instruction encourages the memorization of content, through notetaking followed by review, rather than comprehension of content through the construction of knowledge. Memorization is an impractical approach to the study of astronomy (Marché, 2001). While there have been extensive studies on collaborative learning, the effects of collaborative learning in the discipline of astronomy at the university level have not been widely researched (Bailey & Slater, 2003).

This study relied on a Convergent Parallel Mixed Methods Research strategy in which quantitative and qualitative methodologies are intertwined. This mixed methods study was designed to probe student learning when collaborative learning was used as an instructional strategy. A summary of the findings is presented in the following sections.

Research Questions (and Hypothesis)

This research sought to investigate:

1. What are students' perceptions, attitudes and opinions of collaborative group learning in an astronomy class?
2. What are the effects of collaborative learning on student comprehension of concepts related to electromagnetic radiation?

It was hypothesized that engagement in collaborative learning groups would have a positive impact on perceptions, attitudes and opinions and improve student comprehension. These positive impacts would result in higher assessment scores among the intervention group than the control group and engage students actively in the construction of knowledge through collaborative learning groups.

Research Question 1: What Are Students' Perceptions of Collaborative Group Learning?

The collaborative learning groups were observed participating in a variety of behaviors. Sometimes students appeared to be engaged in collaborative learning while others appeared disengaged. On some occasions students conducted research while other students seemed to merely benefit from the work of their peers. Observation records indicated that some students appeared to be disengaged at different points in the class. It is possible that some were very high performing students who in fact had completed their group assignment and were waiting for their peers to catch up. Therefore, data collected through interviews provided additional insights to supplement the observations.

Interviews revealed that some of the participants held an objectivist view of learning and did not necessarily realize that they were co-constructing knowledge with their group. The objectivist view is the notion that information exists independently of the learner and that learning is an act of accessing knowledge (Bhattacharya, 2017). The objectivist view was revealed through the emergent code *information.* Participants spoke of *information* as an asset or commodity which they shared with their peers. One interviewee reported “extracting” information from their peers who were unwilling to collaborate.

Some students felt vulnerable to the level of *participation* in which others engaged. Interviewees reported the perception that not everyone was participating and if a member of a home group failed to construct knowledge in their expert group, the other three members of their home group would not have all of the information needed for the final portion of the *Jigsaw* method, where the home group reconvenes and co-constructs knowledge base on the experience of each member in their respective expert group experience. Therefore, students correlated their own success with the *participation* of their peers. Interviewees also expressed concern about the accuracy of co-constructed knowledge and expressed a desire for feedback and validation.

Participants did not perceive participation in expert groups as collaborative, which supported the observations made by the research assistant. Participants repeatedly referred to *collaboration* when discussing the final stage of the *Jigsaw* method, in which they returned to their home group and conveyed their expert knowledge to their peers. From the participant frame of reference, the majority of *collaboration* occurred when students explained and received explanations in their home group, where *collaboration* emerged as a code. The *Jigsaw* method design of this study called for collaboration in the expert group meetings as well as the home group meetings. Some participants considered themselves to be experts after participating in the expert group sessions

Students felt that the expert groups lacked structure and cohesiveness in this study. Student perception of *chaos* contributed to the belief that *collaboration* occurred exclusively in the home groups. Students expressed a perception of comfort and familiarity in their home group of four participants with whom they were familiar and chose to associate. Expert groups were composed of eight participants in which students were less familiar. The interviewees reported that many of the eight members had no idea what to do or how the project was structured, and that the process was chaotic even though they had been provided written instructions, verbal instructions, a diagram, and had participated in a practice collaborative session.

Participants offered constructive criticism of the *Jigsaw* method which indicated reflection on the part of the participants in terms of their learning, as well as a sense of ownership in the learning process which was expressed through their desire to improve the structure of collaborative groups. The interviewees almost unanimously indicated that the collaborative learning process would benefit from smaller expert groups as well as more time to complete tasks, although interviewees did feel that learning occurred as a result of the collaborative learning process.

Research Question 2: What Are the Effects of Collaborative Learning on Student Comprehension of Concepts Related to Electromagnetic Radiation?

The quantitative data analysis indicated that the intervention group experienced greater gain between pretest and posttest than the control group. The control group learned about light in a direct instruction class format while the intervention group attended short lectures followed by engagement in collaborative learning groups.

The qualitative data also provided insight to student comprehension of electromagnetic radiation. Interviews revealed that collaborative learning improved student comprehension of concepts related to electromagnetic radiation. Participants indicated that they benefitted from the exchange of *Information.* Participants also indicated that *information* was discussed, and knowledge was co-constructed and later exchanged in the home groups. *Comprehension* emerged as a theme in the qualitative interview responses.

Students who engaged in activities other than the assigned collaborative learning assignment did not construct knowledge with their peers. Some participants felt that exposure to information is learning and should be sufficient to prepare them to teach and apply concepts as well as to co-construct knowledge with the participants in their home group. Such a perception aligns with the direct instruction method, to which most students are accustomed. In direct instruction, an instructor presents information rather than guiding students in the construction of knowledge. These participants relied on learning strategies that are familiar to them rather than engaging in collaboration and the construction of knowledge. *Conceptual knowledge* was discussed by two of the interviewees. In the first instance, the participant claimed to possess conceptual understanding but also was perplexed by their inability to apply the knowledge to assessments. Similarly, a participant used flash cards to learn the concepts quickly rather than constructing knowledge with peers. It seems as if the two respondents missed a key concept of the collaborative learning assignment, that students were supposed to become experts in a subtopic and then teach their peers.

Hypothesis

The qualitative and quantitative findings agreed with the hypothesis that engagement in collaborative learning groups would have a positive impact on perceptions, attitudes and opinions and improve student comprehension. Participants reported the perception of conceptual mastery of topics discussed in collaborative learning sessions. Observations and interviews supported the assertion that participants found working in their home collaborative learning groups to be a positive and enjoyable educational experience, although participants did find expert group meetings to be chaotic and non-collaborative. Participants expressed the opinion that they did co-construct knowledge. Evidence of the co-construction of knowledge by participants was revealed through interviews and observation. Pretest and posttest results supported improved student comprehension.

Discussion of the Research

In collaborative learning groups, the construction of knowledge was at risk without the full participation of collaborative group members. While participating in the expert groups, some participants in this study engaged in research while others benefitted from the work of their peers by refusal to engage in the collaborative process and reliance on the knowledge constructed by the other group members. Such behavior contributed to the breakdown of collaboration as well as the breakdown of the construction of knowledge. Such behavior was exclusively reported by interviewees to occur in expert groups. Students correlated their own success with the *participation* of their peers. Students often felt vulnerable to the level of *participation* in which others engaged. Collaborative learning, which is rooted in Vygotsky's (1978) Zone of Proximal Development, was based upon collaboration among groups where students can work with more qualified peers towards a common goal. Knight and Wood (2005) also noted in their collaborative learning research that some students did not conduct research and only received answers from their peers. Knight and Wood (2005) did not express their opinion about such a group dynamic. In this research, interviews revealed that students were concerned about the lack of engagement from some of their peers in expert groups. Students reported feeling that all group members should engage in the collaborative learning process because, without full participation, the remaining students had to do all of the work. Also, interviewees expressed concern that nonparticipating expert group members would return to their home group without constructed knowledge.

To encourage student engagement, it was necessary to develop individual and group learning goals (Kleingeld et al., 2011; Slavin, 1989). In this research, the individual goal was to construct sufficient knowledge about a specific aspect related to the electromagnetic spectrum in the expert group and then to convey the content to the participant's home group. Additionally, it was expected that through this process individual performance would be improved on the individual posttest assessment. Although the group goal was to work collaboratively to construct knowledge as a group, interviews revealed that some of the participants hold an objectivist view of learning, which is the view that information exists independently of the learner and that learning is an act of accessing knowledge (Bhattacharya, 2017). Interviewees discussed information as if it were an object which may be shared, withheld, or even extracted from a person.

Interviews revealed that participants questioned the accuracy of co-constructed knowledge and expressed a desire for feedback and validation. In collaborative learning, participants should apply, synthesize and cognitively restructure information (Webb, 1982). In this research, students were observed applying, synthesizing and cognitively restructuring information by giving and receiving explanations, engaging in discussion and sharing illustrations and online content. Accuracy of constructed knowledge is important and could easily be confirmed or denied by the instructor, but such direction would undermine the collaborative learning process in which students should co-construct knowledge rather than relying on the instructor to convey information. In this study, this researcher circulated through the room while students were engaged in collaborative learning and directed students to resources through which they might obtain information upon which they could construct knowledge. As reported in the classroom observations, this instructor also engaged participants in discussion to understand their knowledge and provide feedback. Such formative assessment may be used to guide the collaborative process and to facilitate consensus, but groups should be directed to the root source of their foundational knowledge, such as the textbook or other background materials that were provided to them, as the basis of their collaboration.

Participants were more comfortable working in their home groups than working in expert groups. Some participants considered themselves to be experts after participating in the expert group sessions, although expert group meetings were seldom referred to as being *collaborative*. The home groups were not only smaller groups, compared to the expert groups, but they were also comprised of self-selected members. The participants repeatedly referred to *collaboration* when discussing the final stage of the *Jigsaw* method, in which they returned to their home group and conveyed their expert knowledge to their peers. Although Audette (2017) cautioned that self-selected collaborative learning groups may be homogeneous, self-selected groups were preferred in this study. From the participant frame of reference, *collaboration* only occurred when they explained and received explanations in their self-selected home groups.

Expert groups were observed to be chaotic and were reported to be chaotic by interview participants. Chaos is an inherent part of collaborative learning in that collaboration itself may be described as chaotic because participants join groups in which they were encouraged to discuss and debate topics. Such behavior may seem chaotic in comparison to students passively participating in a direct instruction lecture (Bruffee, 1999). In this study, chaos was not exclusively due to discussion; there was an element of chaos that hindered expert group interaction and the construction of knowledge. Participants reported difficulty initiating collaboration due to poor organization and confusion about the topic to be discussed. Chaos was reported and observed in expert groups but not in the home groups. The home groups were self-selected, meaning that members chose to associate with each other. Self-selection may have contributed to home group cohesion. Also, group size was a key difference in the two group types and reported by interview participants as one of the factors of chaos. In Bruffee's (1999) collaborative learning groups, there were four students. In this study there were four students in the home groups and up to eight students in the expert groups due to the class size. The interviewees almost unanimously indicated that the collaborative learning process would benefit from smaller expert groups as well as more time to complete tasks. Similarly, Knight and Wood (2005) preferred smaller collaborative groups of three to four students. By shifting the structure of the *Jigsaw* method into a format in which there were only four participants per expert group, communication, participation, and organization could have been better controlled, resulting in a potential reduction of chaos and possible shift in students' perceptions of collaboration in group learning.

Knight and Wood (2005) also conducted focus groups and found that, in their English class, they were devoting too much time to instruction and too little time for student collaboration. In this research, ample time was allotted for collaboration but the eminent university closure, at the time of data collection, caused time constraints. The time constraints accelerated the research schedule, causing the participants to comment that they would have benefitted from more time.

Skala et al. (2000) conducted qualitative research on collaborative learning in an introductory astronomy course. Skala et al. relied on focus groups to determine the impact of assigned small group learning activities. This research supports Skala et al.'s findings that students perceived that collaboration improved learning and that time is an important aspect of the collaborative learning process. The results of this research diverged from the findings of Skala et al. in that focus groups in Skala et al.'s study called for more regulation of collaborative group formation. Interviewees in this research preferred self-formed groups.

Some participants were observed to be, or reported to be, confused about the *Jigsaw* method collaborative learning exercise as well as the individual and group expectations. Such constructive criticism of the *Jigsaw* method indicates reflection on the part of the participants as well as a sense of ownership in the learning process expressed through their desire to improve the structure of collaborative groups. More time should have been allotted to explaining instructions, engaging in practice collaborative learning sessions and increased instructor oversight. Further, participants may have benefited from knowledge about collaborative learning and social constructivism so that they may form a more complete perspective of the purpose of their participation in the collaborative learning groups.

Vygotsky's Zone of Proximal Development, and by extension, Collaborative Learning, was not merely a way for students to learn with assistance but is a method of developing a student's ability to accomplish progressively more difficult tasks independent of others (Smagorinsky, 2018). In this study, collaborative learning improved student comprehension of concepts related to electromagnetic radiation as evidenced by a greater gain between pretest and posttest scores than the control group. Participants indicated that also believed that they benefitted from the exchange of *information* and indicated that information was discussed and conceptual knowledge was co-constructed and then exchanged later in the home groups. Fielding and Pearson (1994) found that "students gain access to one another's thinking process" (n.p.) in collaborative groups and that comprehension is a process in which students construct knowledge, make inferences and evaluate rather than memorize information (n.p.).

Results show that some students felt more comfortable with direct instruction methods. Some participants felt that exposure to information was learning and should have been sufficient to prepare them to teach and apply concepts as well as to co-construct knowledge with the participants in their home group. Such a perception aligned with the direct instruction method to which most students are accustomed. Most students in a direct instruction environment were passive learners, meaning that they received information from their instructor without engaging in the process of applying or synthesizing concepts (Cerbin, 2018; Rau & Heyl, 1990). Some students reported that they used flashcards to study their expert topics. Memorization through flash cards did not equate to conceptual mastery or prepare a participant to apply concepts through synthesis or answer questions about the application of concepts (Fielding & Pearson, 1994). Flash cards facilitated memorization, which was representative of Bloom's (1956) lowest cognitive level as well as McCabe and Lummis's (2018) observed activity of low performing students. In this research, the interviewee who used flash cards also reported difficulty applying conceptual knowledge.

Implications of the Research

Implication for Higher Education Practice

The findings of this research showed that improved student gains in assessment results can be realized through integrating collaborative learning sessions into an undergraduate level astronomy course. Joyce et al. (1987) found that humans learn best when they collaborate with others while learning new information. Light is foundational to the study of all concepts in astronomy and as such was chosen as the content explored by students in this study. In this research, the students were asked to become experts and teachers of the fundamental physics associated with astronomical observation.

This research demonstrated improvement in student comprehension and provided insight into perceptions related to collaborative learning strategies, in which students are encouraged to explore and discuss concepts with the goal of constructing knowledge. Discussion with the goal of construction of knowledge is a key component of collaborative learning (Vygotsky, 1978).

Implications for Theory

This research found a disconnect between comprehension and application of conceptual knowledge, as discovered through participant interviews. Some students seem to be under the impression that reading or listening to information in the expert groups, without understanding the information or constructing knowledge and contextualizing the information, should result in their ability to apply and explain the subject matter to their peers. This limited perception of learning may be due to the common practice of direct instruction, through which instructors cover as much material as possible, often to the detriment of comprehension and meaningful construction of knowledge.

Implications for Students

Typically, in an astronomy lecture section, equal time is dedicated to electromagnetic radiation and each of the individual topics in astronomy that rely on knowledge of electromagnetic radiation. In this study, participants benefitted from extended exposure to concepts related to electromagnetic radiation on which complex topics are founded.

The results of this study may potentially impact the practice of educators, which would affect their students. In this research, the practice of direct instruction was shifted to student-centered collaborative learning. The intervention applied in this study, the use of collaborative learning groups using the *Jigsaw* method, correlated with improved comprehension as well as a largely positive student perception of the collaborative learning process, with the exception of the chaotic aspects of the expert collaborative learning groups. The results of this research provide the rationale for educators to shift the locus of their class from the lecturer to students, and to include collaborative learning sessions as a part of their teaching strategies. This research supports the creation of a student-centered learning environment and opportunities for formative feedback from the instructor and peers.

Limitations of the Study

One limitation that must be addressed is that this study and the participants would have benefitted from more time. The COVID-19 pandemic began in the midst of data collection and impacted the implementation of this research by shortening the treatment. The intervention and data collection phases for this research were thus accelerated by several weeks, impacting the methods and outcome. Also, this research was limited by small sample size and relied upon small number statistics.

While the goal was to interview ten students during this study, the sudden change in the course due to the pandemic led to reduced student participation in this phase of data collection. Additionally, only half as many interviews were conducted as were originally expected. One interview question, asking students to discuss an improvement in their pretest and posttest scores, was intended to anonymously tie the qualitative data to the quantitative data. However, this question was problematic as none of the interviewees were able to remember their pretest score to compare it to their posttest score. Participants could only speculate about their results based on perceptions without information that would have been provided if the pandemic had not brought the study to a sudden close.

Future Research

One finding of this research was that the large expert groups were considered by students to be chaotic. The chaos associated with large expert groups is disruptive to the collaborative learning process and is, in that sense, different than the chaos described by Bruffee (1999). Bruffee's description of chaos associated with collaborative learning referred to groups of students engaged in conversation and debate as a result of collaboration. The correlation between disruptive chaos and expert group size should be researched further. Participant interviews and observations revealed that some participants were confused, which impacted group collaboration. Although participants were well prepared for the collaborative learning sessions through verbal instruction, written instruction, visual representations, and diagrams, as well as a practice session, confusion remained about how to initiate expert group collaboration, and in some cases there was confusion about which topic was assigned to participants in their collaborative group moments earlier. Despite this level of preparation for the collaborative learning assignment, some students seemed to be confused. Also, observations revealed that some students had not prepared for collaboration by completing the assigned reading. Research should be conducted to find best practices for preparing students to engage in collaborative learning and for evaluating individual student preparation for collaborative learning assignments.

Finally, research should address the process of co-construction of accurate conceptual knowledge during the *Jigsaw* process. The participants indicated a desire for validation that they were constructing or receiving accurate knowledge from their peers, as well as feedback on their work. The results of this research found that student perception of collaborative learning is impacted by trust in the validity of peer presented information. Comprehension is affected by the accuracy of information from which knowledge is constructed and, in the case of collaborative learning groups, dependent on individual student preparation before expert group meetings and the quality of research conducted in the expert group meetings. Future research should include verification of foundational information collected in expert groups, or increased instructor formative assessment of concepts assigned to expert groups.

Conclusion

Learning is a social process through which intellectual development is attained through co-construction of knowledge with the help of others. Collaborative learning is a natural phenomenon and the method through which knowledge is passed from human to human or shared (Vygotsky, 1978). This study attempted to explore this phenomenon, as it applies to a college introductory astronomy class, by engaging students in a collaborative learning experience through which they co-constructed knowledge. The participants of this study responded positively to the practice of participation in learning groups and the construction of knowledge and exhibited measurable outcomes and perceived benefits to participation in the collaborative learning process.

In order to be applied or explained, information has to be internalized through the process of construction of knowledge. Collaborative learning is one such method of effectively fostering the construction of knowledge based on correlated gains in student comprehension and student perceptions in an undergraduate level astronomy class.

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Appendix A

Collaborative Learning Assignment

Name________________________ Date _________

Section Topic____________ (Light or Light Analysis) Expert Group Topic ____________

What do you already know about this section topic?

After meeting with your expert group, what do you know about the expert group topic?

In your own words, explain the expert group topic as you will teach it to your collaborative learning group.

What are some possible misconceptions that people may have in regard to your expert topic?

What original or internet visual aids will you use while teaching your collaborative learning group mates?

Notes and ideas:

After returning to your collaborative learning group to learn and teach, what did you learn?

Appendix B

Collaborative Learning Observation Protocol

Course ________________ Date ________________

Observer________________ Instructor_____________

Number of students in class (_____)

Group number (_____)

Group Composition (heterogeneous/homogeneous)

Number of students in group (Female____ Male_____)

Collaborative Group / Expert Group Task ________________________________

Time	Instructor Activity	Student Activity	Observer Notes

1. General Notes on Collaborative Learning Group Interaction
2. General Notes on Expert Group Interaction
3. Student Engagement/Participation/ Interactions
4. Peer Teaching
5. Discourse / Disputes / Resolution
6. Hierarchy / Leadership
7. Any Student Utterances Related to course content and materials

Appendix C

Interview Questions

Grand Tour

What do you think of collaborative learning groups?

Please describe your experiences working in collaborative learning groups.

Mini Tour

What do you think about receiving and giving explanations in collaborative learning groups?

What was the effect of discussion and the application of concepts in your collaborative learning group?

How many people were in your collaborative learning group and how did the number of participants impact the group?

Was there a balance of group goals and individual accountability in your collaborative learning group? Please explain.

Please tell me about the ability of your group members.

Please tell me if your test results improved between the pretest and posttest: how do you feel that collaborative group learning impacted your astronomical knowledge?

Structural

Please rank some of the topics covered in this course from favorite to least favorite. Why?