AN UNDERUTILIZED TOOL:
THE PHYSICAL CLASSROOM ENVIRONMENT IMPACTS STUDENT COLLABORATIVE WORK

A Thesis

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Master of Science

By

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ABSTRACT

Objectives: 1. To examine what physical classroom elements high school students perceive would promote collaboration, 2. To examine the influence these physical classroom elements have on collaboration.

Methods: This research was conducted in two studies: study I, a structured photographic Q-sort *($N = 46$)*, study II, a quasi-experiment *($N = 24$)*.

Study I: students examined 30 photos and determined which physical elements they preferred for the promotion of collaboration.

Study II: based on the results from study I, a collaborative classroom was created. Researchers analyzed the differences in aspects of collaborative work in a collaborative design versus a traditional design.

Results*:* Students identified which physical elements they preferred for collaboration. Type of room influenced how students perceived their collaboration via group dynamics, personal experience, and impact of the physical environment.

Conclusions*:* Physical classroom design influences student collaborative work. Further research should be conducted to examine these results long term.

BIOGRAPHICAL SKETCH

Jacqueline is a second-year graduate student from Somers, New York. She is in the Master of Science in Human-Environmental Relations program in the department of Design + Environmental Analysis at Cornell University. Her concentration is in Environmental Psychology.

Prior to graduate school, she received her bachelor's degree in Psychology, with minors in Law and Society, as well as Business, from the College of Arts and Sciences at Cornell University.

She is currently embarking on a career that integrates psychology and design with hopes to focus on educational facilities. Her research is intended to inform and improve the design of spaces intended for children and adolescents.

To my family:

Mom, Dad, Brian, Cristen, Michael, Sarina, & Paige,

for your unconditional love and support.

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CHAPTER 1

INTRODUCTION

This research examined ways in which high school student perception of physical design elements can promote collaborative work. Current research suggests that the world is rapidly changing, yet our school system is fairly static (Bellanca & Brandt, 2010). In order to adequately prepare our students for higher education and the professional world, we must transform various aspects of their educational system to facilitate the necessary skill and knowledge building needed for success. With the ubiquitous use of technology, the need to work collaboratively with others has only increased (Bellanca & Brandt, 2010). Thus, collaborative work at the secondary school level should further develop across curriculums. However, to optimize students' experience while working collaboratively, they need an environment that affords them the ability to work together and learn from one another. Traditional classrooms are static and hinder group work rather than facilitate it (Ramli. Ahman, & Masri, 2013). Thus, in this thesis I examine the relationship between classroom design and how students' work collaboratively.

Traditionally, the school environment has been examined as an organization, consisting of students, teachers, and administrators. Environmental psychologists introduced the importance of also studying the physical building and examining its effects on students and staff. There is also evidence that suggests the importance of collaboration for adolescent academic achievement. However, there is a gap in the literature. The majority of studies on collaborative learning focus on the benefits of collaborative work in school or on collaborative work in the workplace. Most studies about the physical classroom environment at the high school level discuss the ambient environment or seating arrangement. The connection between providing physical space to facilitate a collaborative work environment and the benefits of collaborative work has yet to be examined. Understanding the relationship between the physical classroom environment and how students work collaboratively will allow educators to further improve the learning environment of students. Thus, the purpose of this research is to examine the aforementioned relationship to determine whether, and if so, how classroom design can influence how students work collaboratively.

CHAPTER TWO

LITERATURE REVIEW

2.1 Theoretical Perspective

To begin, the literature is examined through two perspectives. The first perspective is Bronfenbrenner's bioecological theory of development, which focuses on development throughout the lifespan, as well as the bidirectional influences between the individual and the environmental context (Bronfenbrenner, 2005). Through this perspective, development is defined as a "phenomenon of continuity and change…[that] extends over the life course" (Bronfenbrenner, 2005). This framework thus suggests the importance of development across the lifespan, including the crucial high school years. This is substantial as high school serves as a point in time for major changes amongst many students; motivation, goal orientation, and responsibilities all shift.

The second perspective we will examine the literature through is the life course perspective. The life course perspective examines an individual's development over time through an interdisciplinary approach (Wethington, 2005). This framework suggests points of intervention, where environmental influences can make a difference on one's development. From this perspective, providing adolescents with learning environments designed to improve their experiences could alter their educational trajectory (Wethington, 2005). In this manner, collaborative spaces have the potential to improve the student experience.

While both perspectives examine development through a holistic approach, the bioecological theory of development provides us with a lens to focus on the influence of features within environments on development; this includes one's experience with the built environment (Bronfenbrenner, 2005). Meanwhile, the life course perspective allows us to hone in on adolescence as a turning point for many individuals (Wethington, 2005). Every individual has a trajectory, however through this lens, we understand that intervening at this delicate age could provide lifelong benefits.

Using these two perspectives as lenses, the literature will be reviewed in three sections: development, the physical environment, and collaborative work. The methodology used to select the body of literature included specific criteria. The first criterion used was to only incorporate literature that was published a maximum of twenty years ago. Although valuable research has been performed prior to this timeframe, the focus of this review is to advocate for research for school-based, collaborative workspaces, which is a fairly novel concept and not to be confused with other, older school design suggestions such as open classrooms. Further search criteria included, development during adolescence, the physical environment of schools and its effects on students, and studies regarding collaborative work with students above the age of twelve years old. The databases used during the selection process include: EbscoHost, ERIC, PsycINFO, ProQuest, Wiley Online Library, and Google Scholar. The following table presents the relevant literature:

Table 1: Topic and Relevant References

Topic	**Relevant References**
I. Development	Bronfenbrenner (2005)
	Wethington (2005)
	McClean & Breen (2007)
	Dahl (2006)
	Fredericks, Blumenfield, & Paris (2004)
	Marks (2000)

II. The Physical Environment	Cheryan, Ziegler, Plaut, & Meltzoff (2014)
	Graetz (2006)
	Kuuskorpi & Cabellos Gonzalez (2011)
	Ramli, Ahmad, and Masri (2013)
	Haghighi and Jusan (2013)
	Imms and Byers (2016)
	Vischer (2008)
III. Collaborative Work	Liao (2014)
	Lee, Huh, & Reigeluth (2015)
	Odagiri (2012)
	Duran, Hoft, Lawson, Medjahed, & Orady (2013)
	Rozenszayn & Assaraf (2009)

2.2 Development

Development is a complex process that involves both the individual and his or her environment. Bronfenbrenner (2005) address the complexities of development by proposing a theoretical model about development, called the bioecological model. This model suggests that future development is a function of process, person, context and time. The model suggests that there are dynamic relationships between these various aspects of the individual and his or her environment. These interactions between individuals with themselves, others, or aspects of the environment can be referred to as proximal processes, and proximal processes influence development (Bronfenbrenner, 2005).

The functions of these proximal processes are analyzed, however for the purpose of this study, we will focus on context. Context refers to an individual's interactions with objects and symbols; and thus, context suggests the relevance that the physical environment has on one's development (Bronfenbrenner, 2005). In addition to discussing these proximal processes, the author suggests the importance of analyzing these processes as bidirectional during research. That is to say that data is often recorded from one side, how X affects Y, but scholars should also consider how Y affects X (Bronfenbrenner, 2005). This is indeed relevant as this current study aims to examine the dynamic relationship between high school students and the physical environment of their classroom. Development is more than just a combination of the individual and other human beings that he or she is surrounded by; the environment has a direct impact on the development of the individual and the individual simultaneously impacts the environment. Thus, the physical elements of high schools, including collaborative workspaces, may influence how students work together and thus their overall performance.

Similarly, Wethington (2005) discusses the life course perspective as a framework to examine development and health. The perspective focuses on seven major concepts: trajectories, transitions, turning points, cultural and contextual influences, timing in lives, linked lives, and adaptive strategies. Briefly, trajectories refer to patterns or behaviors across a lifetime, while transitions are changes in roles or responsibilities. Turning points are similar to transitions, but focus on more substantial, major changes in a lifetime, while cultural and contextual influences refer to the circumstances that influence the processes of adaption and/or change. Timing in lives focuses on the interaction of age, point on life, and time of event, while linked lives looks at the interaction or influence of another person or people on one's life. And lastly, adaptive strategies are conscious decisions that are made to adapt to externalities (Wethington, 2005).

Evidently, there are many facets which affect development throughout the full lifespan, some involve agency and others do not. Proponents of the life course perspective suggest focusing on turning point's in people's lives, in order to have an effect. We argue that early high school is a turning point as students are at a point of development that has the potential to affect the rest of their lives. Within the walls of the schools, they begin to have more freedom and responsibility; outside of school, students learn to venture further out and can have more control over their own lives. Many of the habits, passions, and motivations that develop during this period will last a lifetime.

As made evident by McClean and Breen (2009), adolescence serves as a turning point as adolescents begin to engage in narrative meaning-making. The authors recruited a sample of 171 adolescents, ages 14-18 years old, and had them complete a self-esteem questionnaire, as well as write a narrative task (McClean & Breen, 2009). Their findings suggest that narrative meaning-making involves reflection of past events in a significant way allowing the individual to learn something and thus affect his or her identity (McClean & Breen, 2007). Their research found as adolescents reach about fifteen years of age, their meaning making of experiences greatly increases from childhood and levels off at about eighteen years old (McClean & Breen, 2007). The authors note that the sample comes from a single private school with a strong academic focus, which may limit generalizability. However, with their high participation rates, the authors feel they sampled participants with a diverse range of abilities and backgrounds (McClean & Breen, 2007).

Based on the aforementioned literature, it seems that enacting change in a static environment, in which students have been involved with their entire lives, may result in effective change. As evidence suggests that adolescence already serves as a turning point, implementing a more engaging, learning environment could alter their future educational trajectory. Using the lens of the bioecological theory, in tandem with the life course perspective, we argue that an environmental intervention during the early stages of adolescence could benefit students learning experience. Our proposed environmental intervention has the potential to improve students' classroom experience while working with others, which has the potential to provide students with beneficial skill sets for the future.

Further, Dahl's (2006) focus on development identifies adolescence as a transitional period involving brain development, behavioral development, and social-contextual development. Neurobehavioral changes occur, which have significant effects on motivation and emotion (Dahl, 2006). Dahl (2006) suggests that the complexities of this developmental period may be linked to biological neural systems which increase desires toward risk taking, emotion seeking, and sensation seeking. These vast changes in development can activate lifelong motivations and passions (Dahl, 2006). It therefore seems imperative to restructure learning environments to afford students with the opportunity to seek out personal interests, motivations, and passions. By incorporating student perceptions into classroom design, this may allow students feel engaged within their classrooms. By also providing an environment that facilitates, rather than hinders, collaboration, performance may improve, as well as lead way to a passion toward learning.

Because adolescents spend much of their life within the walls of a school, much of development can be directly related to their experience within schools. This time within schools should be focused on increasing engagement, as a way to activate the lifelong passions, habits, and emotions mentioned above. Providing students with a voice in their physical classroom environment may generate engagement. Additionally, introducing these collaborative spaces into the school environment has the potential to directly influence engagement as students can increase feelings of control and social support, which we will discuss below.

In their work, Fredericks, Blumenfield, and Paris (2004) conceptualize engagement and suggest that school engagement is a multifaceted construct involving behavioral, emotional, and cognitive facets. All three aspects of engagement are important to academic success, but each varies. Behavioral engagement focuses on participation; emotional engagement encompasses reactions, both positive and negative; and cognitive engagement involves investment (Fredericks et al., 2004). The three facets overlap but are also independent of one another.

Based on their understanding of engagement, Fredericks and colleagues (2004) have concluded that behavioral engagement is correlated with higher achievement across ages. Additionally, cognitive engagement is associated with academic achievement in the middle and high school years (Fredericks et al., 2004). Engagement not only improves academic achievement but decreases the likeliness of dropping out. Increasing behavioral, cognitive, and emotional engagement is a critical intervention point to decrease drop outs (Fredericks et al., 2004).

Within the context of a classroom, Fredericks and colleagues (2004) have found that teacher support, peer involvement, classroom structure, autonomy support, and task characteristics all influence the varying facets of engagement. Teacher support can be academic, but also personal and has been correlated with behavioral, cognitive, and emotional engagement. Peer involvement is associated with socialization and can enhance student experience within a classroom. Classroom structure is associated with behavioral and emotional engagement as student and teacher perception of a space is associated with improved engagement. Autonomy support is characterized by choice and shared decision making and affects all assets of engagement. Lastly, task characteristics relates to engagement as tasks that are authentic and provide students with the opportunity of ownership, collaboration, and diverse talents increase engagement (Fredericks et al., 2005). Given this evidence, providing students with collaborative spaces can generate behavioral, cognitive, and emotional engagement. The environment will afford students with the opportunities to engage in learning by working with others while still allowing teachers to be actively involved. The collaborative spaces will afford students the ability to be actively involved in their work giving them autonomy, while providing support.

In continuation, Marks (2000) examines development specifically through the psychological process of behavioral and cognitive engagement in the classroom, which includes attention, interest, investment, and effort. Marks utilizes questionnaire data collected by the Center on the Organization and Restructuring of Schools, grades eight through ten, on attitudes, behaviors, and experiences. Marks (2000) argues that engagement spans across social and cognitive development and therefore directly affects achievement. Students, however, are often chronically disengaged; it is reported that about 40%-60% of secondary school students experience disengagement (Marks, 2000). Marks (2000) found that at the tenth-grade level, instructional and social support can increase engagement. Based on these findings, it is plausible that engaging students in classroom design may promote overall engagement as their voice will be heard. Further, providing a collaborative workspace to promote their work and provide students with autonomy while working may improve collaboration. With improved collaboration, students may feel more engaged as their groups are work well together.

Overall, adolescence serves as a complex, but powerful period of development. Individuals are undergoing physical, emotional, and social changes, resulting in a turning point of development. If school environments can be transformed utilizing student voices and then providing collaborative workspaces, students will be afforded with a physical environment that promotes learning. If collaboration is improved, it is possible that performance and the desire to be in school can be transformed to beneficially affect development.

2.3 The Physical Environment

As previously mentioned, the physical environment of educational facilities greatly impacts students' development and achievement. Due to the specificity of this study, we will focus only on classroom design its effects on students.

As an overview, Cheryan and colleagues (2014) conducted a review and found that both the structural and symbolic features of a classroom can facilitate or hinder the learning and achievement of students. These features include ambient characteristics, accessibility, classroom layout, and objects within the classroom. Classroom layout can specifically influence students' feelings and goals (Cheryan et al., 2014). Similarly, Graetz (2006) argues for the need of integration of environmental psychology, educational psychology, human factors, and social psychology when designing learning spaces and classrooms (Graetz, 2006). He suggests the importance of collaboration in the classroom, which results in the need to alter current classroom design. Rather than serving as a theater environment where students watch as their teachers perform, the learning environment must serve as a flexible meeting space (Graetz, 2006). The work by both Cheryan and colleagues (2014) and Graetz (2006) suggests the relevance of the physical classroom environment and its effects on student learning, engagement, and well-being.

Kuuskorpi and Cabellos-Gonzalez (2011) conducted a study with six European school systems (Belgium, Holland, Finland, Portugal, Spain, Sweden) to analyze the relationship between education, the physical learning environment, and the users' needs. Students, ages 14-15 years, modeled their ideal classrooms, while also answering written questionnaires and in-person interview questions. Instructors and administrators also answered questionnaires (Kuuskorpi &

Cabellos-Gonzalez, 2011). The findings suggest that altering the physical environment allows for the possibility of new teaching methods and learning goals, which also involves further developing an operational culture. Operational culture refers to aspects that influence the outcome of the schools' users, including administrators, teachers, and students. The spaces designed were flexible, dynamic, and had the ability for both individual and group work (Kuuskorpi & Cabellos-Gonzalez, 2011). All participants acknowledged the need for physical learning environments to change to better support users. The authors argue that a better physical learning environment will facilitate a greater acquisition of skills (Kuuskorpi & Cabellos-Gonzalez, 2011).

It should be noted that the authors did not test outcomes of an ideal classroom and thus we must interpret these findings accordingly. The results are solely based on responses from participants and no experiment took place. These findings should lead to the testing of ideal classrooms. Altogether, based on these findings, it is evident that the participants believe the physical space has a significant impact on staff, faculty, and students. These findings are relevant as they point out the need to incorporate users in the design of a space. When a space can appropriately support its users, the space has the ability to facilitate positive outcomes for said users. Thus, students as well as teachers should be involved in the design of classroom workspaces.

Ramli, Ahmad, and Masri (2013) analyzed user perception of the physical classroom environment. They conducted a study involving 50 students and ten teachers from a secondary school where surveys were analyzed regarding perception of their current conventional classrooms as well as their preferred design of classrooms. Students and teachers were from Language, Humanities, Science, and Mathematics classes. The researchers found that both students and teachers believe that altering classroom layout, seating arrangement, and furniture type could improve teaching and learning processes (Ramli, Ahmad, & Masri, 2013).

The results of the first questionnaire suggest that 94% of students felt that classroom seating arrangement did not change regularly and 78% of students felt that they were not involved with classroom arrangement. Further, 76% of students felt that the physical environment of their classroom should be improved (Ramli, Ahmad, & Masri, 2013). Improvements included the inclusion of lockers for their belongings, additional spaces for IT and reading, and tables for group work.

The second questionnaire results suggest that 94% of students desire to change their current classroom layout. The preferred layouts provide lockers, spaces for discussion, group tables, and smaller reading areas (Ramli, Ahmad, & Masri, 2013). Overall, the results suggest that students and teachers acknowledge the importance of classroom design on learning processes. The evidence suggests that conventional classrooms of desks in rows facing the teacher desk is not optimal for learning in the 21st century (Ramli, Ahman, & Masri, 2013). The researchers did not test for improved teaching or learning measures, and therefore these results are solely regarding perception. We therefore understand that students and teachers desire alterations to their classrooms, but these changes were not empirically examined for improvements.

Further, Haghighi and Jusan (2013) conducted a study with 370 public high school students in Iran, ranging from ages 14 years to 15 years, that examined the impact of classroom design on academic performance. The researchers analyzed the relationship between classroom architectural elements and student motivation and performance. The results indicate that both male and female students performed significantly better in a mathematics course when they were given the ability to choose their seat (Haghighi & Jusan, 2013). Seat selection was associated with visual factors, including reflections, eye contact with teachers and peers, and the ability to observe the whiteboard, as well as auditory factors. The researchers found that in the environment crated when students were able to choose their seats, their motivation improved and so too did academic performance. These findings suggest that allowing the user the ability to adjust their physical environment may promote achievement. When students are in a classroom, their perspective of their physical environment is significant in terms of optimizing their learning.

Similarly, Imms and Byers (2016) examined the impact of classroom design on pedagogy, student engagement, and performance. The researchers worked with 170 seventh grade (12-13-years old) students in Queensland, Australia. The researchers analyzed differences between a traditional, teacher centered classroom, versus student centered classrooms (dynamic, adaptive spaces). The results suggest that teachers in the more dynamic, adaptive spaces (student centered classrooms) tend to use technology more and thus the space altered pedagogy (Imms & Byers, 2016). This change in pedagogy led students to have more positive perceptions on the quality of teaching. Students also performed best in the dynamic, adaptive spaces. The researchers suggest that the student centric classroom allows for increased problem solving, increased responsibility of one's learning, and increased engagement (Imms & Byers, 2016). It is therefore evident that there is a significant relationship between classroom design and student learning. As technology continues to become more pertinent in classrooms, classroom design should afford the use of technology for both teachers and students.

Vischer (2008) examines the relationship between the physical environment of workspaces and its users, as she suggests that individuals' behavior is influenced by the physical workspace features surrounding them. Visher's (2008) work focuses on the physical environment of the workplace, thus examining an older age group than high school students. However, her main themes regarding the relationship between workspaces and work are relevant to the younger age group of high school students.

By reviewing previous research and observing workspaces, Vischer (2008) found that ambient environmental conditions, furniture and office layout, and user participation affect workers' satisfaction, territoriality, belonging, and productivity. Her research suggests that work is diversifying and thus types of workspace must too diversify. There is a shift in the workplace from being a passive space to functioning as an active support to workers as the physical design features affects workers' feelings, performance, commitment, and creation of new knowledge (Vischer, 2008). Again, it is relevant to acknowledge that workspaces and schools are not synonymous, however Vischer (2008) addresses the fundamental relationship between physical workspace and type of work. As work continues to become more active and collaborative, workspaces should adjust to adequately support those using the space.

Given the discussed literature regarding classroom and workspace design, there seems to be an important relationship between individuals and their physical environment. Users do not simply sit in a space, rather the space actively influences their work, and thus their learning and performance. Therefore, because adolescents spend a great portion of their time in schools, further research examining this relationship between physical space and learning should occur. And, as the use of technology increases and the nature of work shifts, physical spaces should be included to afford students the opportunity to adequately engage. Collaborative spaces may serve as a location where students can adequately engage with other students, faculty, technology, and themselves.

2.4 Collaborative Work

Collaborative work is the third and final section of this literature review. As the necessary skills to succeed in our technology-heavy society shift toward collaboration so too should our education system. There is significant evidence to suggest the importance of collaboration in a variety of disciplines, with a variety of age groups (Fransen, Kirschner, & Erkens, 2011; Kirschner, Paas, & Kischner, 2009). Because adolescence is a malleable time in an individuals' life, the benefits of collaboration could further promote engagement, as well as help students develop necessary lifelong skills for future success.

Liao (2014) assessed collaborative learning at the undergraduate level in communication. Liao (2014) was interested in investigating whether or not collaborative learning affected students' grade in the course, sense of speech efficacy, and speech anxiety in public speaking courses. The sample included two cohorts during two different semesters. Students were evaluated three times throughout the semester via a close-ended questionnaire measuring speech efficacy and speech anxiety, open-ended questions, and professor evaluation during speeches (Liao, 2014). Each class was divided into learning teams, where each team had varying levels of collaborative work (Liao, 2014).

The findings suggest that collaborative learning increased overall student learning and was most beneficial to African American, Hispanic, and students whose mothers had no more than a high school education (Liao, 2014). Overall, the collaborative learning enhanced the course experience for all students, but was especially beneficial to minority students (Liao, 2014). In sum, Liao (2014) offers evidence for the beneficial aspects of collaborative learning. Although this study focuses on an older age group, the multimethod approach toward examining collaboration was sound. Additionally, the study occurred early during the undergraduates' university experience, thus they likely share many of the same developmental milestones of a high school student.

Moreover, many view the ability to collaborate as an essential learning outcome for the twenty-first century (Lee, Huh, & Reigeluth, 2015). Lee et al. (2015) examined how collaboration could be used affectively as an instructional method, as well as a learning outcome. A case study was conducted using two high school classrooms that utilized collaborative, project-based learning, commonly referred to as PBL (Lee et., 2015). Individual differences, intragroup conflict (task conflict, process conflict, and relationship conflict), and social skills were examined for their effects on collaboration. The sample consisted of 111 students from the ninth and tenth grade in two American history studies classrooms from the same school. An online survey was administered to students during the study and follow-up interviews with students were conducted (Lee et al., 2015). It is important to note that interviews were only conducted with sixteen students who agreed to participate in the follow- up interviews. Students were given one of three projects, which all consisted of a planning phases, as well as a production phase (Lee et al., 2015). Once the project was complete, students completed the questionnaire that included questions about intragroup conflict, social skills, and collaboration (Lee et el., 2015). Lee et al. (2015) found that the more students work together, the better their group social skills were. And, although individual differences were apparent, group social skills had a greater impact on reducing intragroup conflict and enhancing collaboration than individual student's social skills (Lee et al., 2015). These findings should be furthered on a broader range of participants; however, they do provide evidence suggesting that collaborative work actually aids in student development during the high school years.

Further research has been conducted examining the relationship between collaborative learning and an individual's understanding (Odagiri, 2012). Odagiri (2012) examined 66 eleventh grade students at a high school in Japan. Students were given mathematical problems to solve in three stages. The first stage was the pre-test, the second was during the lesson, which included two conditions: collaborative learning and explanation by the teacher, and the last was the post-test (Odagiri, 2012). The pre and post tests were conducted via questionnaire with both open and closed ended questions, as well as analyzing the students' work. Odagiri (2012) found that students who were able to collaborate were able to make their ideas clear through linking prior knowledge with other students' knowledge, This process then enabled them to generate new ideas, and the students who experienced this process had the greatest knowledge of the math problems during the post-test. These conclusions suggest that working collaboratively with other students allowed for greater knowledge with the math problems than from receiving an explanation from the teacher (Odagiri, 2012).

Collaborative work studies have also been conducted outside of the typical class setting. Duran, Hoft, Lawson, Medjahed, and Orady (2013) conducted a study that examined the impact of collaborative learning on urban high school students in an afterschool program, which concentrated on using information technology (IT) within the context of science, technology, engineering, and mathematics (STEM). The sample consisted of 77 high school students. Duran et al. (2013) included pre and posttest questionnaires for students, an analysis of final projects, evaluations reports from both the teacher and expert, and follow up interviews with students. The study occurred over an eighteen-month period. The results suggest that the program significantly increased students' understanding of IT and STEM and their IT/STEM skills. Students' frequency of technology use was also increased (Duran et al., 2013). Researchers also noted attitude changes regarding participants where more students viewed the STEM field in a more positive manner after completing the program (Duran et al., 2013). One limitation to this study is causality. The researchers examined the findings from a "collaborative inquiry," however the findings are a result of the program as whole. Thus, some of the positive outcomes may have been a result of working with the teacher and STEM expert, as opposed to simply working with other students. Overall, the study presents a program focused on collaborative learning, which impacted students' academic ability, as well as general attitudes (Duran et al., 2013).

A study conducted by Rozenszayn and Assaraf (2009) focused on the effects of utilizing collaborative learning in a fieldwork setting on students' inquiry, meaningful learning, and the teacher's role. The sample consisted of nine Israeli high-school students who majored in biology. The sample was intentionally kept small, in order to allow for fine-grained analysis (Rozenszayn & Assaraf, 2009). The study was conducted during the students' biology matriculation exam and focused on the portion in which both groups chose a subject of inquiry and designed their inquiry (Rozenszayn & Assaraf, 2009). The study occurred over nine months. Data was collected by recording students' discussions, interviewing students, observing interactions, recording field notes about the process, and analyzing student assignments (Rozenszayn & Assaraf, 2009).

The findings suggest that a major portion of students' collaborative work time was spent discussing methods of measurement and observation in the field. Based on this finding, the authors propose that collaboration allowed students to decrease the novelty of conducting an open field inquiry (Rozenszayn & Assaraf, 2009). Rozenszayn and Assaraf (2009) also found that students with similar learning abilities were more likely to work together to form knowledge construction. Task orientation was also increased during the collaborative sessions (Rozenszayn & Assaraf, 2009). Altogether, the researchers present a longitudinal study that examines the effects of collaborative work in the form of a fieldwork, class assignment (Rozenszayn &

Assaraf, 2009).

Based on the presented literature, it seems evident that collaborative work has many benefits to high school students of varying disciplines. In short-term studies, students' understanding and performance appear to improve (Liao, 2014). In long-term studies, in addition to improvement of understanding and performance, achievement and social skills also improve with collaborative work (Lee et al., 2015; Odagiri, 2012; Duran et al., 2013; Rozenszayn & Assaraf, 2009). To counter these claims, we also conducted a search looking for the negative impacts of collaborative learning. However, at the high school age there is no empirical evidence to suggest that collaborative learning negatively impacts students. The lack of evidence for the negative impacts of collaborative learning at the high school level and the large amount of evidence showing positive effects supports the idea that collaborative learning, when implemented correctly, does positively affect students.

2.5 Conclusion

The literature reviewed involved the significance of adolescence development, the importance of the physical classroom environment, and the benefits of collaborative work. The literature on development suggests that individuals are constantly developing as a result of interactions with their environment (Bronfenbrenner, 2005). And, adolescence appears to be a turning point in many individuals lives where long-term motivations and passions can begin to be developed (Wethington, 2005; Dahl, 2004). The research surrounding classroom environments suggests an important relationship between the physical classroom and students. Classroom design can impact learning, achievement, and motivation (Cheryan et al., 2014; Ramli, Ahman, & Masri, 2013; Haghighi & Jusan, 2013; Imms & Byers, 2016).

Lastly, the literature reviewed on collaborative work suggests that at the high school level, students can significantly benefit from collaborative learning. Collaborative work is associated with increased academic understanding, improved social skills and conflict resolution, and increase performance (Liao, 2014; Lee et al., 2015; Odagiri, 2012; Duran et al., 2013; Rozenszayn & Assaraf, 2009). Therefore, given the aforementioned research regarding development, the physical environment, and collaborative work, I examine the intersection of these three subtopics. If students are given a physical space that affords their ability to work collaboratively, this intervention may enhance their experience working with other students. By improving this collaborative experience, the intervention may influence development through behavioral, emotional, and cognitive engagement. This slight change in the physical environment of a classroom may alter their educational trajectories. The intervention should improve short term collaboration with the intent that when examined longitudinally, this alteration may improve long-term outcomes.

Overall, jointly considering development, physical environment, and collaborative work has the potential to provide valuable insight into the design and organization of high schools, which could benefit students, faculty, and staff. An improved understanding of the effect of the physical design of classrooms on how students work collaboratively may allow instructors to design more effective physical environments for group work. Classroom design often functions as an underutilized tool that could be strategically used to improve how students work. The benefits of effective collaborative work include improved learning, understanding, and engagement. If classroom design can facilitate improved collaboration between students and their instructors, then the design may provide a positive impact on performance, engagement, and future skillsets.

CHAPTER THREE

METHODS

3.1 Research overview and objectives

The primary objective of this research is to examine how the design of a classroom affects how high school students work collaboratively. This objective is achieved through two studies conducted with high school students: study I: a structured photographic Q-sort and study II: a quasi-experiment during class time. Study I focuses on what physical environmental characteristics students think will promote collaboration in a classroom, through a structured questionnaire based on 30 photographs of learning spaces. The results inform study II. Study II examines the implementation of specific design elements and focuses on group dynamics, personal experience while collaborating, and the influence of the physical environment on collaboration. The studies pose the following research questions:

1. What physical classroom characteristics do high school students feel promote collaboration?
2. Do students' perceptions of what physical classroom characteristics promote collaboration have an effect on collaboration?
3. Does providing students with a collaborative physical classroom design facilitate collaboration to a greater extent than providing them with a traditional classroom design?

Study I

3.2 Hypotheses

I. Students will prefer spaces that include a flexible layout and reconfigurable furniture for the promotion of collaboration.

II. Students will prefer spaces that allow them to easily access other students for the promotion of collaboration.

III. Students will prefer spaces that include the ability to display work to one another for the promotion of collaboration.

3.3 Design

To examine what physical characteristics in a classroom are most preferred by high school students in the promotion of collaboration, an initial pool of 50 photographs was selected and examined by the researcher for content. From the pool, 30 photographs were selected as adequate representation of classroom environments. The photographs were selected based on the visibility of desks, chairs, displays, and walls within each room.

Two graduate student raters from a convenience pool were trained to analyze the physical elements in the photographs based on ten dimensions identified in the literature as physical features that might affect collaboration. Each rater first individually determined which physical elements were present in each photo. Then the raters jointly reviewed and came to agreement on the identified physical elements in each of the 30 photos. These dimensions were:

1. The existence of writing surfaces
    a. Chalkboard, whiteboard, none, both
2. The existence of spaces where small groups can gather to work together
    a. Yes, no
3. Types of chairs
    a. Height: tall, short, mixed
    b. Wheels: wheels, no wheels
    c. Attachment: desk attached, desk separate

4. Types of Desks/Tables
    a. Size: individual working space, multiple person working space
    b. Shape: rectangular, round
    c. Wheels: wheels, no wheels
5. Displays
    a. Tack board, electronic board, none, both
6. Accessibility of each space (level of ease of access to workspaces of other students)
    a. High accessibility of each space, low accessibility of each space
7. Proximity of one working space to the next
    a. Working spaces are immediately adjacent, close, or far from each other
8. The ability for the class to function as one large group (i.e. no visual divisions; entire class can function together when necessary)
    a. Yes, no
9. Configurability
    a. Furniture can easily be re-configured, furniture cannot be easily re-configured
10. The ability for visual privacy
    a. Existence of dividers, no existence of dividers

The raters' determination of what physical elements were present in each photo was not made available to participants. This information was set aside for analysis.

A questionnaire was developed to be paired with each photo based on the overall category of each of these ten dimensions. This questionnaire asked if the overall category promoted collaboration (i.e. do the chairs promote collaboration?). Thus, this enabled the participants to make their own determination on what physical elements were present in a photo and did not bias their interpretation of the photo. When each photo was presented, the participants answered the corresponding questions asking about the promotion of collaboration.

3.4 Participants

Forty-six students from four different classes at a central New York high school participated (45.65% male, 52.17% female, 2.17% prefer not to disclose). The classes ranged in sizes of 8, 13, 10, and 15 students. All participants were between the ages of 14-17 years old (56.52% 14 years, 4.35% 15 years, 13.04% 16 years, 26.09% 17 years). All participants volunteered to partake in the study. Cornell University Institutional Review Board requirements were complied with; school approval came from the principal and teacher. Parents completed a consent form prior to the study, and students completed an assent form at the time of the study. No compensation was offered.

3.5 Apparatus/Setting

The structured photographic Q-sort was conducted in two science classrooms. The classrooms were adjacent to one another. Both classrooms were well lit and the walls were painted white. Both classrooms included windows, tables, and chairs. The photographs were presented on an electronic board at the front of the room via connection to a desk top computer. Each photograph was shown for 60 seconds before moving to the next photo. The questionnaires were on paper and completed at the workspace of each participant.

3.6 Measures

The Q-Sort focused on the physical elements of layout and furniture for the promotion of collaboration. Each photo was paired with a set of ten questions that focused on the physical elements related to collaboration: the existence of writing surfaces, existence of furniture allowing for small group work, types of chairs, types of desks/tables, types of displays, accessibility of each space, proximity of one working space to the next, ability to arrange configuration to function as a large group, and the ability for visual privacy. Each question focused on whether or not the physical element promoted collaboration. The same ten questions were used for each of the 30 photos (see appendices A & B).

3.7 Procedure

All participants were informed that the purpose of this study was to examine the relationship between classroom design and collaboration. They were told that they would be shown a set of 30 photographs and would answer the ten-corresponding set of questions for that photograph. During the Q-sort, the researcher took notes on participant comments. At the completion of the questionnaire, the researcher opened the floor for questions or comments. Participants were given the opportunity to respond and have a discussion with both the researcher and the classroom teacher.

3.8 Analysis

To analyze the results of the structured Q-sort, a pairwise comparison of row proportions was conducted in a cross tabulation. This cross tabulation compared the physical elements identified in each photograph by the graduate student raters to the participants' responses to each question about each photograph. This analysis was conducted to determine which physical elements were those participants identified to promote collaboration.

Then, a z-test was run comparing the proportions of each row to identify if the difference in proportion was significant, i.e. comparing the proportion of students who felt chairs with wheels promoted collaboration to those who felt chairs did not promote collaboration. This analysis was completed for all ten physical elements. This analysis was completed to determine which physical elements identified by participants to promote collaboration were statistically significant.

Study II

3.9 Hypotheses

I. Students completing group work in an environment that supports collaboration will rate their group dynamics higher during collaboration than students in a traditional classroom environment.

II. Students completing group work in an environment that supports collaboration will be rate their personal experience higher during collaboration than students in a traditional classroom environment.

III. Students completing group work in an environment that supports collaboration will rate the physical environment higher during collaboration than students in a traditional classroom.

IV. Students completing group work in an environment that supports collaboration will produce work of a higher quality than students in a traditional classroom environment.

3.10 Design

The quasi-experiment was conducted to determine if the perceived physical characteristics to promote collaboration, do indeed have an impact on collaboration within a high school classroom. Study II was informed by the results of study I. In this study, a space was created based on the preferences of students identified in Study l. Furniture was selected to create the space based on what students felt promoted collaboration.

3.11 Participants

The participants were twenty-four ninth and tenth grade (54% male, 46% female) students from two different Earth Science classes. This population included some overlap from study I as class 2 (8 students, 62.5% male, 37.5% female) participated in study I in the previous semester. Class 1 (16 students, 50% male, 50% female) was new to the study and did not participate in study I.

Both classes were taught by the same instructor. All students in the high school were mandated to take the course, however the grade level to take the course is not specified. Students generally take the course within their first two years in high school, but can also take it in eighth grade if they are selected by their instructors to do so. University IRB requirements were again complied with and student assent was given at the beginning of the study. All participants volunteered to be in the study. No compensation was offered.

3.12 Apparatus/Setting

The quasi-experiment was conducted in two classrooms. The first classroom, classroom A, is the students' normal classroom. Classroom A has one wall of windows, without the option for sun control, and an electronic writing board. There was a large chalkboard at the front of the room. The tables (14 in total) are rectangular and fit two students per table. Two chairs are at each table. Because the feedback from study I was so positive, the chairs were altered before study II. Previously the chairs did not have wheels and were the same chairs in the classroom since the 1980s. However, during the time between study I and study II, the chairs were replaced and newly had wheels. The tables did not have wheels.

The second space, classroom B, did not function as a classroom and is currently underutilized. Classroom B was transformed into the experimental classroom based on the results from Study I. Classroom B had one wall with windows that did not have the option for sun control. Classroom B included seven chairs on wheels that had movable, attached work surfaces; eight single chairs of adjustable height on wheels; four two-person tables that had three straight ends to enable the combination with other tables; four stools that allowed for swiveling while sitting; one circular glass work surface that allowed for dry erase writing directly on the surface; one large two-sided white board on wheels; and eight smaller white boards that could attach to the middle and/or ends of the tables.

3.13 Measures

a. Questionnaire

To assess the collaborative process, a post-task questionnaire consisting of 30 items was given. The questionnaire was adapted from one developed by Yeon, Han and Ying (2016). Each item used a 5-point Likert scale, ranging from strongly disagree, disagree, neutral, agree, to strongly agree. The questions refer to the collaborative processes, group dynamics, and the relationship between the physical environment and collaboration (see Appendix C). These three categories were assessed specifically via questions about cohesion (Cronbach alpha = .91), communication (Cronbach alpha = .88), coordination (Cronbach alpha = .91), mutual support (Cronbach alpha = .82), spatial support (Cronbach alpha = .90), distraction (Cronbach alpha = .73), and satisfaction (Cronbach alpha = .92).

b. Observations

The entirety of each class period was observed, and field notes were taken. At each five-minute interval, the following notations were made: number of groups, what materials and furniture were being used, if verbal communication was occurring, if participants were engaging with the instructor, if participants were visibly distracted, if participants had left the room for a bathroom break.

c. Collaborative Task

There were two collaborative tasks, one assigned to students on each day of the study. The first was an exercise involving the development of atoms. This was followed by creating isotopes. Students were asked to work together to generate their responses and create their models of various atoms and isotopes. They were also asked to create definitions for various terms, such as position, electron, nucleus, etc.

The second collaborative task involved testing different samples of minerals and rocks, in order to properly identify the objects. Students were again asked to work together in doing so. This task was followed by the previous task as the instructor explained that the various atoms and isotopes are what make up rocks and minerals and directly related to what they have been studying thus far in Earth Science. At the end of both tasks, the instructor collected deliverables from each group.

3.14 Procedure

The quasi-experiment was conducted during the participants' regular 40-minute class time. Prior to the quasi-experiment, the researcher sat in on both classes in the winter to gain a better sense of classroom dynamics. The quasi-experiment took place in the spring and spanned across two consecutive school days.

Due to the nature of the school schedule, participants had a lab period every other day. This lab period meant that participants had science class for two periods in a row (80 minutes). Both classes had their lab period when they were in the collaborative classroom. Only one period was used to complete the quasi-experiment.

In each of the scenarios, class began as it does on a typical school day for these students.

Participants reported to their traditional classroom (classroom A) and either entered the space or were directed to classroom B. The students were previously informed of the use of a new space, so they were not alarmed that they would have class in an alternate location. Due to the lab period (elongated) schedule, when students were in classroom B, they were allowed time at the beginning of the class to look around, try out, and ask questions about the furniture and the space. This took about 20 minutes.

Once inside the respective classroom, the instructor reintroduced the researcher and briefly explained the schools' desire to create optimal learning spaces. The instructor then reviewed any questions on the previous night's homework. During the sessions in classroom B, the homework review was more extensive and test scheduling concerns were addressed to adequately use the first 40-minute session. The instructor then moved into the lesson the day. As mentioned above, one lesson focused on atoms and isotopes, while the other focused on rocks and minerals. At the beginning of both lessons he briefly discussed their relevance, asked students about their knowledge, and then asked them to begin their group work. Students were told that they were permitted to rearrange the furniture in ways that would promote their collaboration. Students were informed that each group would only hand in one deliverable, thus collaboration was essential. Students were also informed that the last five minutes of class would be dedicated to answering a questionnaire.

Class 1 (16 students) had their first class in classroom A, the traditional classroom. Their group task focused on the modeling of atoms and isotopes. Class 2 (8 students) had their first lesson in classroom B, the classroom designed to promote collaboration. These students began class with the ability to explore the new environment and ask questions. They then had a more extensive homework review session and then completed the same task as Class A. Both classes concluded their sessions with the completion of the post-task questionnaire.

On day two, class 1 had class in classroom B. As this was a lab period, they were given time to explore the new environment and ask questions. At the end of the first period, they began their group work on rocks and minerals. Class 2 had class in classroom A and completed the same group work on rocks and minerals. In the final five minutes of the sessions, both classes completed the post-task questionnaire that they had the previous day.

During sessions, the researcher was present in the classroom and observed students. The researcher was available to answer any questions as necessary.

At the conclusion of day two, the researcher and the instructor met and had a debriefing session (See Appendix D). This debriefing session took place in classroom A, the standard classroom, but occurred during planning time so there were no students present. The instructor answered questions as asked by the researcher and expressed interest for the future re-design of classrooms within the school.

3.15 Analysis

The questionnaire responses were analyzed quantitatively via factor analysis. The factor analysis was used to investigate underlying concepts related to collaboration. This analysis was intended to further the understanding of what influenced collaboration. The results were examined in three sections based on category of question: group dynamics, personal experience, and physical environment. An ANOVA analysis was then run using the identified factors for each of the three sections as the dependent variable. The ANOVA was run to determine if there were any main effects or interactions present between the dependent and independent variables.

The observation and debriefing session notes were examined for patterns to gain a more holistic understanding of the environment and will be considered in the discussion section.

CHAPTER FOUR

ANALYSIS AND RESULTS

4.1 Study I

To analyze the results of the structured Q-sort, we conducted a pairwise comparison of column proportions (for each row) via a cross tabulation in SPSS. The purpose of this analysis was to determine what physical elements students believe would promote collaboration. Once determined, the results inform classroom design for study II, the quasi-experiment. We analyzed the results across pictures and participants to examine which physical elements in each photograph were preferred by participants to promote collaboration.

A chi-square test, Pearson P-value significance level <. 05, was run for each of the 14 relationships to ensure there was a relationship between the student answers and the rater identified physical elements. The 14 relationships compare the ten physical features previously identified (page 23). to participant responses. To allow for more precise analysis, elements three and four, types of chairs and types of desk, were each examined three ways. Chairs were examined via height, wheels, and desk attachment. Desks were examined via size, shape, and wheels.

A z-test was then run for each pair of columns. If the pair of values are significantly different, a differing subscript letter (a-c) is assigned to them. This subscript demonstrates which elements are statistically preferred by participants.

Tables 2.1-2.14 provide the results of the cross tabulation.

Table 2.1*: Contributes to collaboration responses * Writing surface elements*

		Writing Surface					
Contributes to Collaboration		Chalkboard	Whiteboard	None	Both	*Total*	*Pearson P-Value*
	Yes	44_a	605_b	117_a	102_b	868	
		47.8%	69.7%	42.9%	73.9%	63.3%	
	No	46_a	246_b	128_a	33_b	453	
		50.0%	28.3%	46.9%	23.9%	33.0%	
	N/A	2_a	17_a	28_b	3_a	50	
		2.2%	2.0%	10.3%	2.2%	3.6%	
Total		92	868	273	138	1371	
		100%	100%	100%	100%	100%	
							.000

Each subscript letter denotes a subset of writing surface categories whose column proportions do not differ significantly from each other at the .05 level.

The results shown above in Table 2.1 suggest that the existence of a whiteboard is preferred by participants to promote collaboration. This could be the presence of a whiteboard alone or both a whiteboard and a chalkboard. A whiteboard alone, 69.7%, or both a whiteboard and chalkboard, 73.9%, are not statistically different from each other. However, either option is preferred to a chalkboard alone, 47.8%, or neither writing surface, 42.9%.

According to participant preference, whiteboards should be present in the collaborative classroom.

Table 2.2: Contributes to collaboration responses * Existence of spaces where small groups can gather to work together

Contributes to Collaboration		Existence of Spaces where Small Groups Can Gather to Work Together: Yes, Small Groups	No Small Groups	*Total*	*Pearson P-Value*
	Yes	572a	290b	862	
		77.9%	45.1%	62.6%	
	No	150a	317b	467	
		20.4%	49.3%	33.9%	
	N/A	12a	36b	48	
		1.6%	5.6%	3.5%	
Total		734	643	1377	
		100%	100%	100%	
					.000

Each subscript letter denotes a subset of existence of spaces where small groups can gather to work together categories whose column proportions do not differ significantly from each other at the .05 level.

The results shown above in Table 2.2 indicate that spaces for small groups are preferred by participants to promote collaboration. The preference for small groups, 77.9%, differs significantly from the preference for no spaces for small groups, 45.1%.

According to participant preference, spaces where small groups can gather to work together should be present in the collaborative classroom.

Table 2.3: Contributes to collaboration responses * Chair height

Contributes to Collaboration		Chair Height: Tall	Short	Mixed	*Total*	*Pearson P-Value*
	Yes	113_a	602_b	185_b	900	
		82.5%	62.4%	67.0%	65.3%	
	No	22_a	362_b	88_b	472	
		16.1%	37.5%	31.9%	34.3%	
	N/A	2_a	1_b	3_a	6	
		1.5%	0.1%	1.1%	0.4%	
Total		137	965	276	1378	
		100%	100%	100%	100%	
						.000

Each subscript letter denotes a subset of chair height categories whose column proportions do not differ significantly from each other at the .05 level.

The results shown above in Table 2.3 indicate that tall chairs are most preferred by participants to promote collaboration. The preference for tall chairs, 82.5%, was significantly different than the preference for short chairs, 62.4%, or mixed (both tall and short), 65.3%. It should be noted that though tall chairs were most preferred, responses for short and mixed were also well above 50%, indicating that although they are not statistically most preferred, chairs of varying heights may still contribute to collaboration.

According to participant preference, tall chairs should be present in the collaborative classroom.

Table 2.4: Contributes to collaboration responses * Chair features

Contributes to Collaboration		Chair Features: Wheels	No Wheels	*Total*	*Pearson P-Value*
	Yes	657_a	243_b	900	
		79.5%	44.0%	65.3%	
	No	165_a	307_b	472	
		20.0%	55.6%	34.3%	
	N/A	4_a	2_b	6	
		0.5%	0.4%	0.4%	
Total		826	552	1378	
		100%	100%	100%	
					.000

Each subscript letter denotes a subset of chair features categories whose column proportions do not differ significantly from each other at the .05 level.

The results shown above in Table 2.4 suggest that chairs with wheels are most preferred by participants to promote collaboration. The preference for wheels, 79.5%, was significantly different than the preference for no wheels, 44.0%.

According to participant preference, chairs with wheels should be present in the collaborative classroom.

Table 2.5: Contributes to collaboration responses * Chair-desk attachment

Contributes to Collaboration		Chair-Desk Attachment: Desk Attached	Desk Separate	Both	*Total*	*Pearson P-Value*
	Yes	290_a	569_a	41_b	900	
		63.0%	65.3%	89.1%	65.3%	
	No	169_a	298_b	5_b	472	
		36.7%	34.2%	10.9%	34.3%	
	N/A	1_a	5_a	0_a	6	
		0.2%	0.6%	0.0%	0.4%	
Total		460	872	46	1378	
		100%	100%	100%	100%	
						.009

Each subscript letter denotes a subset of chair-desk attachment categories whose column proportions do not differ significantly from each other at the .05 level.

The results above in Table 2.5 indicate that there is no statistically significant preference for either chairs that are attached to the desk, 63.0%, or chairs and desks that are separate, 65.3%. However, there is a significant difference suggesting that both types of chair-desk arrangements are most preferred, 89.1%, for the promotion of collaboration.

According to participant preference, both types of chair-desk arrangements should be present in the collaborative classroom.

Table 2.6: Contributes to collaboration responses * Desk size

Contributes to Collaboration		Desk Size: Individual	Multi	Both	*Total*	*Pearson P-Value*
	Yes	411_a	413_b	37_b	861	
		56.0%	69.1%	80.4%	65.2%	
	No	321_a	184_b	9_b	514	
		43.7%	30.8%	19.6%	37.3%	
	N/A	1_a	5_a	0_a	3	
		0.3%	0.2%	0.0%	0.2%	
Total		734	598	46	1378	
		100%	100%	100%	100%	
						.000

Each subscript letter denotes a subset of desk size categories whose column proportions do not differ significantly from each other at the .05 level.

The results above in Table 2.6 suggest that the combination of both individual and multiple person desks are the most preferred for the promotion of collaboration. There is no statistical difference in preference between these two selections of both (multiple & individual desks), 80.4%, or multiple person desks, 69.1%. However, these two were significantly different from preference of individual desks, 56.0%.

According to participant preference, multiple person desks should be present in the collaborative classroom. A mixed type of desks (both multiple person and individual) is also acceptable.

Table 2.7: Contributes to collaboration responses * Desk shape

Contributes to Collaboration		Desk Shape: Rectangular	Round	Both	*Total*	*Pearson P-Value*
	Yes	625_a	198_b	38_b	861	
		59.1%	72.0%	82.6%	62.5%	
	No	430_a	76_b	8_b	514	
		40.7%	27.6%	17.4%	37.3%	
	N/A	2_a	1_a	0_a	3	
		0.2%	0.4%	0.0%	0.2%	
Total		1057	275	46	1378	
		100%	100%	100%	100%	
						.000

Each subscript letter denotes a subset of desk shape categories whose column proportions do not differ significantly from each other at the .05 level.

The results shown above in Table 2.7 suggest that round desks alone or desks of mixed shapes (both round and rectangular) were most preferred for their contribution to collaboration. The results for both types of desk, 82.6%, did not differ significantly from the results for round desks, 72.0%. However, both responses were significantly different from only rectangular desks, 59.1%.

According to participant preference, round desks should be present in the collaborative classroom. A mixed type of desk shape (both round and rectangular) is also acceptable.

Table 2.8: Contributes to collaboration responses * Desk features

Contributes to Collaboration		Desk Features: Wheels	No Wheels	Total	*Pearson P-Value*
	Yes	442_a	419_b	861	
		74.0%	53.6%	62.5%	
	No	153_a	361_b	514	
		25.6%	46.2%	37.3%	
	N/A	2_a	1_a	3	
		0.3%	0.1%	0.2%	
Total		597	781	1378	
		100%	100%	100%	
					.000

Each subscript letter denotes a subset of desk features categories whose column proportions do not differ significantly from each other at the .05 level.

The results shown above in Table 2.8 indicate that desks with wheels are most preferred for the promotion of collaboration. The results indicating that desks with wheels are preferred, 74.0%, were statistically different than desks with no wheels, 53.6%.

According to participant preference, desks with wheels should be present in the collaborative classroom.

Table 2.9: Contributes to collaboration responses * Type of display

Contributes to Collaboration		Type of Display: Tackboard	Electronic	None	Both	*Total*	*Pearson P-Value*
	Yes	$25_{a, b}$	528_{b}	149_{a}	37_{a}	739	
		54.3%	60.6%	40.5%	40.2%	53.7%	
	No	$18_{a, b}$	303_{b}	192_{a}	49_{a}	562	
		39.1%	34.8%	52.2%	53.3%	40.8%	
	N/A	3_{a}	40_{a}	27_{a}	6_{a}	76	
		6.5%	4.6%	7.3%	6.5%	5.5%	
Total		46	871	368	92	1377	
		100%	100%	100%	100%	100%	
							.000

Each subscript letter denotes a subset of type of display categories whose column proportions do not differ significantly from each other at the .05 level.

The results shown above in Table 2.9 indicate that the most preferred type of display to promote collaboration is an electronic board. The results for an electronic board, 60.6%, are not statistically different than for a tackboard, 54.3%. However, the preference for an electronic board, is statistically significant for preference of neither type of board, 40.5%, or both types of board, 40.2%. A tackboard is not statistically different from the other responses.

According to participant preference, an electronic board should be present in the collaborative classroom. A tackboard could also be acceptable.

Table 2.10: Contributes to collaboration responses * Accessibility

Contributes to Collaboration		Accessibility: High	Low	Total	Pearson P-Value
	Yes	716_a	209_b	925	
		71.0%	56.9%	67.3%	
	No	275_a	152_b	427	
		27.3%	41.4%	31.1%	
	N/A	17_a	6_a	23	
		1.7%	1.6%	1.7%	
Total		1008	367	1375	
		100%	100%	100%	
					.000

Each subscript letter denotes a subset of accessibility categories whose column proportions do not differ significantly from each other at the .05 level.

The results shown above in Table 2.10 indicate that workspaces that are highly accessible are most preferred for their contribution to collaboration. The results indicating that highly accessible spaces are preferred for collaboration, 71.0%, are significantly different than spaces with low accessibility, 56.9%.

According to participant preference, spaces that are highly accessible should be present in the collaborative classroom.

Table 2.11: Contributes to collaboration responses * Proximity

Contributes to Collaboration		Proximity: Adjacent	Close	Far	*Total*	*Pearson P-Value*
	Yes	444_a	335_b	112_c	891	
		74.5%	60.7%	48.7%	64.7%	
	No	150_a	208_b	117_c	475	
		25.2%	37.7%	50.9%	34.5%	
	N/A	2_a	9_a	1_a	12	
		0.3%	1.6%	0.4%	0.9%	
Total		596	552	230	1378	
		100%	100%	100%	100%	
						.000

Each subscript letter denotes a subset of proximity categories whose column proportions do not differ significantly from each other at the .05 level.

The results shown above in Table 2.11 suggest that workspaces that are adjacent are most preferred. The preference for adjacent workspaces, 74.5%, for the promotion of collaboration is significantly different from close workspaces, 60.7%, and far workspaces, 48.7%.

According to participant preference, workspaces that are immediately adjacent to each other should be present in the collaborative classroom.

Table 2.12: Contributes to collaboration responses * Ability for class to function as one large group

Contributes to Collaboration		Ability for Class to Function as One Large Group: Yes Large Group	No Large Group	*Total*	*Pearson P-Value*
	Yes	330_a	247_b	577	
		45.3%	38.7%	42.2%	
	No	345_a	325_a	670	
		47.3%	50.9%	49.0%	
	N/A	54_a	67_b	121	
		7.4%	10.5%	8.8%	
Total		729	639	1368	
		100%	100%	100%	.018

Each subscript letter denotes a subset of existence of large groups categories whose column proportions do not differ significantly from each other at the .05 level.

The results shown above in Table 2.12 suggest that the ability for the class to function as a large group is slightly preferred to the inability to function as a large group. The results for preference of a large group in promotion of collaboration, 45.3%, is significantly different from the preference for no large group in promotion of collaboration, 38.7%.

According to participant preference, the ability for the class to function as one large group should be present in the collaborative classroom.

Table 2.13: Contributes to collaboration responses * Reconfigurability

Contributes to Collaboration		Reconfigurability Mobile	Stationary	*Total*	*Pearson P-Value*
	Yes	432_a	339_b	771	
		62.8%	49.5%	56.2%	
	No	232_a	323_b	555	
		33.7%	47.2%	40.4%	
	N/A	24_a	23_b	47	
		3.5%	3.4%	3.4%	
Total		688	685	1373	
		100%	100%	100%	
					.000

Each subscript letter denotes a subset of reconfigurability categories whose column proportions do not differ significantly from each other at the .05 level.

The results shown above in Table 2.13 indicate that mobile furniture is the most preferred for its contribution to collaboration. The preference for mobile furniture, 62.8%, differs significantly from the preference for stationary furniture, 49.5% in the promotion of collaboration.

According to participant preference, mobile furniture should be present in the collaborative classroom.

Table 2.14: Contributes to collaboration responses * Privacy

Contributes to Collaboration		Privacy: Dividers	No Dividers	*Total*	*Pearson P-Value*
	Yes	93_a	582_b	675	
		68.4%	47.1%	49.2%	
	No	40_a	620_b	660	
		29.4%	50.2%	48.1%	
	N/A	3_a	33_a	36	
		2.2%	2.7%	2.6%	
Total		136	1235	1371	
		100%	100%	100%	
					.000

Each subscript letter denotes a subset of privacy categories whose column proportions do not differ significantly from each other at the .05 level.

The results shown in Table 2.14 suggest that participants preferred the existence of dividers for the promotion of collaboration. The preference for dividers, 68.4% is significantly different than the preference for no dividers, 47.1%.

According to participant preference, dividers should be present in the collaborative classroom.

4.2 Summary of Results

As shown by the Pearson P-Value (<.05) in Tables 2.1-2.14, there is a statistically significant relationship between the identified physical feature and the participant response for all 14 pairs.

Altogether, the results suggest that the statistically significant physical features to promote collaboration as preferred by participants are:

1. The existence of writing surfaces

    d. Whiteboard; or both whiteboard and chalkboard

2. The existence of spaces where small groups can gather to work together
    a. Spaces where small groups can work together
3. Types of chairs
    a. Height: Tall chairs
    b. Wheels: Chairs with wheels
    c. Attachment: Both chairs attached to desks and chairs separate from desks
4. Types of Desks/Tables
    a. Size: Both individual workspaces and multiple person workspaces; or only multiple person working spaces
    b. Shape: Both rectangular and round desks; or only round desks
    c. Wheels: Desks with wheels
5. Displays
    a. Electronic board or tackboard
6. Accessibility (level of ease to access) of each space
    a. High accessibility to each space
7. Proximity of one working space to the next
    a. Working spaces that are immediately adjacent to each other
8. The ability for the group to function as one large group
    a. Yes, the ability to function as one large group
9. Configurability
    a. Furniture is mobile and can be easily be re-configured
10. The ability for visual privacy

a. Existence of privacy dividers

4.3 Study II

To analyze the data from questionnaire responses a factor analysis was conducted using SPSS. The questionnaire can be found in Appendix C. The results were analyzed in three groups based on category of question: group dynamics (questions 1-13), personal experience in the group (questions 14-20), and the physical environment (questions 21-29). Group dynamics and personal experience in the group were extracted via Principal Axis Factoring. Physical environment was extracted by Principal Axis Factoring and was then orthogonally rotated using Varimax to get a more holistic understanding of the concept. The three factors that were extracted for physical environment were as follows: physical environment supports collaboration, participants' personal experience in the environment, and distractions/impediments in the environment.

The corresponding factors of each group of questions were further examined using a two-factor ANOVA analysis to examine if class, room type, gender, and age had an effect on the results.

Table 3.1: Descriptive Statistics for Group Dynamics

Descriptive Statistics

	Mean	**Standard Deviation**	**Analysis N**
Question 1	3.98	.785	48
Question 2	3.83	.753	48
Question 3	3.92	.767	48
Question 4	3.81	.842	48
Question 5	3.88	.815	48
Question 6	3.94	.755	48
Question 7	4.02	.601	48
Question 8	3.83	.930	48
Question 9	3.77	.831	48
Question 10	4.04	.798	48
Question 11	3.73	.962	48
Question 12	3.79	.874	48
Question 13	3.98	.863	48

Table 3.2: Correlation Matrix, KMO, and Bartlett's for Group Dynamics

Correlation Matrix Determinant	2.46E-005
Kaiser-Meyer-Olkin Measure of Sampling Adequacy	.867
Bartlett's Test of Sphericity	Sig. .000

Table 3.1 shows the descriptive statistics for this section of questions. As shown, the mean answer for the first group of questions, 1-13, regarding group dynamics was fairly consistent with the minimum mean of 3.73 and a maximum mean of 4.04. The results of the

Kaiser-Meyer-Olkin (KMO) and Bartlett's Tests shown in Table 3.2, measure the strength of relationship among the variables. A KMO value of .867 is highly acceptable, while a significance of .000 for Bartlett's Test suggests that the null hypothesis can be rejected (α = .05). Thus, further analysis should occur.

Table 3.3: Total Variance Explained for Group Dynamics

Total Variance Explained

	Initial Eigenvalues		*Extraction*	
Factor	**Total**	**% of Variance**	**Total**	**% of Variance**
1	7.57	58.27	7.146	54.971
2	1.07	8.235		
3	.890	6.845		
4	.771	5.930		
5	.636	4.891		
6	.528	4.062		
7	.383	2.946		
8	.270	2.076		
9	.263	2.019		
10	.204	1.573		
11	.172	1.326		
12	.133	1.027		
13	.103	.793		

Extraction Method: Principal Axis Factoring

Figure 1: Factor Analysis Scree Plot for Group Dynamics

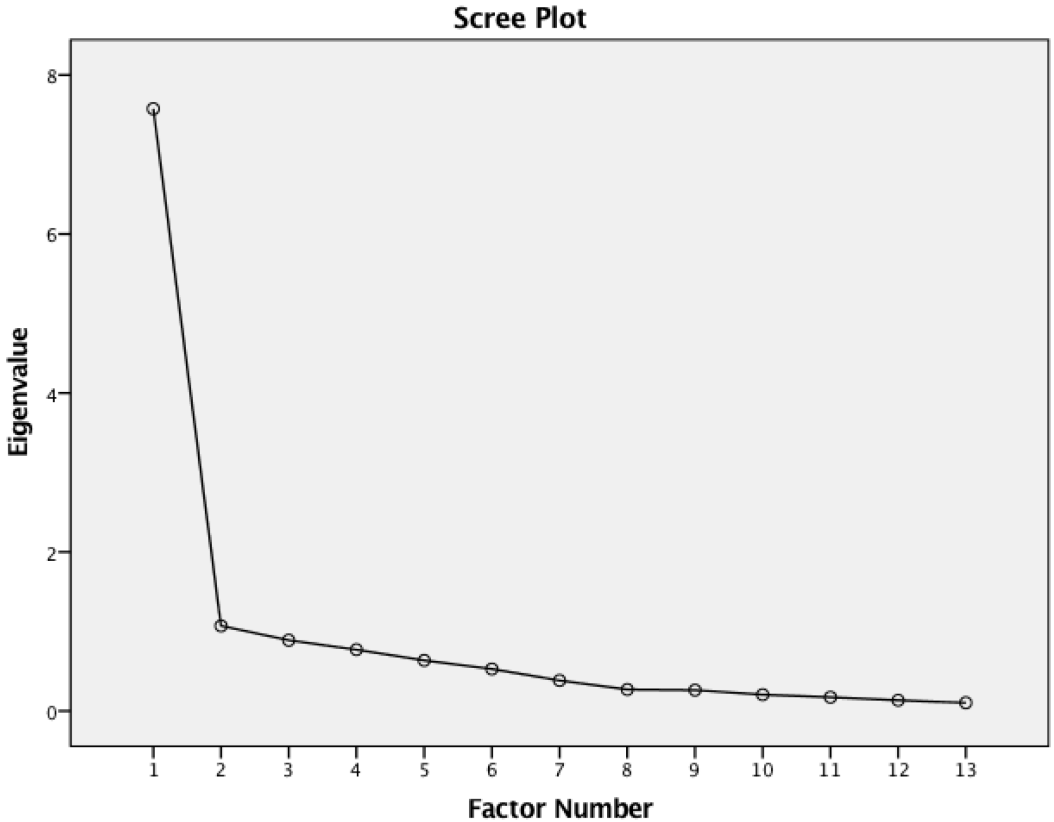


Table 3.4: Factor Matrix for Group Dynamics

Factor Matrix

	Factor 1
Q 1	.756
Q 2	.679
Q 3	.733
Q 4	.688
Q 5	.735
Q 6	.759
Q 7	.671
Q 8	.667
Q 9	.654
Q 10	.895
Q 11	.874
Q12	.734
Q13	.749

As shown in Table 3.3, Factor 1 explains 58.27% of the variance while Factor 2 explains

8.235%. Figure 1 shows that although Factor 2 has an Eigenvalue > 1, the scree plot falls nearly flat after Factor 1. Therefore, it is difficult to discuss these two factors as two different conceptual ideas. Thus, the first group of questions can be explained by one factor and once it was extracted by principal axis factoring, this factor explains 54.971% of the variance. The results from Table 3.4, the Factor Matrix, suggest that every question in this group, 1-13, is loaded quite highly onto Factor 1 with values ranging from .667 to .895.

Table 4: Univariate Analysis of Variance Between-Subjects Factors

		N
Class	Class 1 (n = 16)	32
	Class 2 (n = 8)	16
Type	Traditional	24
	Collaborative	24
Gender	Male	26
	Female	20
	Choose not to disclose	2
Age	14 years	26
	15 years	16
	16 years	6

Table 4 shows the Univariate Analysis of Variance Between-Subjects Factors for the factors from all questions. As shown, the analysis examined whether class, type of room, gender, or age had an effect on group dynamics, participants' personal experience in their group, or physical environment supports collaboration.

Table 5: Two-way ANOVA Tests of Between-Subjects Effects for Factor 1 (Group Dynamics)

Source	Type III sum of Squares	df	Mean Square	F	Significance
Class	1.361	1	1.361	1.631	.209
Room Type	6.909	1	6.909	8.279	.006
Gender	1.721	2	.861	1.031	.366
Age	1.804	2	.902	1.081	.349
Total	44.678	48			

R Squared = .234 (Adjusted R-Squared = .122)

Table 5 displays the results of the ANOVA with the single Factor 1 of group dynamics as the dependent variable. The results suggest that there is a main effect of room type ($\alpha = .05$), $F(1,48) = 8.279$, $p = .006$, on how the participants' scored their group dynamics while working collaboratively. On average, participants in the collaborative classroom felt they had better group dynamics while working together. There are no further main effects or interaction effects demonstrated. The adjusted R-squared value suggests that 12.2% of the variance in group dynamics is attributable to type of room.

Table 6.1: Descriptive Statistics for Personal Experience while Working in Group

Descriptive Statistics

	Mean	Standard Deviation	Analysis N
Question 14	3.98	.911	48
Question 15	3.83	.930	48
Question 16*	3.44	1.201	48
Question 17	3.88	.789	48
Question 18	3.96	.771	48
Question 19	3.81	.867	48
Question 20	3.92	1.069	48

**Question 16 Recoded in reverse*

Table 6.2: Correlation Matrix, KMO, and Bartlett's for Personal Experience

Correlation Matrix Determinant	.004
Kaiser-Meyer-Olkin Measure of Sampling Adequacy	.811
Bartlett's Test of Sphericity	Sig. .000

Similar to the first group of questions, the results from Table 6.1 suggest that the second group of questions, 14-20, regarding personal experience in their group, had consistent means with a minimum mean of 3.44 and a maximum mean of 3.98. Question 16, *my own creativity and initiative were suppressed by this group*, was reversed coded. The results from Table 6.2 demonstrate a highly acceptable KMO value of .811 and a significance level of .000 suggesting that the null hypothesis can be rejected ($\alpha = .05$). Thus, further analysis should occur.

Table 6.3: Total Variance Explained for Personal Experience

Total Variance Explained

	Initial Eigenvalues		*Extraction*	
Factor	**Total**	**% of Variance**	**Total**	**% of Variance**
1	4.529	64.701	4.236	60.519
2	1.009	14.412		
3	.563	8.041		
4	.385	5.501		
5	.268	3.827		
6	.154	2.200		
7	.092	1.318		

Figure 2: Factor Analysis Scree Plot for Personal Experience while Working in Group

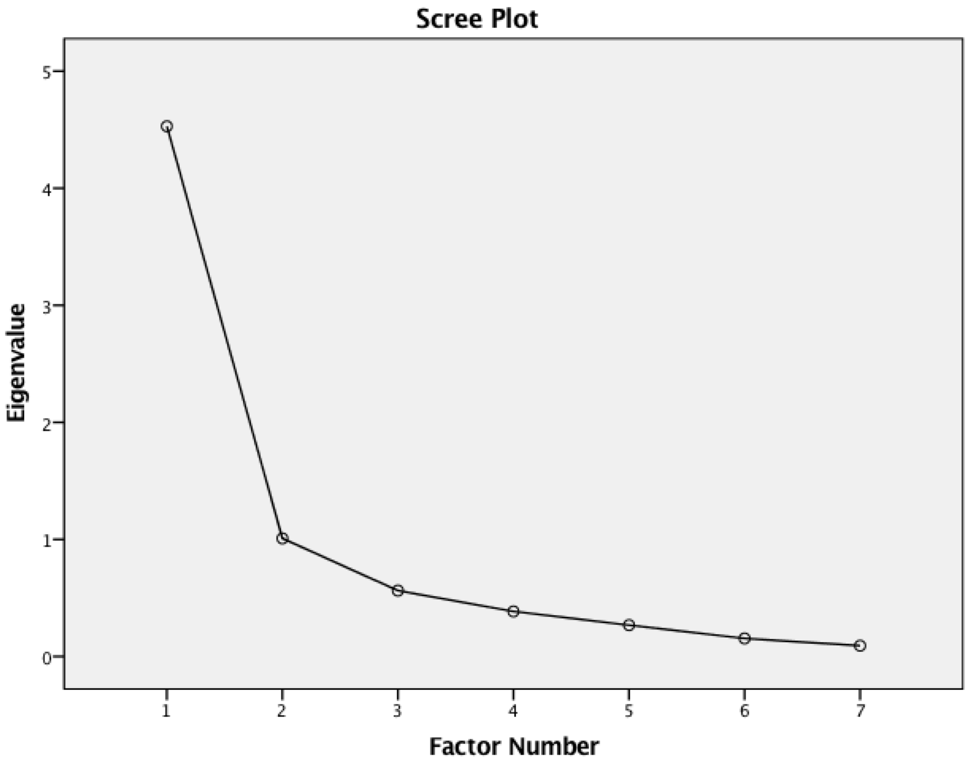


Table 6.4: Factor Matrix for Personal Experience

Factor Matrix

	Factor 1
Q 14	.756
Q 15	.917
Q 16	.118
Q 17	.792
Q 18	.818
Q 19	.867
Q 20	.801

As shown in Table 6.3, Factor 1 explains 64.701% of the variance, while Factor 2 explains 14.412%. After further analyzing the factors for natural groupings, it was difficult to differentiate Factor 1 and Factor 2 into two different conceptual groups. Additionally, as shown in Figure 2, the scree plot drastically falls after Factor 1. Thus, the second group of questions can be explained by one factor and once it was extracted via principal axis factoring, this factor explains 60.519% of the variance. The results from Table 6.4 suggest that questions 14, 15, 17, 18, 19, and 20 all loaded highly onto Factor 1. Question 16 with a value of .118 did not load highly onto any factor.

Table 7: Two-way ANOVA Tests of Between-Subjects Effects for Factor 1 (Personal Experience)

Source	Type III sum of Squares	df	Mean Square	F	Significance
Class	3.888	1	3.888	4.600	.038
Room Type	2.921	1	2.921	3.455	.070
Gender	2.331	2	1.166	1.379	.263
Age	4.665	2	2.333	2.759	.075
Total	44.347	48			

R Squared = .218 (Adjusted R-Squared = .104)

Table 7 displays the results of the ANOVA with the single Factor 1 of personal experience as the dependent variable. The results suggest that there is a main effect of class (α = .05), $F(1,48) = 4.600$, $p = .038$, on the participants' personal experience while working collaboratively. Participants in class 2 felt they had a better personal experience in their group than participants in class 1. There are no further main effects or interaction effects demonstrated. The adjusted R-squared value suggests that 10.4% of the variance in personal experience is attributable to which class the participant was part of.

Table 8.1: Descriptive Statistics for Physical Environment

Descriptive Statistics

	Mean	Standard Deviation	Analysis N
Question 21	4.02	.785	48
Question 22	4.08	.767	48
Question 23	4.04	.743	48
Question 24*	3.90	1.015	48
Question 25*	3.54	1.071	48
Question 26*	3.65	1.101	48
Question 27	3.77	.831	48
Question 28	3.83	.753	48
Question 29	3.94	.783	48

**Questions 24,25,26 Recoded in reverse*

Table 8.2: Correlation Matrix, KMO, and Bartlett's for Physical Environment

Correlation Matrix Determinant	.005
Kaiser-Meyer-Olkin Measure of Sampling Adequacy	.814
Bartlett's Test of Sphericity	Sig. .000

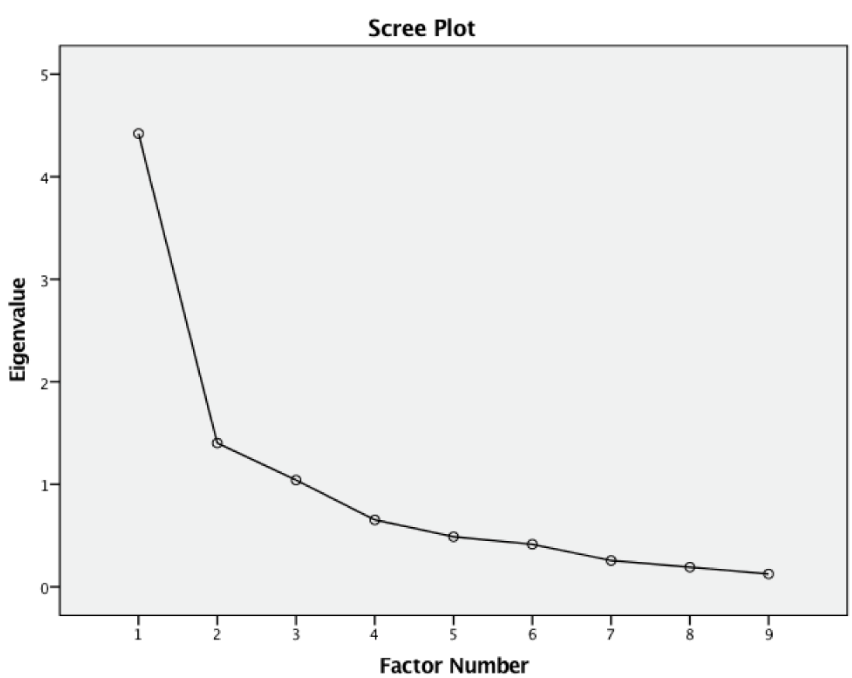
The final group of questions, 21-29, are regarding the physical environment. As shown by the results in Table 8.1, all the means are consistent with a maximum mean of 4.08 and a minimum mean of 3.54. Question 24, *I was too far away from my group members to communicate face-to-face*, question 25, *there was too much informal, casual conversation around me such that I found it difficult to concentrate on my work*, and question 26, *I experienced visual distractions in our work area*, were all reverse coded. The results shown in Table 8.2 suggest that the KMO value of .814 is highly acceptable and the null hypothesis can be rejected with a significance level of .000 ($\alpha = .05$). Thus, the analysis should continue.

Table 8.3: Total Variance Explained for Physical Environment

Total Variance Explained

	Initial Eigenvalues		*Extraction Sums*		*Rotation Sums*		
Factor	**Total**	**% of Variance**	**Total**	**% of Variance**	**Total**	**% of Variance**	**Cumulative %**
1	4.421	49.120	4.164	46.270	2.889	32.095	32.095
2	1.403.	15.585	.964	10.712	1.494	16.595	48.690
3.	1.042	11.574	.682	7.578	1.428	15.870	64.560
4	.653	7.260					
5	.489	5.438					
6	.416	4.618					
7	.257	2.859					
8	.193	2.140					
9	.127	1.406					

Figure 3: Factor Analysis Scree Plot for Physical Environment



As shown in table 8.3, Factor 1 explains 49.120% of the variance, Factor 2 explains 15.585% of the variance, and Factor 3 explains 11.574% of the variance. Once these factors were further examined, it was determined that they were three different conceptual ideas. Factor 1 is about the physical environment supporting collaboration, Factor 2 is about participants' personal experience in the physical environment, and Factor 3 is about distractions/impediments in the physical environment. Because these factors are uncoordinated with one another and the physical environment is what we manipulated in our quasi-experiment, we furthered the analysis and rotated the data via varimax to generate a more holistic understanding. After the rotation, the results suggest that Factor 1, the physical environment supports collaboration, explains 32.095% of the variance. Factor 2, participants' personal experience in the physical environment, explains 16.595% of the variance; and Factor 3, distractions/impediments in the physical environment, explains 15.870% of the data. The three factors cumulatively explain 64.560% of the data. Figure 3 shows that scree plot begins to level off after factor 3 and thus no other factors were considered.

Table 8.4: Rotated Factor Matrix for Physical Environment

Factor Matrix

	Factor 1	*Factor 2*	*Factor 3*
Q 21	.923	.201	.126
Q 22	.818	.200	.164
Q 23	.733	.239	.355
Q 24	.217	-.245	.377
Q 25	.103	.068	.501
Q 26	.117	.269	.889
Q 27	.288	.773	.048
Q 28	.403	.606	.210
Q 29	.716	.504	.172

The results from Table 8.4 show how each question loaded onto each of the factors once the data was rotated. The results suggest the following:

Factor 1, the physical environment supports collaboration, was most strongly associated with:

- Question 21 (.923; *the classroom furniture adequately allowed group members to freely collaborate and share information*),
- Question 22 (.818; *the classroom furniture supported collaboration and teamwork*)
- Question 23 (.733; *the classroom furniture and layout support exchanging of information and ideas frequently with my group mates through face-to-face communication*)
- Question 29 (.716; *overall, my current work environment was useful to the collaboration of my group*).

Factor 2, participants' personal experience in the physical environment, was most strongly associated with:

- Question 27 (.773; *the classroom layout supported my individual work productivity*)
- Question 28 (.606; *overall, I felt supported by the space for the activities that we were doing today*).

Factor 3, distractions/impediments in the physical environment, was most strongly associated with:

- Question 24 (.377; *I was too far away from my group members to communicate face-to face*)
- Question 25 (.501*; there was too much informal, casual conversation around me such that I found it difficult to concentrate on my work*)

- Question 26 (.889*; I experience visual distractions in our work area*).

Table 9: Two-way ANOVA Tests of Between-Subjects Effects for Factor 1 (Physical Environment Supports Collaboration)

Source	Type III sum of Squares	df	Mean Square	F	Significance
Class	.075	1	.075	.116	.735
Room Type	15.595	1	15.595	24.38	.000
Gender	.501	2	.251	.392	.678
Age	.102	2	.051	.080	.923
Class * Type	.471	1	.471	.704	.407
Type * Gender	.227	2	.113	.169	.845
Total	42.907	48			

R Squared = .389 (Adjusted R-Squared = .299)

Table 9 demonstrates the results of the ANOVA with Factor 1, the physical environment supports collaboration, as the dependent variable. The results suggest that there is a main effect of room type ($\alpha = .05$), $F(1,48) = 24.38$, $p = .000$, on the physical environment supporting collaboration. Participants in the collaborative classroom felt the physical environment promoted collaboration to a greater extent than the traditional classroom. There are no further main effects or interaction effects demonstrated. The adjusted R-squared value suggests that 29.9% of the variance in physical environment supporting collaboration is attributable to type of room.

Table 10: Two-way ANOVA Tests of Between-Subjects Effects for Factor 2 (Personal Experience in the Physical Environment)

Source	Type III sum of Squares	df	Mean Square	F	Significance
Class	4.129	1	4.129	6.418	.015
Room Type	2.869	1	2.869	4.459	.041
Gender	.028	2	.014	.022	.978
Age	1.241	2	.621	.965	.390
Class * Type	.514	1	.514	.793	.379
Type * Gender	1.480	2	.740	1.143	.330
Total	34.325	48			

R Squared = .232 (Adjusted R-Squared = .119)

Table 10 demonstrates the results of the ANOVA with Factor 2, participants' personal experience in the physical environment, as the dependent variable. The results suggest that there is a main effect of class ($\alpha = .05$), $F(1, 48) = 6.418$, $p = .015$, on the participants' personal experience. Participants in class 1 felt they had a better personal experience while working in the collaborative classroom than participants in class 2.

The results also suggest that there is a main effect of type of room ($\alpha = .05$), $F(1, 48) = 4.459$, $p = .041$, on the participants' personal experience in the physical environment. Participants in the collaborative classroom felt they had a better personal experience while working in the collaborative classroom than in the traditional classroom. There are no further main effects or interaction effects demonstrated. The adjusted R-Squared value suggests that 11.9% of the variance in participants' personal experience is attributable to which class and which room the participant was in.

Table 11: Two-way ANOVA Tests of Between-Subjects Effects for Factor 3 (Distractions/Impediments in The Environment)

Source	Type III sum of Squares	df	Mean Square	F	Significance
Class	1.335	1	1.335	1.418	.241
Room Type	.018	1	.018	.019	.890
Gender	.435	2	.217	.231	.795
Age	.899	2	.450	.478	.624
Class * Type	2.911	1	2.911	3.174	.083
Type * Gender	.366	2	.183	.200	.820
Total	40.275	48			

R Squared = .042 (Adjusted R-Squared = -.099)

Table 11 demonstrates the results of the ANOVA with Factor 3, distractions/impediments in the environment, as the dependent variable. The results suggest that there are no main effects or interaction effects upon class, room type, gender, age, class * room type, or room type * gender. The adjusted R-squared value of -9.9% suggests that none of the variance in distractions or impediments is attributable to these variables.

4.4 Summary of Results

Based on the results of the factor analysis, the first group of questions on the questionnaire regarding group dynamics can be explained by one factor after extraction by principal axis factoring; 54.97% of the variance is explained by this factor. After conducting a two factor ANOVA, the results suggest the type of room influenced how students perceived their group dynamics while working collaboratively.

The second group of questions on the questionnaire, regarding personal experience in their group, can also be explained by one factor after extraction by principal axis factoring; 60.52% of the variance can be explained by this factor. After conducting a two factor ANOVA, the results suggest the class a participant was in influenced how he or she perceived his or her personal experience while working collaboratively.

The third group of questions on the questionnaire, regarding physical environment, can be explained by three, uncorrelated factors after rotation by varimax; 64.56% of the variance can be explained by these factors. After conducting a two factor ANOVA on each of these three factors, the results suggest that the type of room participants were in influenced how they perceived the physical environment supporting collaboration. Additionally, the type of room also had an influence on how participants perceived their personal experience in the physical environment. The class a participant was in, also influenced how the participants perceived their personal experience in the physical environment.

CHAPTER FIVE

DISCUSSION

5.1 Overview

The two studies analyzed if classroom design facilitates student collaboration. Study I, the structured photographic Q-sort, examined what physical features, within a classroom, high school students perceived would promote collaboration. The results from Study I informed classroom design for Study II. The results suggest that the students' preferred the following physical features, in order to promote collaboration:

- The existence of whiteboards,
- the existence of spaces where small groups can work together,
- varying types of chairs and desks, all with wheels,
- an electronic board,
- highly accessible spaces that can be immediately adjacent to each other,
- the ability for the class to function as one group,
- furniture that can be easily re-configured,
- and the existence of privacy dividers.

Study II, the quasi experiment, utilized this information to create a classroom designed for collaborative work. Study II examined how students work collaboratively in a traditional classroom versus a collaborative classroom. The results suggest that the type of classroom students worked in influenced how they perceived their group dynamics, how they perceived the physical environment to promote collaboration, and how they personally experienced the physical environment. In each of the aforementioned situations, the collaborative classroom was preferred. The students in the collaborative room also produced a higher quality deliverable than while in the traditional classroom after a grading assessment conducted by their instructor.

5.2 Study I: Structured Photographic Q-Sort

The primary goal of study I was to determine what physical characteristics were preferred by students for the promotion of collaboration. The results suggest that the students were able to clearly indicate which physical characteristics they preferred in order to promote collaborative work. Hypothesis I, students will prefer spaces that include a flexible layout and reconfigurable furniture for the promotion of collaboration, was supported. Hypothesis II, students will prefer spaces that allow them to easily access other students for the promotion of collaboration, was supported. And lastly, hypothesis III, students will prefer spaces that include the ability to display work to one another for the promotion of collaboration, was supported.

While the Q-sort was administered, a researcher observed student reactions to photographs. Many ad-hoc comments expressed a desire for a collaborative space. These included, “I wish our chairs had wheels!”, “A classroom can actually look like this? I’d want to be in school more!”, “This would make working together better!”, and “I would love to work in a space like that!”. On the other hand, some students also expressed outward distaste for traditional classrooms; many of their current classrooms are set up in a traditional fashion. Comments included, “I hate boring classrooms, they make class boring!” and “I hate when everything is so straight, it makes me want to bang my head against a wall!”. These observations help illuminate, in students’ own language, how they perceive different types of classrooms.

Work by Graetz (2006) and Kuuskorpi and Cabellos-Gonzalez (2011) suggests that traditional classroom design should be altered to accommodate for collaboration within the classroom. The results of the structured photographic Q-sort align with this current research.

Both through the questionnaire and their verbal responses, it seems students desire alternative classroom design to increase collaboration, and to possibly aid with learning, and engagement.

5.3 Study II

Did the students' perception of physical elements in a collaborative classroom result in better perceived collaboration? Utilizing the result of Study I, a collaborative classroom was created that included:

1. whiteboards,
2. spaces and furniture with the ability to create small groups,
3. chairs of varying heights with wheels, some attached to desks and some separate,
4. both individual and multi person work spaces of varying shapes, all with wheels,
5. an electronic board,
6. highly accessible spaces,
7. working spaces that can be immediately adjacent to each other,
8. the ability for the class to function as one large group,
9. an easily reconfigurable layout,
10. and the availability of privacy dividers.

Thus, all the physical features that were preferred by students for the promotion of collaboration were included.

The quantitative results suggest that working in the traditional classroom versus the collaborative classroom influenced how students perceived their group dynamics while working collaboratively. On average, students in the traditional classroom gave a mean score of 3.63 out of 5 on the group dynamics questions. Participants in the collaborative classroom gave a significantly higher mean score of 4.13 on the group dynamic questions. Thus, the collaborative space allowed for improved perception of group dynamics between students while working on a joint assignment.

The results also suggest that type of room had an effect on how participants felt the physical work environment facilitated collaboration. On average, participants in the traditional classroom gave a mean score of 3.59 on questions regarding how the physical environment promoted collaboration. Participants in the collaborative classroom gave a significantly higher mean score of 4.45 on this group of questions. This sizable difference in mean scores suggests that participants felt their ability to collaborate was improved while working in the collaborative classroom. Similarly, type of room had an effect on how participants scored their personal experience while working in the physical environment. For questions regarding individual work productivity and the space supporting oneself while working, participants in the traditional classroom had a significantly lower mean score of 3.48, while participants in the collaborative classroom had a mean score of 4.13. These results suggest that the collaborative classroom design improved perceptions of overall collaboration and personal experience.

The class a participant was in had an effect on participants' personal experience while working in a group, as well as participants' personal experience working in the physical environment. On average, participants in class 1(n=16) gave a mean score of 3.00 on questions regarding their personal experience while working in their group, while participants in class 2 (n=8) gave a significantly higher mean score of 3.69. However, on average, participants in class 1 (n=16) gave a mean score of 3.97 on questions regarding their personal experience in the physical environment, while participants in class 2 (n=8) gave a means score of 3.47. These results suggest that students in class 2 had a better experience while working in their group, while students in class 1 had a better experience while working in the physical environment.

Class 2 was the class that participated in Study I, therefore although they may have felt more agency over the collaborative classroom due to carry over effects as their responses helped design it, the results do not suggest this affected their responses in the quasi-experiment. Class differences may be partially attributable to the difference in class size.

5.4 Observations

While participants took part in the quasi-experiment, the researcher was present in each class period and took observations. Every five minutes, the researcher observed each group while they worked together. It should be noted that these observations were non-systematic and thus their interpretation can only illuminate the quantitative results.

In the traditional classroom, there were multiple instances of participants with their back to the instructor while he was speaking. There were also multiple instances of participants standing up and moving around, once already in groups, to work with another participant and share their work. One student fell asleep during the work session, despite multiple attempts by the instructor to keep the student awake. Every group completed their tasks on both days. The class that returned to the traditional classroom after first working in the collaborative classroom expressed a desire to return to the collaborative classroom.

Figure 4: Participants working in traditional classroom

Instructor addresses the entire class,
multiple students have their backs to the instructor

Figure 5: Participants working in traditional classroom

Participants within same groups are moving during work session to share information with group members

In the collaborative classroom, participants from both classes appeared to be more engaged than in the traditional classroom (see figures 6-8 below). Every group worked for the entirety of the work session with minimal interruptions. When the instructor spoke to the entire class, every student faced the instructor. Participant comments during this session included:

"Whoever invented this style classroom is ingenious!",

"This would make work in almost every class so much better!",

"Could I come back with my group from another class and work here in open periods?",

"I'd love to do homework in here."

Every group also completed their tasks on both days.

Figures 6-8: Participants working in collaborative classroom

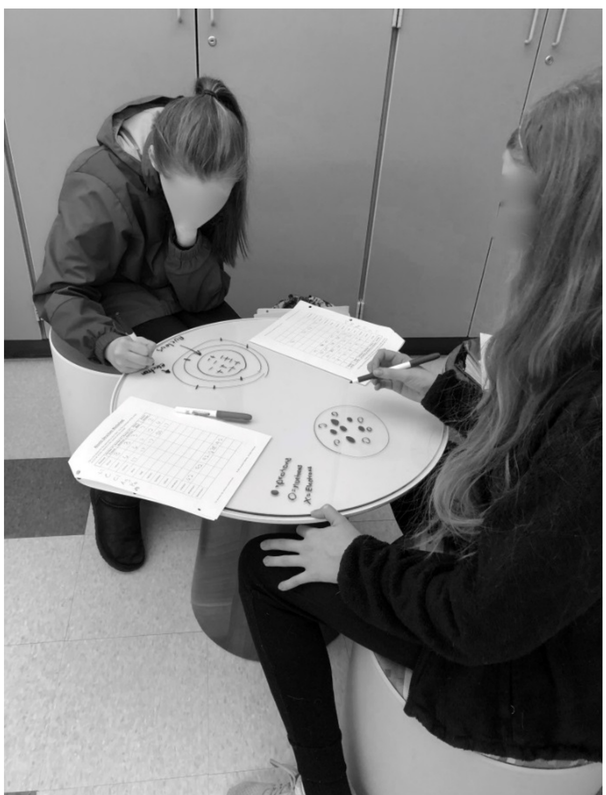


Figure 6*: Group of two working together using a whiteboard table*

Figure 7: *Groups working together, instructor engaging with one group*

Figure 8*: Groups working together, one group utilizing mobile whiteboard as divider*

At the conclusion of the experiment, the researcher had a debriefing session with the instructor (See Appendix D). The instructor stated the classroom with the modular furniture facilitated better quality collaboration. He did note that he was not certain if this was due to the modular furniture or if it was simply the novelty of a different type of classroom. He also stated that from his perspective, engagement was higher in the collaborative classroom, especially with material that was a little dry. He stated that this difference was notable but not tremendous. He also pointed out that he did not have to physically keep students awake in the collaborative space, while it was an issue in the traditional space. His overall takeaway was positive and felt that continued use of a collaborative classroom could eventually aid with engagement, performance, and even attendance.

Lastly, the instructor assessed the deliverables following the same guidelines that he normally used. The assessment looked for correct, well-thought out answers. They were graded on a check-plus (the highest grade: excellent work), check (good work), check-minus (poor work) scale. The exact breakdown of these deliverables was not provided. However, he did inform the researcher that the deliverables from the assignments given in the collaborative classroom were more thorough with higher quality answers than those in the traditional classroom. Answers were more often more extensive and more thought out. Models were also more often correct on the first try, which the instructor felt was a direct result of the ease of ability to work with others and collaborate on ideas. These results support the work of Haghighi and Jusan (2013) that suggests allowing the user the ability to adjust their physical environment improves motivation and academic achievement. It also supports the work of Imms and Byers (2016) that suggests students perform better and are more engaged in dynamic, adaptive spaces.

Overall, hypothesis I, students completing group work in an environment that supports collaboration will rate their group dynamics higher during collaboration than students in a traditional classroom environment, was supported. Hypothesis II, students completing group work in an environment that supports collaboration will be rate their personal experience higher during collaboration than students in a traditional classroom environment, was supported. Hypothesis III, students completing group work in an environment that supports collaboration will rate the physical environment higher during collaboration than students in a traditional classroom. And, hypothesis IV, students completing group work in an environment that supports collaboration will produce work of a higher quality than students in a traditional classroom environment, was supported.

5.5 Limitations

While interpreting the results, limitations to both studies deserve mention. First and foremost, neither sample for study I nor study II was randomized. The lack of random assignment led to non-equivalent control groups, and thus the generalizability to the greater population is limited. Similarly, due to the nature of quasi-experimental design, there could have been pre-existing factors or other influences that had an effect besides the treatment of altering the physical classroom design. As shown by our results, which class a participant was in influenced some of the results. For instance, participants in class 1 (n=16) rated their personal experience in the collaborative classroom higher, than participants in class 2 (n=8). Further, type of room was never responsible for all of the variance in responses. Therefore, although type of classroom design had an influence on collaboration, it cannot be stated that it was the sole factor for the differences seen between classes.

Moreover, novelty may have also influenced the external validity of both studies. In study I, participants were shown images for the first time. Therefore, viewing new and innovative classroom designs for the first time may have influenced their responses on the questionnaire. Additionally, the participants were given a choice; they had the ability to choose whichever physical features they preferred. This ability to use their voice was also a novel experience (when it came to classroom design). Therefore, viewing differently designed spaces, as well as having the opportunity to choose elements in these spaces, may have affected the results.

Similarly, in study II, participants worked in a completely new environment for the first time. Though participants were given one class period to acclimate to the collaborative classroom prior to the experiment, the overall environment was still fairly new. The knowledge of participating in an experiment in a new environment with dynamic furniture may have influenced results. There was also novelty in having the freedom to choose which classroom they preferred. It is difficult to tease apart the influence of the novelty of the physical environment and the novelty of having agency when it came to the design of the classroom. However, it should be noted that both likely influenced results.

Furthermore, because researchers wanted to work with actual students during the school day, the sample size was limited. This may have affected the statistical validity of the results. The non-diverse population may have also affected statistical validity as participants were all from the same high school. Participants may have discussed results after any point of either study and thus created non-independence in the results.

Lastly, there was likely some level of confirmation bias present. The instructor was a strong believer in the importance of collaboration, as well as the importance of the physical environment. It is therefore possible that his responses and assessments of collaborative work in the collaborative classroom were, to a certain extent, confirming his preexisting beliefs. He did note that the differences were not tremendous and that he would like to understand these differences in a longitudinal study, however it is important to note the possibility of this cognitive bias as it may have influenced the results.

Overall, the discussed limitations may weaken the strength of the conclusions. However, improvements in future studies can help combat these limitations.

5.6 Future Research

Altogether, these studies provide a starting point for future research looking at the effects of classroom design on how high school students work collaboratively. A future improvement that should occur, in order to limit the novelty of the collaborative classroom, would be to conduct a longitudinal study with classes. By studying the effects of the collaborative classroom over an extended period of time, researchers would further limit alternative explanations. This would allow researchers to examine whether differences in classroom type had a long-term difference on collaboration through engagement and performance levels.

Future studies should also include more measures. Participants may still fill out questionnaires, however future researchers may also want to hold interviews or focus groups with participants to allow for further qualitative analysis. This would be feasible in a study that occurs over a longer period of time. Researchers should hold these interviews or focus groups at set points throughout the entirety of the study to examine if the dialogue changes over time. It is possible that once the novelty of the collaborative space wears off, the improvements seen may also deteriorate.

Moreover, in order to further increase the generalizability and statistical validity of the findings, it is recommended that a more diverse sample be used. Classes of participants from different schools should be recruited so that participants with greater variety are included.

Although it may not be possible to randomly assign participants to classes, more participants with greater differences would be included and thus naturally the diversity of the sample would increase.

Lastly, the incorporation of technology could also improve future studies. Videotaping would allow researchers to review work sessions and analyze differences more deeply. Furthermore, if participants wore recording devices, group dialogue could be more closely analyzed to examine quality and intent of discussions. It is important to note that when working with participants in this age group, researchers must be careful about violating privacy. However, recording techniques that allow for more in depth analysis of group work during collaboration sessions would be a powerful tool for future research and should be explored in future studies.

CHAPTER SIX

CONCLUSION

6.1 Overall conclusions

Overall, the results of the two studies suggest that students' perceptions about what classroom design elements would promote collaboration, did indeed, have a significant effect on collaboration. Collaboration improved when students worked in the collaborative classroom versus the traditional classroom. Both studies incorporated student beliefs and perception as students are the main users of classrooms, but often do not have a voice in classroom design.

There is a significant amount of literature on the importance of collaborative work at the high school level (Lee et al., 2015; Odagiri, 2012; Duran et al., 2013; Rozenszayn & Assaraf, 2009), however there is currently a disconnect between pedagogy (how instructors are teaching and how instructors are requiring students to work) and classroom design. Many public high school classrooms do not support collaborative work through their design. Our two studies suggest that the type of classroom students work in can influence their ability to work collaboratively with other students.

Our studies support past research regarding the importance of group work, as well as the importance of classroom design. Study II demonstrates that group work is not only influenced by the instructor and other students, but also physical design elements within the classroom. Collaborative work provides many cognitive, social, and emotional benefits to developing adolescents, and in order to maximize the benefits of this type of work, the physical environment should facilitate, rather than hinder, collaboration.

When analyzing this research through the perspective of the Bioecological Theory of Development, we can clearly see that there are dynamic relationships between an individual and his or her environment. While an instructor and classmates play a large role in a student's development, so too does the physical environment of one's classroom. This context of the physical environment should be considered, in order to maximize the positive aspects of development during adolescence. Further, from a life course perspective, it is clear that education is a trajectory that all children in the United States will experience to some extent. However, by taking a multi-disciplinary approach, we have the potential to alter this trajectory. High school can go with the flow of the trajectory, or we can utilize multiple aspects, including the physical environment, to create a turning point. This turning point has the potential to positively impact the student for the rest of his or her life.

6.2 Practical Implications

The findings of the two studies confirm the potential for classroom design to improve high school student collaborative work sessions. Thus, the findings from this study, partnered with future research, could suggest the following implications for practice:

1. High school administrative teams should not overlook the importance of physical classroom design. Strategically designed classrooms could potentially improve collaborative work sessions between students, as well as academic achievement, engagement, and social skills.
2. In order to ensure a beneficial physical environment for all users, students should be involved in the design of classrooms. Teachers should consider student input when laying out a classroom to create a space that facilitates and engages students while working.
3. Improving classroom design does not need to be expensive or difficult. Small changes to layout and furniture choices can make an impactful difference.

In conclusion, there is no one size fits all for classroom design. However, the incorporation of collaborative classrooms into high schools may improve how students are working with one another. As the need to work collaboratively continues to increase, it is a necessity that students gain the skills needed for doing so (Bellanca & Brandt, 2010). If the physical design elements within a classroom are carefully considered, classrooms can be used as another tool to improve student collaboration, and ultimately performance and achievement.

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APPENDICES

Appendix A: Structured photographic Q-sort questionnaire

Age: ___ years old **Gender:** Female [ ] Male [ ] Other [ ] Prefer not to disclose [ ]

You will be presented a photograph on the screen in the front of the room. Please examine the photograph. While looking at the photograph, please respond to the prompt below.

> What about this space would promote collaboration? Collaboration means to work with other students. Please check off yes, no, or does not apply for each physical characteristic listed below.

Do the **writing surfaces (i.e. white boards, chalkboards, etc.)** promote collaboration?

Yes [ ] No [ ] Does not apply [ ]

Does the **existence of space to work in small groups or clusters** promote collaboration?

Yes [ ] No [ ] Does not apply [ ]

Do the **chairs** promote collaboration?

Yes [ ] No [ ] Does not apply [ ]

Do the **desks or tables** promote collaboration?

Yes [ ] No [ ] Does not apply [ ]

Do the **displays (i.e. tackable surfaces, electronic boards, etc.)** promote collaboration?

Yes [ ] No [ ] Does not apply [ ]

Does the **ability to access each space (easy to enter and exit)** promote collaboration?

Yes [ ] No [ ] Does not apply [ ]

Does the **proximity of one desk to the next (closeness of desks)** promote collaboration?

Yes [ ] No [ ] Does not apply [ ]

Does the **ability to function as one large group in the space (no visual distractions)** promote collaboration?

Yes [ ] No [ ] Does not apply [ ]

Does the **reconfigurability (the ability to move furniture, easily shift the layout)** promote collaboration?

Yes [ ] No [ ] Does not apply [ ]

Does the **ability for privacy** promote collaboration?

Yes [ ] No [ ] Does not apply [ ]

Appendix B: Photos from Q-sort

Image via Kent Innovation High School

Image via Smith System

Image via Lavaellee Architects

Image via CLLC at OSU

Image via Harvard University

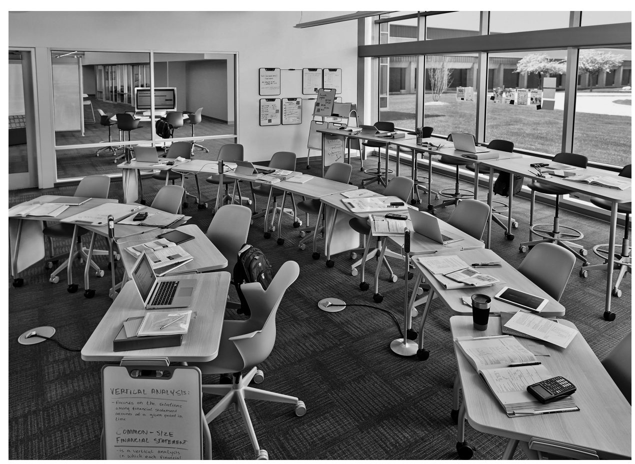

Image via Steelcase Education

Image via George Mason University

Image via Aquest Design

Image via Eat, Write, Teach

Image via Tilden-Coil

Image via Getty Image stock images

Image via George Mason University

Image via Steelcase

Image via Google classroom

Image via BFX Furniture

Image via Knoll, Inc.

Image via Aquest Designs

Image via Georgian College

Image via Wichita Public Schools

Image via Nordisk Group

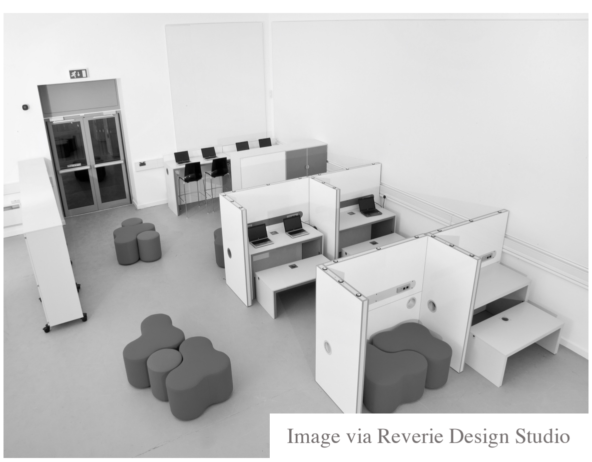

Image via Reverie Design Studio

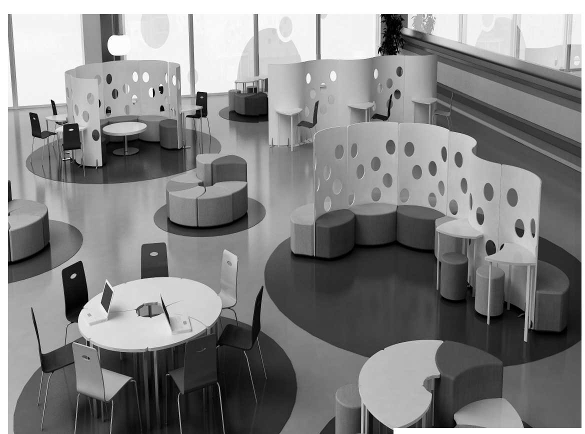

Image via Steelcase

Image via Harvey Construction

Image via Seattle Times

Image via Google Classrooms

Image via Huffington Post

Image via Avon High School

Image via University of Maryland

Image via California State University, Fullerton

Image via Steelcase

Appendix C: Post-task questionnaire

The purpose of this study is to understand your experience and perception of working with your classmates in this classroom environment. With respect to your feelings and experience, please indicate how you rate according to each question.

What is your gender? [ ] Male [ ] Female [ ] I prefer not to specify

What is your age? ___________

Please answer each question in Groups A, B, and C on a scale from strongly disagree to strongly agree.

Group A

1. Everyone I worked with was motivated to have the group succeed.
   [ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree
2. Members of my group actively shared their knowledge with one another.
   [ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree
3. Group members helped each other in the group by sharing information.
   [ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree
4. Working together energized and uplifted members of our group.
   [ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree
5. My group developed clear collaborative patterns to increase team learning efficiency.
   [ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree
6. My group members communicated with each other frequently.
   [ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree
7. My group members received feedback from one another.
   [ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree
8. My group members communicated in a courteous tone.
   [ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree
9. Our group accomplished tasks smoothly and efficiently.
   [ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree

10. Suggestions and contributions of group members were discussed and further developed.
[ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree

11. Group members encouraged diverse perspectives and differing points of view from others in the group.
[ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree

12. Group members demonstrated interest and enthusiasm during group activities.
[ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree

13. Group members were working together toward a unified goal.
[ ] Strongly Disagree [ ] Disagree [ ] Neutra l [ ] Agree [ ] Strongly Agree

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Group B

14. I very much enjoyed talking and working with the members of my group.
[ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree

15. I feel a real sense of personal satisfaction with our collaboration.
[ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree

16. My own creativity and initiative were suppressed by this group.
[ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree

17. Working collaboratively stretched my personal knowledge and skills.
[ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree

18. Communicating with group members regularly helped me to understand the group exercise better.
[ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree

19. I was satisfied with the ease of interaction with my group members.
[ ] Strongly Disagree [ ] Disagree [ ] Neutra l [ ] Agree [ ] Strongly Agree

20. I wouldn’t hesitate to participate on another task with the same group members.
[ ] Strongly Disagree [ ] Disagree [ ] Neutral [ ] Agree [ ] Strongly Agree

Group C

21. The classroom furniture adequately allowed group members to freely collaborate and share information.

[ ]	[ ]	[ ]	[ ]	[ ]
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

22. The classroom furniture supported collaboration and teamwork.

[ ]	[ ]	[ ]	[ ]	[ ]
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

23. The classroom furniture and layout supported exchanging of information and ideas frequently with my group mates through face-to-face communication.

[ ]	[ ]	[ ]	[ ]	[ ]
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

24. I was too far away from my group members to communicate face-to-face.

[ ]	[ ]	[ ]	[ ]	[ ]
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

25. There was too much informal, casual conversation around me such that I found it difficult to concentrate on my work.

[ ]	[ ]	[ ]	[ ]	[ ]
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

26. I experienced visual distractions in our work area.

[ ]	[ ]	[ ]	[ ]	[ ]
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

27. The classroom layout supported my individual work productivity.

[ ]	[ ]	[ ]	[ ]	[ ]
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

28. Overall, I felt supported by the space for the activities that we were doing today.

[ ]	[ ]	[ ]	[ ]	[ ]
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

29. Overall, my current work environment was useful to the collaboration of my group.

[ ]	[ ]	[ ]	[ ]	[ ]
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Appendix D: Debriefing notes

Q: What are the titles of these classes?
A: Earth Science

Q: What is the grade make-up of the students?
A: 9^{th} and 10^{th} grade

Q: Are they representative of the general population?
A: Yes

Q: How are classes selected?
A: Earth science is a required course.

Q: What was your experience in the four classes?
A: With both groups, the modular furniture facilitated collaboration – not totally certain because it was modular, or it was new; feedback was all positive – which was cool; the proof will come with long term test, does engagement increase, does performance increase? Do they like learning better? Attendance? I think yes; we did not see students falling asleep in collaborative room

Q: Do you think the new classroom facilitated collaboration?
A: From a teacher's perspective, engagement was really good, especially with stuff that was a little dry; difference isn't tremendous going from this classroom to that given our classroom; would love to see other classes bring their kids and try out for different things

Q: Can we receive the assessment of deliverables?
A: Yes, will email to touch base