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Effects of Teaching Collaborative Learning Strategies to Teachers on Student Transferable Skills and Adaptability Development in the High School STEM Classroom

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by

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TABLE OF CONTENTS

CHAPTER ONE

Introduction

Each individual person's view of the world is created and molded from the phenomena they experience and observe; as well as how they synthesize meaning from those events. Furthermore, how they approach situations later in life is heavily influenced by interactions they have at younger ages (Eddy et al., 2015). In essence, how a student interacts with their peers in school and how they learn from them, and themselves, has long-term implications of how they will see the world as adults in both the professional and educational world.

As a science teacher and someone who has spent much time in the world of science at the collegiate level and also the professional level, I have a deep understanding of the importance of larger sample sizes. With only one or two data points, it is extremely hard to notice any sort of periodicity or trend in a phenomena. Furthermore, a graph with only two points can result in a conclusion that is often up to chance, or riddled with bias. If you were to run an experiment with only two trials there would be no way of knowing if the two results are extremes, directly/inversely correlated with each other, or even if the points could have just been misinterpretations of the data. It is my belief that more data points always has a better chance of illustrating a better picture. Consequently, I am extremely interested in whether this hypothesis holds in the educational world with student perspective and their synthesis of the information into meaning, alongside their usage of that information to make decisions later in life.

One of my greatest passions has been to understand the gap between a student's final years in high school and their subsequent ventures into the world, either to

secondary education, trade school, or directly into the professional world. Alongside that I also want to know how a student's transition into these realms of society can be enhanced, or inhibited, by their interactions with peers in a collaborative learning environment. Essentially, I want to know what types of effects working with peers might have on a student's development of adaptability and transferable skills, especially in the context of their journey from high school to post-graduation. To that end, I seek an answer to the question: *What are the effects of teaching collaborative learning strategies to teachers in the high school STEM classroom on student adaptability and transferable skills development?*

Personal Rationale

In my high school chemistry class, I have students do an activity where they are given a stack of cards that have the name of an element, a circle, a number of "legs", and some other information about a specific element (atomic weight, phase of matter, compounds formed). Each card is different in that it is meant to represent a set of elements and have students identify trends based on how they order the cards. They could order them by the number of "legs", by the size of the circle, whether they are the same phases of matter, and a ton of other combinations. The end goal of the activity was to have students take in all of the information and construct a periodic table that would allow them to see trends in multiple directions (left to right, up and down), although the base goal was for them to organize them in some fashion, regardless of whether it looked like an actual periodic table.

The first time I used this activity, I had students complete it individually as I was a new teacher and thought that it would be a relatively easy task for students. However, I

soon found that students were extremely quick to give up when they could not immediately see the “answer” and became frustrated when I would also not just give them the “answer”. I put the word answer in quotation marks so as to note that there was not really one way of finding meaning from this activity but that it was meant to introduce the idea of trends and patterns while also connecting it to the content of the class. It was eye-opening to see how much the concept of learned helplessness severely inhibited a student’s ability to really immerse themselves in inquiry, especially given that inquiry is one of the tenets of STEM learning (Zan & Di Martino, 2009). In this context, learned helplessness applies to a student’s academic stamina, or their ability to tackle problems on their own before asking for help.

After reevaluating how the activity had worked in the first period, I instead opted to put students in groups of four for the subsequent period to see if this would curb the individual learned helplessness. What I observed first was that students who had given up quickly when the activity was done as an individual were almost always encouraged to keep going by their peers rather than concede defeat. It seemed like all the students were readily able to support each other long before they were considering supporting themselves in that same way.

The next thing that I learned was the power of student conversation. Not only were students more comfortable doing the activity as a whole when they had a chance to do it with their friends, but they were also better able to incorporate each other’s ideas into a larger schematic for their periodic table. Lastly, I saw students teaching each other chemistry concepts using analogies and references that were relatable to them such as comparing the organization of the periodic table to the way shoes might be organized in a

closet. Consequently, students reinforced their understanding of the concepts in the activity by learning from their peers. One of the last things that students needed to do for the activity was to predict an element that was conveniently missing from their periodic table, which stumped many of the students initially. One student I observed was getting visibly frustrated at the final step and as I was just about to step in to give them some guidance, another student in their group began to explain his process for finding the atomic weight of the element that they were missing. After a minute or two of explanation, the initially distressed student had this look on their face that will always stick with me as a real-life version of the lightbulb moment after which he quickly started to jot down his answer.

This activity exhibits a great example of some of the effects that group learning, or collaborative learning, can have on a student's growth as an individual as well as their ability to synthesize information from a plethora of different sources (what they see, what others see, what they already know). That being said, this activity was not successful with all students when adapted to become more collaborative. There were students in my class who were able to quickly identify trends when working individually. In fact, the students who completed the activity individually and were able to identify trends and make predictions on their own were more likely to recede into themselves when put into a group. Watching this happen better allowed me to assess whose strengths were centered around individual or collaborative learning. This gave me a chance to think about how I could find a way for those students to have success in both mediums of learning as opposed to resigning myself to looking at students as whether they preferred working alone or in a group. Furthermore, I began to think about those two types of work and how

they would most likely need to be adept at both to be successful when exploring the vastness of the professional and educational world outside of high school. The development of those so-called “soft skills” are pivotal in their ability to successfully integrate themselves into almost any work environment.

Professional Rationale

One of the research projects that I was involved in as an undergraduate revolved around students working with a student attending a different university in another country in order to do homework for a college chemistry class. Students would meet online weekly to work on the assignment with each student tasked with explaining half of the content to the other in their own words. What I found was that there were a variety of ways to teach the same content. Furthermore, students would then explain the different ways they were taught in distinct ways. In essence, each student was getting a personalized lesson of the material from their partner. That being said, not every student was successful in these interactions. Some students struggled explaining content to others even if they understood it which resulted in a vastly different experience in the class for each of those students. Observing this phenomenon in the college classroom led me to want to learn more about how students receive information and then further explain it to someone else as well as how those skills can be developed starting even in the high school classroom.

Although not explicitly named at the high school level, soft skills are the hidden goals of many good teachers as we move towards teaching a generation of students how to interact with each other in the context of a world that is constantly changing. Soft skills would be defined simply as a student’s “people skills”, or their understanding of how to

work with others while also regulating themselves. Furthermore, educators also spend a lot of time working on students' ability to take in information, construct meaning for themselves using that information, and then apply that information in some way that displays their understanding of the content. This second set of skills is what many would call hard skills, or a student's ability to apply technical information using specific content skills such as writing code and balancing equations (Huda et al., 2017).

The melding of these two sets of skills is what I believe is pivotal in preparing students for success in the world outside of school. Today's world is filled with situations that require an understanding of how to take in information as well as how to explain that information or use that information in everyday conversation without being overwhelmed. Climate science is a great example of the type of situation where a student would need to utilize both soft skills and hard skills in the same context. It is one thing to understand science or any other content area but it is an entirely different thing to be able to then explain that information to someone else. This is especially difficult when attempting to explain to someone who might not understand that information as well or someone who has a differing opinion. With only the content, it is easy to individually make meaning out of climate science, but having conversations about climate science with others can be daunting.

Summary

In chapter 1, I introduced the primary topic and research question of this capstone project: *What are the effects of teaching collaborative learning strategies to teachers in the high school STEM classroom on student adaptability and transferable skills development?* Once the question itself was introduced I discussed an experience I had as

a first year teacher, my personal rationale, that assisted me in coming up with my research question, that being an activity that had results changed due to a shift from individual learning to collaborative learning. Next, I went into my professional rationale which included a research project that I had been involved in when I was an undergraduate in university. The research project dealt with students from different universities and countries learning to work together in order to introduce chemistry concepts to each other. That research project showed me the importance of soft-skills and hard-skills in both a professional and academic setting.

In Chapter 2, I explore the development of soft skills and how they connect to a collaborative learning environment. I will find quantitative data to explore the effects that the implementation of collaborative learning can have on a student's experiences in life, both positive and negative. Furthermore, I delve further into the topic of how a student's background and their experiences can further influence their ability to synthesize information and then display their understanding to other students. Next, I will spend time discussing some of the barriers to implementing collaborative learning experiences in the classroom and why some of those barriers might exist in the first place. Alongside this, I will also briefly discuss learning strategies centered around independent learning and examine the effects those strategies have on the development of the student educationally and professionally. Lastly, Chapter 2 will discuss the idea of collaborative learning specifically in the STEM classroom and how the implementation of collaborative learning opportunities affect a student's success inside other content areas as well as their experiences at the secondary education level and in professional settings. All of this information will hopefully bring me closer to an understanding of the answer

to the question: *What are the effects of teaching collaborative learning strategies to teachers in the high school STEM classroom on student adaptability and transferable skills development?*

CHAPTER TWO

Literature Review

Before diving into the research question, *What are the effects of teaching collaborative learning strategies to teachers in the high school STEM classroom on student adaptability and transferable skills development?* It is important to discuss what the main driving forces behind collaborative learning implementation are, what forms collaboration in the classroom can take, and what factors need to be considered before implementation. Furthermore, once an understanding of collaborative learning is achieved it can then be discussed in the context of the STEM (Science, Technology, Engineering, Mathematics) classroom, of which the scope of this literature review was based around. Although multiple methods of collaborative learning implementation are discussed, the primary focus is on inquiry-based learning which offers an excellent scaffolding for cooperation and collaboration both socially and academically (Holbrook & Kolodner, 2020).

Utilizing STEM-based learning as a springboard for collaborative learning allows us to discuss the development of skills, or lack thereof, throughout the collaboration process. Although placed in the context of academics, the research question being addressed has to do with transferable skills and adaptability which play roles both in and out of the classroom with regards to a student's academic and professional development (Brundiers et al., 2010). For these reasons, it would have been remiss to not include a discussion of the professional and social effects of collaborative learning alongside the academic effects. For these reasons, I reviewed literature that discussed collaboration as a

concept in the professional environment, higher education, and in the context of social psychology.

Collaborative Learning

Collaborative learning is used as a catch-all term for teaching strategies and educational approaches that involve students working together to co-construct meaning, or students and teachers working side-by-side, oftentimes in a flipped classroom approach where students encounter the information before class as opposed to direct instruction (Goodsell et al., 1992). Collaborative learning is seen as one of many teaching strategies that teachers can implement in their classrooms in an effort to give students opportunities for different modalities of learning. This section briefly discusses what collaborative learning is at its core, what are some of the methods of implementation, assumptions about what collaborative learning can and can not do, and what collaborative learning is within the context of the high school science classroom.

The birth of collaborative learning as an operative modality of knowledge acquisition in the classroom stems from the modern idea that society as a whole is moving towards a generation that needs to function more as a team rather than focusing on individual ideas (Larson & Miller, 2011). For example, global climate change is a hotly debated topic in today's news, and its slow movement towards meaningful change can often be attributed to the fact that the world struggles to come to one singular conclusion on what course of action to take next. Although subjective, this example illustrates the point that if multiple different perspectives are not considered when discussing important topics, the journey toward actual change can be stagnant as a result. For this reason, an emphasis on teamwork in teaching can be seen as a solution to the

clashing ideas surrounding major issues facing today's society, especially when considering the urgency (Anderson, 2012).

Collaborative learning as a teaching strategy focuses on having students work in groups (pairs or more) working towards a singular goal of creating a product, solving a problem, or completing a task (Saroinsong, 2023). The environment created when students are working through these activities together creates an emphasis on their ability to challenge each other both socially and emotionally when they are confronted with the varying perspectives of their peers (Laal & Laal, 2012). Not only this, but they are also faced with the opportunity to defend their own ideas when conversing with other students. One of the most important concepts behind utilizing this type of learning for students is that they will be able to take in all of the perspectives from their classmates alongside their own understanding of whatever content is being learned to co-construct meaning for themselves (Brindley et al., 2009). Furthermore, their formulation of meaning from this activity runs counter to some of the historical methods of teaching which often has students construct meaning almost exclusively from an expert's opinion or a textbook's framework (Laal & Laal, 2012).

Collaborative learning offers an opportunity for educators to distance themselves from what could be considered an archaic approach to teaching, which is the teacher-centered or lecture-centered style of teaching (Blumberg, 2012). Instead, the implementation of collaborative learning tends to run parallel to many of the activities that are student-run such as discussions, inquiry-based experiments, and any active learning of the content. Rather than presenting themselves as content experts, teachers become the facilitators of learning experiences that assist students in their own creation

of meaning (Przybilla et al., 2021). This is done through both their individual learning acquisition as well as through intentionally group-focused activities where they are able to combine knowledge from themselves as well as group members.

Although collaboration can often be seen in opposition to other styles of learning such as a more lecture-centered approach, it is important to remember that it is only one teaching strategy among hundreds of others (Chang, 2010). Furthermore, collaborative learning is used as a vessel for learning in tandem with excellent teaching, rather than the sole reason for the learning itself (Kilgo et al., 2015). Knowing what collaborative learning is at its core, and some of the reasons as to why it is used, is pivotal in making a grounded connection to the effects that it can have on students.

Methods of Implementation

It is important to note that the implementation of collaborative learning does not mean that all strategies previously used in teaching are thrown out, but that they are now put through a lens that puts students at the forefront of the learning (Overby, 2011). Note-taking and lecturing may still have their place in the classroom when utilized *with* students rather than *for* them. For example, if a teacher wishes to deliver a lesson on the organization of the periodic table using a collaborative learning approach, the teacher will provide opportunities throughout the lecturing process that allows students to have group discussions about concepts in order to make connections to personal experiences and to experiences from classmates (Kaendler et al., 2015). There are multiple ways to implement collaborative learning into the classroom of which many take the form of strategies already commonly used, just with a lens that focuses more on students constructing their own learning (King, 2002).

Collaborative learning often does not have one specific goal in mind, but depends on the teacher's goals and can even focus more on what students wish to learn. This can look like lectures with group activities interspersed in between, as discussed above, or can be adaptable to what students discuss or have questions about. Bonk and Cunningham (2014) suggested that the implementation of collaborative learning in the classroom becomes a combination of important learning factors. Some of the factors of note that they define in their review are the context of the learning, individual differences in learning, social and developmental influences, student and teacher motivation to learn, and the end goals of the learning process. Consequently, the implementation of collaborative learning requires adaptability on the teacher's part which can be daunting to newer teachers or older teachers wishing to change their curriculum to revolve more around students (Huda et al., 2017). Although only two methods of implementation are stated below, there are many more outside of the scope of this review. Furthermore, in a framework and research review of teacher competencies in the implementation of collaborative learning presented in the *Journal of Educational Psychology* (Gillies & Boyle, 2010), it is not the method of implementation that leads to success but rather the intentionality behind the guidance given to students by the teacher and the quality of student interactions in those collaborative learning moments.

Problem-Centered Instruction

Problem-centered instruction is often thought to be distinctly different from collaborative learning as it focuses entirely on students solving a particular problem (Potvin et al., 2010). However, many modern teachers utilize problem-centered instruction as a sub-type of collaborative learning involving students working in groups

to solve problems that are directly related to real-world problems as well as problems related to student experiences (Merrill & Gilbert, 2008). The skills developed through problem-centered instruction include the understanding of relationships of information, problem-solving abilities, and their decision making when faced with uncertainty (Mataka, 2014).

Problem-centered instruction can be implemented in a variety of ways including, but not limited to, guided design, case studies, and simulations (Kobbe et al., 2007). Guided design has students working in groups to practice their decision-making skills through intentionally sequenced activities that build off of each other. As they complete each step feedback is given so that eventually the groups are able to complete the task without guidance. Implementing guided design could be as simple as having students design a playground, or as complex as medically diagnosing a fake patient. Case studies introduce real-life situations that are relatable to the students and involve their understanding of how to relate their own experiences with that of others to dissect the situation given (Kobbe et al., 2007). Global climate change would be an excellent example of a case study as it provides a real-life situation with problems for the students to analyze. Lastly, simulations are related to case studies in that they present relatable real-life situations, but involve students role-playing as characters that may not share the same values as them, eliciting an emotional investment. Debriefing is usually a pivotal part to simulations as it gives students the opportunity to discuss their experiences as well as the actions of their peers in the simulation (Lampert, 1990). An example of a simulation used in STEM classes would be the discussion of nuclear energy where

students might take on the roles of those for, and opposed to, nuclear energy and take on their values and ideals.

Peer Teaching

Another highly implemented version of collaborative learning is peer teaching, which simply involves the process of students teaching their peers (Walker et al., 2009). Although simplistic in concept, peer teaching requires intentional opportunities scaffolded into lesson planning. Hypothetically, students who participate in peer teaching have the opportunity to engage their peers by taking on the characteristics of a teacher which include some amount of authority as well as the attitudes of a teacher. By engaging in this activity the goal is that students are able to synthesize the meaning for themselves which better enhances their ability to explain the same concepts to their peers in ways that they will understand. The end result is that when students act as the peer-teacher they need to construct a method of explanation, enhancing their understanding of the material by thinking more critically about the content, while assisting in their peer's understanding of the material through examples that make sense to them (Falchikov & Goldfinch, 2000). An example of peer teaching at the undergraduate level could look like students from different universities teaching each other chemistry concepts to be used in class rather than getting the information from a standard lecture (McCollum et al., 2018).

However, this method of collaborative learning makes a few assumptions about students that can result in the implementation being unevenly effective. Research done by Graziano (2017) suggested that although the students who acted as the peer-teacher tended to develop an enhanced understanding of the content, they were unable to transfer their understanding of the content onto their peers in meaningful ways which resulted in a

lack of engagement and critical thinking. Although collaborative learning is considered a gateway to enhanced learning by many, there are many assumptions that are made when discussing successful implementation of collaborative learning, especially when considering the contexts such as problem-solving and peer teaching.

Assumptions About Collaborative Learning

It is imperative to understand that the implementation of collaborative learning is made with a few assumptions that are important to keep in mind when deciding what type of implementation to choose and how to facilitate that process within different content areas. These assumptions are made in the context of how students learn and how teachers can enhance that learning through meaningful activities that give students opportunities to utilize their wide breadth of background and cultural knowledge as well as how to take in their peers' perspectives (Arvaja et al., 2000). Consequently, the assumptions made are tied directly to students and how they learn rather than including learning context such as content area or method of implementation (Goodsell et al., 1992). This means that assumptions about student learning must first be made before discussing assumptions in the context of collaborative learning.

Active Learning. The first assumption about student learning is that learning is an active process, meaning that students need to engage with new content in a way that is meaningful to them and then use that content to assess what they already knew (Johnson et al., 1998). In the instance of collaborative learning, students are not just taking in new information to add to a compendium of content, they are utilizing that new information to synthesize new meaning through co-construction with their peers. An example of this would be inquiry-driven experiments in the STEM classroom which involves students

observing phenomena and then discussing with their peers (White & Frederiksen, 1998). Not only does this experience have students engaging actively with new ideas but it also has them using their own understanding of what they see in contrast to what another student might have observed. This conflict of ideas provides a scaffold for learning where students are challenged to think about their own ideas and how those fit with regards to someone else's perspectives (Taraban et al., 2007).

The Whole Learner. Another assumption about students that must be made before the implementation of collaborative learning is that all students have varying experiences, backgrounds, perspectives, and learning styles. Modern teachers are taught to spend ample time observing their students in an effort to understand what each student brings to the classroom. Whether that is a skill they have developed, an experience that they have had, or a specific style of learning that works best for them (Rutledge et al., 2015). Each understanding brings a teacher closer to finding the right fit for each student, resulting in instruction that is understanding of each student as a whole person, rather than just as a student that steps into the classroom. Furthermore, whilst working together students are able to see the same differences in perspectives and experiences as educators do which assists them in placing the content in the context of not only their own experiences but also that of their peers' (Edwards, 2006).

Social Learning. The last assumption to be made about learning is specific to collaborative learning in that it is, at its core, a social strategy. Meaning that the implementation of collaborative learning must take into account that it will involve students conversing about their different perspectives, coming together to solve specific problems, and an understanding that successful collaboration involves group wide

engagement (Sacerdote, 2011). The social aspect of collaborative learning is pivotal in its success and requires that the teacher adapt to the students as they progress through activities to ensure its efficacy in the future. Teachers facilitate a mutual exploration of a topic, assist them in synthesizing what they observe, and provide feedback to the students as well as smooth out the process in which students provide feedback to each other (Clegg et al., 2013).

Summary

The way in which collaborative learning works is dependent on the content area and will differ widely from discipline to discipline. English teachers may find success facilitating peer reviewing in which students provide feedback to each other after reading someone else's work and then receive feedback from a teacher after they have taken in their peers' perspective (Slavin, 2015). Alternatively, science teachers may have students sharing perspectives throughout the entire process of learning such as observing phenomena and talking with each other whilst doing an experiment (Margot & Kettler, 2019). The implementation of collaborative learning is highly dependent on the way in which the student experiences new content, how they learn best, how they interact with others, and the content being learned. For the purposes of this review, I will be focusing primarily on the effects collaborative learning and its implementation have on students in STEM classrooms in an effort to understand what effects it has on student adaptability to learn and their ability to develop transferable skills to be used inside and outside of the classroom.

Collaboration and STEM Teaching

Science is sometimes depicted in the media as a mad scientist alone in a laboratory late at night brewing up some new solution to a problem that will revolutionize the world, while other times it might be depicted as a group of scientists swirling around colorful liquids in random glassware until they accidentally stumble upon a new discovery (Weingart et al., 2003). In either case, the practice of science is often represented as an individual practice, whether that is one person or one group, rather than as a globally connected discipline. With science at the forefront of many news outlets and as a consequence, up for much debate, it is imperative to understand the global nature of science and how it connects to the concept of collaboration almost inherently (Custer & Tuominen, 2017). For this reason, and many others, the teaching of science has changed dramatically throughout the past few decades to focus more on collaboration with an emphasis on inquiry-based learning (Dalton et al., 1997).

Before delving into the modern concept of inquiry-based learning, it is important to understand the historical method of teaching science as a means to discern why a shift away from the old ways was necessary (Schwab, 1960). Lastly, this section discusses the melding of old and new methods of teaching science as well as some of the barriers that educators might encounter when implementing collaborative learning. Many of these barriers stem from a resistance to the educational change emphasized in newer teaching programs while other reasons may erupt from a lack of confidence in success (Lebak, 2015). In any case, those barriers present challenges to educators that may end up depriving students of meaningful learning experiences in the long term.

Historical Science Teaching

Most individuals who participated in a high school science class in the past have experienced an experiment that was summed up in a packet or worksheet that detailed a distinct set of steps, measurements, and answers, all of which were already predetermined as "important". Whether this was confirming some theory, demonstrating the consistency of a law, or illustrating a point, the experiments that are run this way tend to have the students on autopilot when it comes to their learning (Kennedy & Odell, 2014). Schwab (1960) is often thought to be one of the first individuals to emphasize that the teaching of science as a method of defining known "truths" was counterproductive to the way in which science was advancing. He purported that science had become stagnant and was displaying a false image of what it truly was, that of knowledge being permanent or complete. Though many decades have passed since his statements, Schwab left an impression on the education community that lasted intergenerationally (Ben-Peretz & Craig, 2018).

Since its inception, the ideas behind inquiry-based learning have revolutionized the teaching of science. Inquiry-based learning in STEM is based around the idea of having students engage in a process that mirrors that of professional scientists. The experiences themselves typically involve the students discovering relationships between phenomena after which they formulate a hypothesis and conduct experiments to test their hypothesis (Pedaste et al., 2015). Further research over the next few decades confirmed another idea that is connected to inquiry-based learning that showed that students do not come into science classrooms without any preconceived notions about the phenomena they will observe. Instead, Gilbert and Pope (1986) asserted that they come into the

classroom with ingrained conceptions about the world that do not align with the ways of the world. For example, a student might believe that the air around them has no mass because they cannot feel it, when our current understanding is that there are atoms floating around that have volume and mass (Saçkes et al., 2011).

With new understandings of how students might view the world around them when they enter the classroom, many science educators shifted to a teaching method that would be less focused on frontloading information with strict guidance involved, which was the traditional approach, to something that was more student-driven (Krebs, 2015). Alternatively, some science educators moved to blend their curriculums so that they would include aspects of traditional science teaching as well as modern inquiry-based learning approaches that usually arise when it comes to group work (Amesbury, 2006). It is important to note that although the history of science teaching does not explicitly connect to the idea of collaboration, the shift away from the traditional understanding of science teaching made way for teaching that had an emphasis on group work as a means to enhance student learning. Specifically, working in a group to discover something resulted in heightened student engagement and proposed better acquisition of content knowledge (Taraban et al., 2007).

Inquiry-Based Science Teaching

Inquiry-based learning is not a new concept in the realm of STEM teaching, although it is still not widely utilized. Reasons for this might stem from a variety of barriers, but the importance of shifting from the traditional method of STEM teaching to a more modern approach cannot be stressed enough. Rocard (2007) stated that science educators faced “an alarming decline in young people’s interest for key science studies

and mathematics" (p.3). Although dramatic, it illustrates a point that the study of science has not captured the interest of students in high school which then leads to a lack of interest in choosing science as a career, or even becoming a science teacher, continuing the cycle of disinterest (Kennedy & Odell, 2014).

To combat this, inquiry-based learning presents an opportunity for students to work collaboratively to make meaningful connections to the phenomena they observe. The basis behind inquiry-based learning stems from the idea that better solutions to problems come from comparing and contrasting ideas between individuals, rather than only being exposed to one singular "right" answer (Holbrook & Kolodner, 2020). The basis of inquiry-based learning highlights two "pillars" that are ingrained into its design. The first of these concepts is the heavy emphasis on individual engagement with material that challenges students to think differently about what they already know (Lu et al., 2021). Furthermore, students should not know the answer, or means of discovery, before they begin the process of inquiry, whether that is in an experiment or the development of mathematical concepts. The second "pillar" of inquiry-based learning is collaboration in any number of forms. Some examples of this include group work, class discussions, and peer reviews (Lu et al., 2021).

Inquiry-based learning, at its very core, is connected to collaboration, which then begs the question of whether collaboration can then be connected to science as a whole in and out of the classroom (Skagen et al., n.d.). Further information on the connection between collaboration and science as a concept is discussed later in Chapter 2 when discussing whether collaboration assists in the development of skills needed to traverse the world both inside and outside the classroom. For now, it is important to note that

collaboration and inquiry-based learning are deeply connected, especially in the context of STEM teaching, where the co-construction of concepts can prove extremely useful (Palincsar, 1998). Although the benefits of inquiry-based learning are not always apparent, especially when considering the idea that all students learn differently, it is still a teaching strategy that tends to benefit students more often than not (Lee & Bozeman, 2005). That being said, the implementation of inquiry-based learning often needs to be carefully considered when determining whether it is a good fit for a specific set of learners. Furthermore, students need to be exposed to a multitude of teaching strategies to develop the skills necessary to adapt to a wide variety of learning situations (Susilawati et al., 2020). The intentionality behind the implementation of inquiry-based learning can be daunting to new educators and seasoned educators alike, especially considering the ever-changing landscape of students and technology (Bhamani et al., 2020).

Perceived Barriers to Collaboration in STEM Teaching

The implementation of new teaching strategies is a daunting task, especially if the teaching strategy is foreign to the methods of teaching and learning that have become commonplace in education. When considering the implementation of collaborative inquiry-based learning, it is important to discuss some of the potential barriers that teachers discover along the way. With these barriers in place, it is difficult to assess the effectiveness of collaborative learning strategies, especially if the data is skewed by something outside of the scope of the learning itself (Morsch et al., 2018).

One of the primary barriers to the implementation of collaborative inquiry-based learning is the lack of working models which prevents educators from seeing the proposed effects of the teaching strategy. Rather, educators who do not have access to

these models consider the inquiry-based approach as an unrealistic method of teaching students the concepts and processes of science (Fitzgerald et al., 2019). Consequently, these educators tend to resort back to lecture-based teaching which emphasizes the transmission of information. That being said, this reasoning diverts much attention to the acquisition of content specific to the class it is being implemented in rather than the development of skills such as collaboration, critical thinking, and combining perspectives, all of which are interdisciplinary skills (Kilgo et al., 2015).

Another perceived barrier to the implementation of collaborative inquiry-based learning is the pedagogical shift that educators must make in order for the strategy to be functional (Kennedy & Odell, 2014). Generally, the problem tends to lie in the teacher's willingness to step away from a teacher-led instruction and focus more on student-led learning experiences of which some educators might not be entirely comfortable with. Furthermore, a study done by Margot & Kettler (2019) showed that some educators felt that they would implement the curriculum "wrong", which would then result in the content itself being taught in a way that was ineffective. Although this fear of failure is valid in every way, there are some educators who believe that the nature of failing, even in the students' case, is inherently good for learning (Ernst et al., 2017).

One last barrier to the implementation of collaborative inquiry-based learning is the somewhat messy realm of assessments of knowledge (Nadelson & Seifert, 2013). Margot and Kettler (2019) further discussed the idea that some of the educators that they interviewed believed that there was a lack of assessments in the curriculum in both the standardized and formative forms. Furthermore, those same educators tended to struggle with the concept of grading the actual collaborative portion of the learning as they were

unsure how to assess a group's mastery of the content standards. Smith (1998) noted that there are five distinct elements to the success of collaborative work and that the educator serves as the primary facilitator of those elements alongside the students. Those elements are specifications of the objectives, intentional instructional decisions, task explanation with an emphasis on task interdependence, monitoring collaboration with minimal intervention, and group evaluation (Smith, 1998). Through the implementation of these elements in the planning process, the assessment of collaborative work returns back to the assessment of individual work rather than assessment of how a group functioned (Hibbard et al., 2016).

Summary

Modern STEM education is intertwined with the concepts behind collaborative learning with an emphasis on the development of skills that will benefit the student in the long-term even if they do not intend on specializing in science, or even attend any sort of post-high school education options (McGunagle & Zizka, 2020). Historically, STEM teaching has shown that it benefits only the types of teachers that are trying to impart upon students an understanding of the world as "complete" rather than something to continually be observed (Lemke, 1998). Shifting towards a method of science teaching that revolves around students creating meaning out of phenomena they observe alongside their peers, otherwise known as inquiry-based learning, has shown that the lasting effects benefit their ability to take in new information and perspectives and change their own on the fly (Xu & Jaggars, 2013). Although barriers present themselves when attempting to implement these types of learning strategies in the classroom, there is merit to trying new things within the classroom if only to expose students to new learning experiences,

especially considering that the trial and error nature of teaching aligns itself well to the same skills being taught in the lessons; that of the ability to learn from failure (Flynn, 2015).

Having considered collaboration in the context of science as well as why and how it might be implemented, it is time to go one step further and discuss the effects that this learning has on a student's whole self, socially, academically, and professionally. Addressing each of these realms of a student's experiences in the short-term and long-term will give even more insight how they relate to adaptability and the development of transferable skills getting us one step closer to answering the research question: *What are the effects of teaching collaborative learning strategies to teachers in the high school STEM classroom on student adaptability and transferable skills development?*

Effects of Collaborative Learning

The effects that collaborative learning has on students can be divided into three different categories: social, professional, and educational (Cheema & Kitsantas, 2014). It is important to note that the effects of collaborative learning on the student must be considered with regard to a student's ability to perform outside of purely academic tasks. To that end, the literature reviewed for this subsection discusses the effects of collaborative learning on students without focusing primarily on academics, as those can often provide a skewed vantage point of the proposed successfulness, or lack thereof, of collaborative learning (Lampert, 1990).

First, the educational effects of collaborative learning are discussed in the traditional sense of whether students are able to complete tasks more, or less, efficiently

when in collaboration with their peers. Some consideration will also be placed on academic performance in situations where collaboration is not the best fit for student learning (Nokes-Malach et al., 2015). Second, this section discusses the social effects of collaborative learning in the context of the development of communication skills as well as how working with others can affect how a student interacts with others in the future. Further, it is important to discuss how the cultural and social backgrounds of students affect how they interact with collaborative learning experiences (Eddy et al., 2015). Last, the professional effects of collaborative learning are discussed primarily in the context of the development of group skills that affect how a student interacts with the world outside of school. For example, whether collaborative learning skills affect whether an individual will be successful at a specific job (John, 2009).

Educational Effects of Collaborative Learning

The educational effects of collaborative learning are seen within two different realms of thought. The first being what a student develops as a result of collaborative learning and the second being the outcome of collaborative learning in terms of quality (Kilgo et al., 2015). Laal and Ghodsi (2011) noted that there are often three types of interactions (learning styles) that students pursue when working to complete assignments. These are: working cooperatively to achieve learning targets, working competitively to achieve learning targets, and working individually to achieve learning targets (Laal & Ghodsi, 2011). Although all three are present in every classroom, and the fact that learning styles are dependent on the student, this review - primarily discusses the cooperative approach that students take (Morel, 2014).

Some of the primary educational effects that are seen as a result of collaborative learning are promotion of critical thinking skills, active engagement in learning, and application of multiple perspectives when trying to solve future problems (Bonk & Cunningham, 2020). A study done by Warsah et al. (2021) showed that students who participated in cooperative learning in the form of group discussions had significantly improved critical thinking skills with regard to social issues. However, a review done by Sweller (2021) noted that although cooperative learning is oftentimes implemented in many curriculum planning documents, the development of skills such as critical thinking do not positively affect the student's ability to perform better on international standardized tests.

The concept of collaborative learning must be emphasized in the sense that proper guidance is necessary for its success. Putting students into a group and expecting better learning is not going to result in anything positive, and may in fact result in more negative results than anything (Igel & Urquhart, 2012). However, utilizing collaborative learning effectively can result in keeping students accountable for each other and therefore more engaged in their own learning. Furthermore, engaging students more effectively enhances their comfortability and likelihood to contribute to discussions (Igel & Urquhart, 2012). This re-engagement of learners allows students to be exposed to multiple new perspectives which they can then utilize in future problem-solving situations (Palincsar, 1998). However, not every lesson or concept is applicable to collaborative learning, especially in situations where teaching confidence plays a factor in success. In those moments, collaborative learning has been shown to be a non-factor in

student learning, and detrimental at its worst, in a student's acquisition of learning concepts (Capdeferro & Romero, 2012).

Social Effects of Collaborative Learning

Although an emphasis on achievement with regard to standardized testing is often thought of as the main goal behind education, modern teaching in some areas has shifted away from primarily teaching test-taking skills (Williams, 2005). Educators in teaching programs in the last decade have learned to see the entirety of a student as a person rather than as a test score. This means that the development of social skills has become one of the primary goals in teaching alongside the standards inherent to the class being taught (Lampert, 1990).

Collaborative learning at its very core revolves around working with others of which the ability to interact in those situations often predicts success (Eddy et al., 2015). However, a study on the social effects of collaborative learning in primary schools showed that although the positive social effects of collaborative learning were inescapable (the development of communication skills), a precursory period where students are instructed on the ideas behind successful collaborative learning is needed (Tolmie et al., 2010). That being said, the type of collaborative learning also has an impact on skills developed during the process. For example, peer tutoring has seen much success in reducing anti-social behavior in adolescents (Eskay et al., 2012). Overall, the development of social skills seems inherent to collaborative learning and in most cases results in positive experiences, albeit sometimes not resulting in positive results academically. This suggests that there may be some merit in thinking more about what the weighted goals of a lesson are when planning curriculum and whether it might be

necessary to sacrifice content time to focus more on social development (Eccles & Roeser, 2011).

Professional Effects of Collaborative Learning

Of particular interest to this literature review is the relationship between the experience of collaborative learning and the long-term effects that collaborative learning has on a student's experiences outside of high school, particularly in the context of their future professional life. Therefore, it is important to discuss the professional effects that a student might experience as a result of collaborative learning and how those relate to the development of certain skills that may or may not be desirable in the workforce (Wahl et al., 2012).

Collaborative learning experiences provide opportunities for students to work in environments where their perceived roles mimic those of a professional environment (Falkner et al., 2013). In many collaborative teaching strategies, there is an emphasis on assigning roles for learning in an effort to reduce some of the social anxiety of working with individuals that students might not be familiar with (Cheng et al., 2016). A study on collaborative learning by Falkner et al. (2013) showed that students explained their experience in collaborative learning in terms of working towards larger and larger goals and how working in a group reduces the load on each person. Furthermore, that same study showed students identifying group work as an opportunity to teach others who might have less developed skills allowing for one student to gain new skills while the other refines their understanding through teaching (Falkner et al., 2013). However, it is noted in some literature that instances where there is an unequal disjointed understanding of the content being worked on can produce negative collaborative learning experiences

as a result of metacognitive overload (White, 1998). In other words, when there is too much flexibility in the task assigned, students will become overwhelmed with the choices which will detract from the task and result in lower acquisition of the learning objectives (Bonk & Cunningham, 2020).

Summary

The literature shows that there are a plethora of effects stemming from collaborative learning experiences that affect both the experience as the students are working and their development of skills in the long-term. However, the literature also places a heavy emphasis on the ability of a teacher to preface a collaborative learning experience with information on the learning objectives, tasks being assigned, and on what it means to have successful collaborative learning (Hibbard et al., 2016). With education oftentimes placing an emphasis on academic ability, it is important to view students as a human and their experiences in the classroom as opportunities to develop skills that can be useful and transferable to a variety of other situations (Williams, 2005).

The literature also shows that the educational effects of collaborative learning can result in enhanced critical thinking skills and an ability to integrate multiple perspectives into ideas but that the educational benefits might not align with state-standards when considering test results (Taraban et al., 2007). Alternatively, there has also been an increase in inclusion of social skills as a primary factor when planning collaborative curriculum as the nature of collaborative learning is inherently social (Bhamani et al., 2020). Although the educational and social effects of collaborative learning primarily focus on experiences within the classroom which can be thought of as short-term, it is important also to consider the professional effects. Studies discussed showed that

students viewed collaborative learning as an opportunity to mimic the ways in which professional interactions are facilitated (Leak et al., 2018). Each type of effect has its place in terms of the development of skills that are pivotal for a student's growth as an individual. Now that we have discussed the effects, it is now important to circle back to the research question in order to place those effects into two realms of skills, adaptability, and transferability, and how those are particularly emphasized in the STEM classroom and in the STEM field outside of high school.

Development of Adaptability and Transferable Skills

Life in the 21st century is considered a borderless world with the advancement of technology and the development of more ways for information to be dispersed out to larger populations (Turiman et al., 2012). Within this, it has become necessary for students to have not only skills to succeed in this new global environment but also how to utilize the skills developed in high school while navigating professional environments. These skills typically fall into two different categories: soft skills, and hard skills, which work hand-in-hand when considering the success of someone in today's world (Pieterse & van Eekelen, 2016). Furthermore, there is one other category that tends to stem from the other two, that being innovativeness (Rocard et al., 2007). These skills are especially important to consider when discussing science as a context as the world faces larger issues both scientifically and politically of which the clashing of the two results in a multitude of perspectives to take in when processing information (Saroinsong, 2023).

The process of collaborative learning in high school offers students the opportunity to develop skills that will enhance their ability to succeed in science as a global profession. Their ability to adapt to new information as well as how they interact

with others in collaborative environments is directly related to the experiences they have prior to entering the professional world (Slavit et al., 2016). Utilizing the perceived benefits of collaborative learning such as critical thinking skills, integration of multiple perspectives, and self-management are examples of skills needed in a global professional environment (Turiman et al., 2012). Before considering how those skills transform from the inside of the classroom into skills necessary for professional success, it is important to discuss the two categories that literature tends to place these skills into and the necessity for both.

Soft Skills and Hard Skills

Of the two skills necessary to achieve in the professional world, especially in STEM, hard skills are the ones specific to any particular job. Hard skills can simply be defined as the technical skills needed to do some task in a specific job (Rainsbury et al., 2002). This skill set tends to focus more on the acquisition of knowledge and procedures rather than anything else. Consequently, hard skills are learned through specific schooling but do incorporate some aspect of creativity when it comes to utilizing intellectual agility or thinking on your feet (Hendarman & Cantner, 2018). Furthermore, hard skills are rooted in the concept of competency and come more from the length of schooling in a specific area instead of the type of schooling. As a result, collaborative learning does not play a large part in the development of hard skills, although they can still be considered if the job itself is inherently collaborative in nature (Hall et al., 2018). For example, some would argue that science as a professional realm has become globally collaborative in the sense that as science progresses it becomes increasingly important to work with

researchers around the world to solve problems approaching the world faster than an individual research group might be able to (Skagen et al., n.d.).

While hard skills focus primarily on content knowledge, soft skills relate more to interpersonal skills and how they are utilized in terms of personal behavior and managing relationships with others (Rainsbury et al., 2002). Marando (2012) suggested that soft skills also revolve around leadership, communication, and problem-solving. They also suggest that soft skills tend to be something that is not as easily measurable as hard skills since they tend to rely more on the process of working towards a goal rather than what is produced at the end (Marando, 2012). Soft skills have been emphasized highly in the last few decades in STEM as a profession that historically considered soft skills to be unimportant (Kranz, 2019). In a study by Kranz, they noted that the majority of STEM participants attributed the development of their soft skills to experiences in their youth. They also noted that there was a lack of emphasis on teaching soft skills in STEM programs, hence the aforementioned movement towards emphasizing soft skills in science. Specifically, the ability to be persistent, critically think, organize efficiently, think creatively, and work collaboratively were noted as attributes beneficial to STEM work (Karimi & Pina, 2021)

Karimi and Pina (2021) noted that although a large portion of students identified that they felt comfortable with the amount of soft skills they had developed, employers only had confidence that less than half of those students actually possessed the soft skills necessary for success. Research done by Levasseur (2013) showed that although there is much theory behind the process of developing soft skills, in reality the best way to develop the skills themselves is through the continuous practice of the skills themselves.

This directly functions as a connection between collaborative learning and soft skills as the values at the core of collaborative learning align themselves almost perfectly with the properties of soft skill development (Susilawati et al., 2020).

Adaptability and Transferable Skills

Adaptability refers to the ability to adjust to new situations relatively seamlessly, learn from experiences, and apply any knowledge learned to situations both now and in the future (Hendarman & Cantner, 2018). Furthermore, the development of adaptability as a skill is important when considering the changing world around us and the need for skills specific to the 21st century. High school is considered an especially pertinent time for the development of adaptability because at that point students are still exploring professions and attempting to establish some sort of identity for their interests (Porfeli & Skorikov, 2010). Mahon (2016) described a version of adaptability that is essential to STEM which is the idea of career adaptability. Mahon (2016) defined career adaptability as a set of four main traits: preparing for the future, making decisions, inquisitiveness, and self-confidence.

Adaptability is a pivotal skill to have in the professional world outside of high school and has ties directly to the idea of collaboration. The concepts behind adaptability directly relate to the concepts behind collaboration in the sense that to be successful in collaboration you must develop skills in adaptability (Walker et al., 2009). Developing adaptability can be seen in examples such as when students are given real-world applications of scientific concepts such as those in inquiry-driven learning. Students then work together to adjust what they already know to assist in their learning of new material and then further to utilize that new information to help them understand even more

complicated scenarios (George-Williams et al., 2018). The main concepts of inquiry-based learning, and therefore collaborative learning, are deeply rooted in students working in teams, communicating effectively, and thinking critically about how they approach new material in order to make meaning out of what they are observing (Kaberman & Dori, 2009).

Transferable skills are often described as interdisciplinary skills in the sense that it is a skill that can be applied across academic areas (Oliveira & Guimarães, 2010). The transferable skills most commonly associated with STEM are: curiosity, oral communication, written communication, adaptability, and collaboration (Bertrand & Namukasa, 2020). Of note is that adaptability and collaboration are considered transferable skills, meaning they are important to develop even outside of STEM, English, or arts. Within adaptability, emphasis is put on the idea of perseverance as the transferable aspect, meaning that failure and taking risks are necessary parts of growth (Bertrand & Namukasa, 2020).

An example of the development of transferable skills would be the use of project-based learning, which oftentimes involves students working together on a long-term project that requires them to learn new strategies of learning, take in new information, and work collaboratively in order to complete a product (Bell, 2010). Furthermore, inquiry-based learning is also another form of the development of transferable skills. Although oftentimes utilized in the context of science, the act of observing phenomena, making connections between past learned concepts and experiences, and coming up with ideas or predictions is something that can be applied to many other situations (Abdi, 2014). For example, a study performed by Shih et al. (2010)

showed students utilizing inquiry-based learning to assist in their understanding of religious cultural systems while exploring a location called Peace Temple. They then worked together to understand what they were seeing, discussed as a class what they had observed and produced a group presentation (Shih et al., 2010).

Summary

Adaptability as a concept is directly related to collaboration in the sense that in order to be successful in collaboration you must achieve some degree of competency in adaptability (Leak et al., 2018). Furthermore, with adaptability being ingrained into collaboration, it makes sense that the ability to be successful in collaboration, and therefore competent in adaptability, is considered a transferable skill. Underneath those concepts are the two categories of skills being hard skills and soft skills of which both are necessary to the development of a well-rounded individual (Robles, 2012). The act of participating in inquiry-based learning, project-based learning, or a plethora of other strategies that focus primarily on collaborative learning, act as ways for students to develop transferable skills that will benefit them both academically and professionally, especially considering the global need for individuals with more diverse skill sets (Custer & Tuominen, 2017). Understanding hard skills and soft skills and how they can be easily developed at younger ages, as well as how those skills transfer out of the STEM classroom and into other disciplines and areas of a student's life, is pivotal in trying to understand how to answer the research question: *What are the effects of teaching collaborative learning strategies to teachers in the high school STEM classroom on student adaptability and transferable skills development?*

Conclusion

This literature review provided the background behind collaborative learning, types of implementations, STEM context, effects of implementation, and the skills developed and needed for a global society in order to answer the research question: *What are the effects of teaching collaborative learning strategies to teachers in the high school STEM classroom on student adaptability and transferable skills development?*

First, collaborative learning was discussed in order to understand why it is utilized in the first place. Next, the relationship between collaborative learning and the shift away from traditional science teaching was explored in order to understand the emphasis on the STEM high school classroom in the research question. After discussing collaboration in the STEM classroom it was then important to discuss the effects that collaboration can have on a student's development without focusing entirely on academics. Finally, the main concepts of adaptability and transferable skills were discussed and how they are directly tied to the development of skills gained from collaborative learning, being soft skills and hard skills, and why they are important in a world outside of the high school classroom. Furthermore, opposition to collaborative learning was also presented in order to understand the situational nature of collaboration and how it often must be prefaced with learning about what successful collaboration is in order to be beneficial to students. All of this information was pivotal in deciding what content to include in the capstone project as well as making sure that there are multiple perspectives within the capstone project to maintain a sense of objectivity while still containing personality.

The following chapter will give an overview of the capstone project, the setting and audience that the project is focused on, and the product itself which will be a Dummies Guide to Collaborative Learning. The goal of the guide itself is to give teachers who may be stuck on the barriers of collaborative learning a way to see the situational nature of collaborative learning and when it is most effective, especially for people who think that they need to change their entire curriculum to integrate collaborative learning. The timeline for the project itself and how it will be assessed will also be detailed in the next chapter.

CHAPTER THREE

Project Description

Combining the information discussed in the literature review, this chapter will explore the process of creating, and subsequent planned implementation of a Dummies Guide to Collaborative Learning in STEM in order to answer: *What are the effects of teaching collaborative learning strategies to teachers in the high school STEM classroom on student adaptability and transferable skills development?* This chapter will include an in-depth look at the project itself, project design reasoning, setting, audience, timeline, and a proposal as to how the project will be assessed for effectiveness.

Project Overview

The end result of this capstone project was a Dummies Guide to Collaborative Learning in STEM much like the pop culture Dummies Guides for topics like computer technology or social media that you might find on the shelves of a local bookstore. The guide itself is meant to portray information in a relatively informal writing style so that the information and strategies presented sound conversational and easily approachable to newer teachers and experienced teachers alike. The guide discusses the various topics revolving around collaborative learning in STEM as well as how and when it can be implemented. The guide includes six sections; each section of the guide are briefly described as follows:

- What are the primary attributes of collaborative learning and how is it defined?
- How collaborative learning can be implemented in the high school STEM classroom

- How to decide when it is beneficial to implement collaborative learning versus when it is appropriate to use other strategies
- Preparing for collaborative learning in the classroom: why it is necessary and how it works for both students and teachers
- Examples of collaborative learning opportunities in the classroom
- How collaborative learning can be intertwined into curriculum without taking it over

The ordering of the sections is meant to provide a background to the material that guides the reader through the process of determining whether collaborative learning might be right in their own classroom. Once the reader has gained an understanding of the purpose behind implementing collaborative learning in their classroom, it is important to then assess the advantages and disadvantages to its usage as well as opportunities to utilize the strategies in other contexts. Lastly, the reader will be led through the basics of implementation and how to make a relatively smooth transition into collaborative learning with tips on how to facilitate from both a teacher and student perspective. The last section of the guide will detail some easy-to-implement strategies for beginning teachers as well as some examples of how it has been used in the classroom.

Description

The formatting for this project, a Dummies Guide, was chosen as a means to provide educators who may be anxious about the implementation of collaboration in the classroom due to a variety of barriers, as discussed in Chapter 2. A study done by Gillies and Boyle (2010) showed that teachers had almost entirely positive outcomes when implementing collaborative learning, although the difficulties that they found underlying

the positive effects usually lay in their ability to find resources and how to start the implementation (students typically got more comfortable as implementation continued). Furthermore, they also said that their classroom "climate" was much happier, and the socialization generally produced slightly higher quality work. The idea that teachers had positive feedback when implementing collaborative learning, but struggled actually finding ways to implement it was part of the reason why I wanted to provide a beginners guide so that teachers have somewhere to start.

Another study done by Blatchford et al. (2003) showed that although it was easy to conceptualize implementation of collaborative learning, the students and the teachers needed proper preparation. Students needed to be taught how to interact appropriately in groups and how to take instructional roles, and teachers needed to be taught how to work successfully with groups alongside having lessons and tasks that were well organized. Those tasks on their own can seem overwhelming to teachers which is why the formatting for this capstone project was chosen. The goal of the Dummies Guide is to provide preparatory activities for teachers that allow the students to ease into the mindset of collaborative learning while also giving teachers smaller tasks that function the same way. Furthermore, the nature of the writing is meant to give teachers the impression that they are having a conversation with someone sharing their own experiences rather than just being told the information (Hemsley, 1997). This style of writing mirrors the same reasoning behind moving away from lecture-style teaching in the sense that it is more engaging and more likely to result in buy-in from the audience, being teachers and, consequently, students (George-Williams et al., 2018).

Although these resources do not explicitly state the need for a guide, the research has shown that the barriers to implementation usually stem from comfortability in implementation, lack of knowledge in how to prepare students and teachers, and how to just get started and take the leap into trying new strategies (Fitzgerald et al., 2019). Therefore, I think an informal guide that shows teachers that implementation of collaborative learning is not as daunting as it seems, and that it does not need to necessarily mean an entire overhaul of curriculum, is a good way of answering the research question while also providing useful tips and tricks to teachers, much like who I was when I initially started teaching. Furthermore, the information presented in the guide will also be placed not only in the context of the classroom in the present, but also the skills developed in students as they look towards their future endeavors.

Setting and Audience

Science education is important in all realms of teaching and learning and can be found at almost every high school. Whether it is a charter school that focuses more on alternative learning environments such as expeditionary learning and project-based learning, or the standard high school classroom, the guide itself will be framed in a context that is applicable to any situation with STEM as a content. Furthermore, the classroom size used for examples will be modeled using the classroom size associated with districts that I have experience with which is generally around 25-30 students. A further emphasis will be put on the importance of collaborative learning and its effects when utilized in teaching environments that focus more on transferable skills and life skills rather than referencing state standards (which would be highly dependent on the class subject). Lastly, the guide is oriented towards STEM educators in the high school

setting, both new to the profession and those who have served in the teaching community for many years. It can not be overstated that the teaching profession is an ever changing world and that educators should strive to adapt their strategies as the student base changes alongside the world around us (Thoonen et al., 2011).

Timeline

In creating this capstone project and the Dummies Guide associated with it, first a collection of examples of strategies and activities revolving around collaborative learning were compiled in order to get a well-rounded view of the ways in which collaborative learning can be implemented. Furthermore, a smaller section of strategies that involve incorporating collaborative learning methods into already existing curriculum was also created. The resources were organized in order of implementation type with activities that focused on implementation and student/teacher preparation being discussed first, and those that were more elaborate or complicated discussed afterwards. Once all strategies and activities were compiled, a rough structure of the guide was organized in order to provide an equal number of examples in each section. Next, graphics were created to go alongside some of the examples to illustrate some of the situations discussed as well as some examples of group dynamics and roles that could be utilized in the implementation. The process of resource collection for these sections took approximately five weeks.

Lastly, the guide itself was constructed and pieced together in order of implementation level to emphasize early or first implementation at the beginning of the guide and more advanced implementations like large group projects or lab projects towards the end. Organization and writing of the guide spanned the following five weeks after all resources were collected. Once writing is complete, a period of two weeks was

taken to have peers review the guide and provide feedback before working on a final version. Following the creation of the Dummies Guide, the guide itself will be distributed to my peers in the science master's in teaching program at Hamline University with the task that they attempt to incorporate one or more strategies in their curriculum development for the Fall 2023 quarters.

Assessment

In order to assess the effectiveness of this Dummies Guide to Collaborative Learning in STEM, feedback from teachers who use the guide to implement strategies in their classroom will be gathered at the end of the fall 2023 quarters. A survey will go out to teachers that participate in using the guide to implement collaborative learning strategies that asks them about their mentality towards collaborative learning and the effects they perceive to come out of the collaborative learning experience for students. This survey will be distributed before teachers implement any new strategies in the classroom. The survey itself will be a google form with scales rating from 1-5 on various aspects of the implementation such as: student response, student engagement, and perceived success of implementation. Further questions will also revolve around asking teachers if they utilize collaborative learning in their classrooms already, why they use it, and whether they use other strategies as well such as lecture-style teaching. The end survey that teachers will take will ask them about how they viewed the effectiveness of their implementation of collaborative learning in their classrooms, whether they think students were engaged more or less with it, and if they would continue to implement. A final question on the survey will ask teachers if they believe that having a guide that was

written for them had any impact on their ability to implement collaborative learning or not.

Outside of teacher feedback, student feedback will also be taken in order to assess whether the skills gained from collaborative learning have any impact on their development of transferable skills and adaptability. Ideally, student feedback would be collected in interviews with students done by educators outside of their classroom to avoid conflicts of interest. The questions given to students will revolve around how they view collaborative learning experiences with regard to social skills, professional skills, and their ability to acquire content knowledge. The final question for students will ask them about whether they view collaborative learning as an important aspect of school and whether they think it is useful for their future. All feedback will be taken and coded using phenomenography, which qualitatively analyzes the way in which individuals experience something (Ornek, 2008).

Chapter Summary

This chapter described the details of this capstone project and its product, a Dummies Guide for Collaborative Learning in STEM, which seeks to answer the question: *What are the effects of teaching collaborative learning strategies to teachers in the high school STEM classroom on student adaptability and transferable skills development?*

This included a detailed description of the project itself and reasoning behind its formatting, the setting and audience within a STEM context, the timeline for creation and distribution, and how the project will be assessed from a teacher and student standpoint. The final chapter will conclude this capstone project and will be my reflection on the

creation and writing, what I have learned throughout the process, and any implications that this project has for my future as a STEM educator.

CHAPTER FOUR

Introduction

As a new teacher, a vast majority of what I do while teaching is observing students and how they interact with each other. What I have learned as an educator is that a student's success is dependent on a variety of factors of which any given teacher might have a different opinion. My main observation is that how students interact with each other, and the quality of those interactions, directly impacts how they learn new content from both a social and educational standpoint. Furthermore, the skills that they learn by interacting with others has a mirrored appearance to the skills that are desirable in the professional world outside of the classroom. Subsequently, I have also noticed a perceived tentativeness to implement strategies that highlight these skills purely because the advantages or disadvantages are not readily available in a quantitative capacity. With a shift in my view going from an individualistic understanding of students to seeing them alongside their peers in their learning, I am constantly thinking about the question: *What are the effects of teaching collaborative learning strategies to teachers in the high school STEM classroom on student adaptability and transferable skills development?*

Instead of doing what comes naturally to most teachers, which is lesson planning, I decided to go a different direction with my project. At the beginning of my teaching career I was also anxious about implementing new collaborative teaching strategies in the classroom for fear that they would not be responded to well by the students since working together is sometimes foreign to them. What I learned later was that trying, success or not, was the key to learning as a teacher. So, I created a Dummies Guide to Collaborative Learning that addresses some of the common misconceptions about collaborative

learning as well as what worked the best for me. Furthermore, I also included some examples of activities that exemplify collaborative learning that can easily be adapted into any content area classroom. The use of this guide is meant to assuage some of the fears and misconceptions about collaborative learning and give some information about how it can be applied to already existing curriculum rather than trying to design curriculum around collaborative learning.

In this chapter I will be reflecting on the process in which I completed my project as well as what I think are the essential takeaways. I will revisit the literature review and discuss what portions of the literature review were most important for the development of content needed for my project. Afterwards, I will discuss the implications and limitations of my project as they pertain to the intended audience. Lastly, I will discuss what the next steps are for this project, its information, and how gathering any of this information in one single place could be useful in the grand scheme of teaching.

Essential Takeaways

Developing this project was cathartic for me in more ways than one. The project was designed to be informal and function as a way for me to vocalize my thoughts about collaborative learning and what I have observed as potential barriers and anxieties about its implementation. The primary takeaways for me with regard to developing this project is an enhanced understanding of how collaborative learning fits into the grand scheme of education and how there are quite a few ways to incorporate aspects of collaborative learning into the curriculum without feeling overwhelmed. While working on the project I found myself reflecting on many of the activities that I had used in class this year and how I could modify them to better highlight collaborative skills. Furthermore, I also

found myself thinking about routines that I already do that are inherently collaborative, such as small group work at tables.

With regard to one of the main takeaways, how collaborative learning fits into the grand scheme of education, I found that collaborative learning is ingrained into almost every profession outside of the classroom. Furthermore, the skills gained from collaborative learning directly influence a student's social abilities within the classroom as well as outside. Looking at collaborative learning from a lens that includes the educational, social, and professional traits was imperative in understanding the concept as a whole. Furthermore, this has pushed me more towards the mentality that viewing students as far more than their grades is pivotal in becoming a good teacher.

Lastly, science as a profession has changed so drastically over the last century alongside the world and everyone in it. Understanding the ebb and flow of the world's culture and how everything interconnects was a deeply ingrained concept in thinking about collaborative learning. Digging deeper into what science teaching has been historically and how it no longer fits the mold of the students we are teaching in a modern age enhanced my ability to think critically about my own teaching as well as some of the reasons that teachers might be hesitant to utilize collaborative learning in the classroom.

Literature Review

The literature review felt like a mixed bag of emotions in the sense that actually writing it took an extremely long time but that the content that was needed to write it was readily available in large quantities. That being said, I did go through some changes throughout the literature review portion that better assisted me in redefining my research

question. Rather than focusing on the effects on students, which are not always quantifiable in the long-term, I decided to focus more on the effects that teaching collaborative strategies to teachers has on the students' development of the same skills. The key here was making sure that I was looking at the proposed advantages and disadvantages rather than making grand assumptions about how the strategies might affect students later in life.

I primarily used the literature review as a means to contextualize collaborative learning in education as a broad area and further transitioning to discuss collaborative learning in the realm of science teaching. It was important at that point to discuss how science teaching has been taught historically. It was important for me to find resources here that do not always align with my assumptions about the advantages of collaborative learning. Instead, I purposefully looked for resources that showed collaborative learning alongside other teaching strategies such as lecture-style lessons and note-taking. Furthermore, inquiry-based science teaching was a guaranteed include in the literature review as at its core it is inherently collaborative. Lastly, I needed to find reasons for teachers not implementing collaborative learning in the classroom as it is not a widely accepted teaching method in many classrooms, specifically in certain content areas.

The last section of the literature review primarily focused on the effects of collaborative learning of which it was imperative to note the advantages and disadvantages. Understanding the effects of collaborative learning from a lens that views students as a whole individual rather than a grade guided the development of my project immensely. Without thinking about all three effects of collaborative learning (educational, social, professional) there is no way to efficiently design a curriculum that

incorporates collaborative learning. Alongside these important traits it was important to note one key factor that plays a role in all interactions, inside and outside of the classroom, and how collaborative learning might have an effect on its development. That factor is adaptability and its importance in an ever changing world. Students need to be able to adapt to situations, even ones that they were never exposed to before. Implementing collaborative learning is often seen as just having students work together, but in reality it gives students ample opportunities to interact with individuals that do not share the same perspectives as themselves. These interactions lead to students being able to adapt to new situations as well as use what they observe to better prepare them for future reactions.

Implications

One implication of my project's implementation is teachers reflecting more on what they are teaching from more than one perspective. Students today are so dramatically different than they were a century ago and the skillsets they need to develop are changing every day. Teaching teachers to reflect on how they are teaching and the effects that it has on a students development of educational, social, and professional skills is imperative to good teaching. My hope is that there will be a movement towards teachers including sections in their lesson plans, unit plans, even year plans, that address how they can teach skills that are outside of the realm of content. Furthermore, how they can teach skills that are transferable outside of their specific content area.

Outside of teachers, another implication of my project is my hope that students develop an understanding of the social nature of education. They should understand that sharing perspectives is key to their synthesis of information and that it should not be

something they are punished for. Furthermore, I hope that students begin to see what makes good communication and how those skills can be developed by simply working with others, especially those that they do not already know.

Limitations

The biggest limitation for this project is the nature of teaching at this point. First of all, new teachers often get ignored when it comes to implementing new strategies, especially at schools that optimize their teaching methods by having all classes use the same type of assessments. This limits how much change I am actually able to make outside of my own classroom. Furthermore, being new to teaching means that it has been difficult from the start to find my bearings at a school for elongated periods of time. New teachers tend to get tossed around from school to school in the early years before solidifying a position. This means that it has been difficult to design a curriculum that matches both my own teaching style as well as the school and district that I am teaching in.

Next Steps and Why This Matters

The next steps for this project may seem silly, but I feel like it would benefit both myself and perhaps some other new teachers in the future. I would really like to begin a blog, Youtube channel, or something of that nature to detail my journey through being a new teacher implementing strategies and trying things out. I firmly believe that giving resources to teachers that are less formal, something that does not feel like “it is all figured out”. Receiving information about new teaching strategies never really talks through the human nature of the process, just the technical process of materials and results. I want to hear about what went wrong, what went well, and what could be

changed in the future. So, I would like to start reflecting on my teaching and releasing it into the world to see if it helps any other teachers on their journey.

Summary

In this chapter, I have discussed my capstone project which addresses the question: *What are the effects of teaching collaborative learning strategies to teachers in the high school STEM classroom on student adaptability and transferable skills development?* Through the process of working on this project I was able to reflect on my teaching practice and what it could possibly be to enhance student learning and their development of skills needed to be successful in and out of the classroom. The literature that I reviewed showed me the importance of contextualizing collaborative learning and understanding the situational nature of any teaching strategy. Furthermore, the literature showed me the limitations of collaborative learning and how it should never be used as the one and only method of teaching, but rather an accompanying strategy. Lastly, the literature showed me the primary points of interest when discussing the effects of collaborative learning and how the skills developed from those effects might positively or negatively affect students in the future.

Working on my project allowed me to reflect on some of the situations that I have been in with other educators where my opinion on how something should be taught has been shut down on account of the years I have been teaching. This was the main limitation to my project and has driven me to try new things regardless of what other educators might think. Furthermore, making sure that the collaborative learning strategies presented can be applied in different capacities such as just utilizing one portion was imperative to overcoming the limitations in the future.

My hope is that by completing this project that I will be more prepared for the upcoming years of teaching with a newly found understanding of how and what I am teaching. Science has always been my passion, but it has been difficult to find ways of teaching it that invigorate students while still preparing them for life outside of the classroom. Teaching will continue to grow alongside the students and my hope is that I will grow with them in ways that positively impact my teaching practice and the teaching practice of others around me.

REFERENCES

Abdi, A. (2014). The effect of inquiry-based learning methods on students' academic achievement in science courses. *Universal Journal of Educational Research*, *2*(1), 37–41. https://doi.org/10.13189/ujer.2014.020104

Amesbury, C. (2006). *Student Centered Learning in the Chemistry Classroom*. [Master's Thesis, State University of New York Brockport]. SUNY Open Access Repository. http://hdl.handle.net/20.500.12648/5474

Anderson, A. (2012). Climate change education for mitigation and adaptation. *Journal of Education for Sustainable Development*, *6*(2), 191–206. https://doi.org/10.1177/0973408212475199

Bell, S. (2010). Project-Based learning for the 21st century: Skills for the future. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, *83*(2), 39–43. https://doi.org/10.1080/00098650903505415

Ben-Peretz, M., & Craig, C. J. (2018). Intergenerational impact of a curriculum enigma: the scholarly legacy of Joseph J. Schwab. *Educational Studies*, *44*(4), 421–448. https://doi.org/10.1080/03055698.2017.1387099

Bertrand, M. G., & Namukasa, I. K. (2020). STEAM education: Student learning and transferable skills. *Journal of Research in Innovative Teaching & Learning*, *13*(1), 43–56. https://doi.org/10.1108/jrit-01-2020-0003

Bhamani, S., Makhdoom, A. Z., Bharuchi, V., Ali, N., Kaleem, S., & Ahmed, D. (2020). Home learning in times of COVID: Experiences of parents. *Journal of Education and Educational Development*, *7*(1), 9. https://doi.org/10.22555/joeed.v7i1.3260

Blumberg, P. (2012). Book review learner-centered teaching: Putting the research on learning into practice. *Journal of the Scholarship of Teaching and Learning*, *12*(1), 93–94. Retrieved from www.iupui.edu/~josotl

Bonk, C. J., & Cunningham, D. (2020). Searching for learner-centered, constructivist, and sociocultural components of collaborative educational learning tools. *Electronic Collaborators*, 61–86. https://doi.org/10.4324/9780203053805-10

Brindley, J. E., Blaschke, L. M., & Walti, C. (2009). Creating effective collaborative learning groups in an online environment. *International Review of Research in Open and Distributed Learning*, *10*(3).

Brundiers, K., Wiek, A., & Redman, C. L. (2010). Real-world learning opportunities in sustainability: From the classroom into the real world. *International Journal of Sustainability in Higher Education*, *11*(4), 308–324. https://doi.org/10.1108/14676371011077540

Eskay M., Onu V. C., Obiyo N., Obidoa M. (2012). Use of peer tutoring, cooperative learning, and collaborative learning: Implications for reducing anti-social behavior of schooling adolescents. *US-China Education Review A*, *11*, 1548–6613.

Capdeferro, N., & Romero, M. (2012). Are online learners frustrated with collaborative learning experiences? *International Review of Research in Open and Distributed Learning*, *13*(2), 26–44.

Chang, Y. (2010). *Students' perceptions of teaching styles and use of learning strategies*. [Master's Thesis, University of Tennessee]. Educational Psychology Commons. https://trace.tennessee.edu/utk_gradthes/782

Cheema, J. R., & Kitsantas, A. (2014). Influences of disciplinary classroom climate on high school student self-efficacy and mathematics achievement: A look at gender and racial–ethnic differences. *International Journal of Science and Mathematics Education*, *12*(5), 1261–1279. https://doi.org/10.1007/s10763-013-9454-4

Cheng, E. W. L., Chu, S. K. W., & Ma, C. S. M. (2016). Tertiary students' intention to e-collaborate for group projects: Exploring the missing link from an extended theory of planned behaviour model. *British Journal of Educational Technology*, *47*(5), 958–969. https://doi.org/10.1111/bjet.12379

Clegg, T., Yip, J. C., Ahn, J., Bonsignore, E., Gubbels, M., Lewittes, B., & Rhodes, E. (2013). *When face-to-face fails: Opportunities for social media to foster collaborative learning.* Computer-Supported Collaborative Learning Conference, CSCL, University of Wisconsin, Madison, WI, United States.

Custer, L., & Tuominen, A. (2017). Bringing "internationalization at home" opportunities to community colleges: Design and assessment of an online exchange activity between U.S. and Japanese students. *Teaching Sociology*, *45*(4), 347–357. https://doi.org/10.1177/0092055X16679488

Dalton, B., Morocco, C. C., Tivnan, T., & Rawson Mead, P. L. (1997). Supported inquiry science. *Journal of Learning Disabilities*, *30*(6), 670–684. https://doi.org/10.1177/002221949703000611

de Oliveira, E. D., & de Castro Guimarães, I. (2010). "Employability" through curriculum innovation and skills development. *Higher Education Management and Policy, 22*(2), 83-98. https://doi.org/10.1787/hemp-22-5kmbq08jc4wk

Eccles, J. S., & Roeser, R. W. (2011). Schools as developmental contexts during adolescence. *Journal of Research on Adolescence*, *21*(1), 225–241. https://doi.org/10.1111/j.1532-7795.2010.00725.x

Eddy, S. L., Brownell, S. E., Thummaphan, P., Lan, M. C., & Wenderoth, M. P. (2015). Caution, student experience may vary: Social identities impact a student's experience in peer discussions. *CBE Life Sciences Education*, *14*(4), 1–17. https://doi.org/10.1187/cbe.15-05-0108

Edwards, C. (2006). Influences of experiences and training on effective teaching practices to meet the needs of diverse learners in schools. *Educator*, *126*, 580.

Ernst, D. C., Hodge, A., & Yoshinobu, S. (2017). What is inquiry-based learning? *Notices of the American Mathematical Society*, *64*(06), 570–574. https://doi.org/10.1090/noti1536

Falchikov, N., & Goldfinch, J. (2000). Student peer assessment in higher education: A meta-analysis comparing peer and teacher marks. *Review of Educational Research*, *70*(3), 287–322. https://doi.org/10.3102/00346543070003287

Falkner, K., Falkner, N. J. G., & Vivian, R. (2013, March 6-9). *Collaborative learning and anxiety*. SIGCSE '13: The 44th ACM Technical Symposium on Computer Science Education, Denver, CO, United States. https://doi.org/10.1145/2445196.2445268

Fitzgerald, M., Danaia, L., & McKinnon, D. H. (2019). Barriers inhibiting inquiry-based science teaching and potential solutions: perceptions of positively inclined Early adopters. *Research in Science Education*, *49*(2), 543–566. https://doi.org/10.1007/s11165-017-9623-5

Flynn, A. B. (2015). Structure and evaluation of flipped chemistry courses: Organic & spectroscopy, large and small, first to third year, English and French. *Chemistry Education Research and Practice*, *16*(2), 198–211. https://doi.org/10.1039/c4rp00224e

George-Williams, S. R., Soo, J. T., Ziebell, A. L., Thompson, C. D., & Overton, T. L. (2018). Inquiry and industry inspired laboratories: The impact on students' perceptions of skill development and engagements. *Chemistry Education Research and Practice*, *19*(2), 583–596. https://doi.org/10.1039/c7rp00233e

Gillies, R. M., & Boyle, M. (2010). Teachers' reflections on cooperative learning: Issues of implementation. *Teaching and Teacher Education*, *26*(4), 933–940. https://doi.org/10.1016/j.tate.2009.10.034

Goodsell, A. ., Maher, M. ., & Tinto, V. . (1992). What is collaborative Learning? *Collaborative Learning: A Sourcebook for Higher Education*, (1), 10–30. https://doi.org/10.1007/s13398-014-0173-7.2

Arvaja M., Hakkinen, P., Etelapelto A., Rasku-puttonen, H. (2000). Collaborative processes during report writing of a science learning project : The nature of discourse. *European Journal of Psychology of Education*, *15*(4), 455–466.

Hall, K. L., Vogel, A. L., Huang, G. C., Serrano, K. J., Rice, E. L., Tsakraklides, S. P., & Fiore, M. (2018). The science of team science: A review of empirical evidence and research gaps on collaboration in science. *American Psychological Association*.

Hendarman, A. F., & Cantner, U. (2018). Soft skills, hard skills, and individual innovativeness. *Eurasian Business Review*, *8*(2), 139–169. https://doi.org/10.1007/s40821-017-0076-6

Hemsley, M. (1997). The Evaluation of Teachers Guides - Design and Application. *English Language Teacher Education and Development, 3*(1), 72–83.

Hibbard, L., Sung, S., & Wells, B. (2016). Examining the effectiveness of a semi-self-paced flipped learning format in a college general chemistry sequence. *Journal of Chemical Education*, *93*(1), 24–30. https://doi.org/10.1021/acs.jchemed.5b00592

Holbrook, J., & Kolodner, J. L. (2000, June 14-17). *Scaffolding the development of an inquiry-based (science) classroom.* International Conference of the Learning Sciences, University of Michigan, Ann Arbor, MI, United States. 233–239. https://doi.org/10.4324/9780203763865-47

Huda, M., Maseleno, A., Shahrill, M., Jasmi, K., Mustari, I., & Basiron, B. (2017). Exploring adaptive teaching competencies in big data era. *International Journal: Emerging Technologies in Learning*, *12*(3), 69–83.

Igel, C., & Urquhart, V. (2012). Generation Z, meet cooperative learning: Properly implemented cooperative learning strategies can increase student engagement and achievement. *Middle School Journal*, *43*(4), 16–21. https://doi.org/10.1080/00940771.2012.11461816

John, J. (2009). Study on the nature of impact of soft skills training programme on the soft skills development of management students, (September 2009), 19–27. Retrieved from http://papers.ssrn.com/abstract=1591331

Johnson, D. W., Johnson, R. T., & Smith, K. A. (1998). Cooperative learning returns to college: What evidence is there that it works? *Change: The Magazine of Higher Learning*, *30*(4), 26–35. https://doi.org/10.1080/00091389809602629

Kaberman, Z., & Dori, Y. J. (2009). Question posing, inquiry, and modeling skills of chemistry students in the case-based computerized laboratory environment. *International Journal of Science and Mathematics Education*, *7*(3), 597–625. https://doi.org/10.1007/s10763-007-9118-3

Kaendler, C., Wiedmann, M., Rummel, N., & Spada, H. (2015). Teacher competencies for the implementation of collaborative learning in the classroom: A framework and research review. *Educational Psychology Review*, *27*(3), 505–536. https://doi.org/10.1007/s10648-014-9288-9

Karimi, H., & Pina, A. (2021). Strategically addressing the soft skills gap among STEM undergraduates. *Journal of Research in STEM Education*, *7*(1), 21–46. https://doi.org/10.51355/jstem.2021.99

Kennedy, T. J., & Odell, M. R. L. (2014). Engaging students in STEM education. *Science Education International*, *25*(3), 246–258.

Kilgo, C. A., Ezell Sheets, J. K., & Pascarella, E. T. (2015). The link between high-impact practices and student learning: some longitudinal evidence. *Higher Education*, *69*(4), 509–525. https://doi.org/10.1007/s10734-014-9788-z

King, A. (2002). Structuring peer interaction to promote high-level cognitive processing. *Theory into Practice*, *41*(1), 33–39. https://doi.org/10.1207/s15430421tip4101_6

Kobbe, L., Weinberger, A., Dillenbourg, P., Harrer, A., Hämäläinen, R., Häkkinen, P., & Fischer, F. (2007). Specifying computer-supported collaboration scripts.

International Journal of Computer-Supported Collaborative Learning, *2*(2–3), 211–224. https://doi.org/10.1007/s11412-007-9014-4

Kranz, E. (2019). *Critical Soft Skills And The Stem Professional*. [Doctoral Thesis, University of New England]. Educational Leadership Commons. https://dune.une.edu/theses/235

Krebs, D. J. (2015). Implementing blended classroom pedagogy to deepen student understanding in high school biology. Retrieved from https://soar.suny.edu/handle/20.500.12648/5827

Laal, M., & Laal, M. (2012). Collaborative learning: What is it? *Procedia - Social and Behavioral Sciences*, *31*(2011), 491–495. https://doi.org/10.1016/j.sbspro.2011.12.092

Lampert, M. (1990). When the problem is not the question and the solution is not the answer: Mathematical knowing and teaching. *American Educational Research Journal*, *27*(1), 29–63. https://doi.org/10.3102/00028312027001029

Larson, L. C., & Miller, T. N. (2011). 21st Century skills: Prepare students for the future. *Kappa Delta Pi Record*, *47*(3), 121–123. https://doi.org/10.1080/00228958.2011.10516575

Leak, A. E., Sciaky, E., Lenaburg, L., Bianchini, J. A., & Scott, S. (2018). Essential elements of collaboration: Understanding how chemistry graduate students experience collaboration through international research visits. *Journal of Chemical Education*, *95*(5), 749–757. https://doi.org/10.1021/acs.jchemed.7b00781

Lebak, K. (2015). Unpacking the complex relationship between beliefs, practice, and change related to inquiry-based instruction of one science teacher. *Journal of Science Teacher Education*, *26*(8), 695–713. https://doi.org/10.1007/s10972-015-9445-0

Lee, S., & Bozeman, B. (2005). The impact of research collaboration on scientific productivity. *Social Studies of Science*, *35*(5), 673–702. https://doi.org/10.1177/0306312705052359

Lemke, J. (1998). *Teaching all the languages of science : Words, symbols, images, and actions*. Conference on Science Education in Barcelona, Spain. 1–13. https://doi.org/10.13140/2.1.4022.5608

Levasseur, R. E. (2013). People skills: Developing soft skills-A change management perspective. *Interfaces*, *43*(6), 566–571. https://doi.org/10.1287/inte.2013.0703

Lu, K., Pang, F., & Shadiev, R. (2021). Understanding the mediating effect of learning approach between learning factors and higher order thinking skills in collaborative inquiry-based learning. *Educational Technology Research and Development*, *69*(5), 2475–2492. https://doi.org/10.1007/s11423-021-10025-4

Mahon, M. (2016). *Career Adaptability: A Qualitative Understanding from the Stories of Older Women*. [University of Queensland].

Marando, A. (2012). Balancing project management hard skills and soft skills. *Brandeis University*, (February), 28.

Margot, K. C., & Kettler, T. (2019). Teachers' perception of STEM integration and education: a systematic literature review. *International Journal of STEM Education*, *6*(1). https://doi.org/10.1186/s40594-018-0151-2

McCollum, B., Morsch, L., Pinder, C., Ripley, I., Skagen, D., & Wentzel, M. (2019). Multi-dimensional trust between partners for international online collaborative learning in the Third Space. *International Journal for Students as Partners, 3*(1), 50–59. https://doi.org/10.15173/ijsap.v3i1.3730

McGunagle, D., & Zizka, L. (2020). Employability skills for 21st-century STEM students: The employers' perspective. *Higher Education, Skills and Work-Based Learning*, *10*(3), 591–606. https://doi.org/10.1108/HESWBL-10-2019-0148

Merrill, M. D., & Gilbert, C. G. (2008). Effective peer interaction in a problem-centered instructional strategy. *Distance Education*, *29*(2), 199–207. https://doi.org/10.1080/01587910802154996

Morel, N. (2014). Setting the stage for collaboration: An essential skill for professional growth. *Delta Kappa Gamma Bulletin*, *81*(1), 36.

Morsch, L., McCollum, B., Skagen, D., & Shokoples, B. (2018). Overcoming barriers for implementing international online collaborative assignments. *Canadian Journal for Scholarship of Teaching and Learning*.

Nadelson, L. S., & Seifert, A. (2013). Perceptions, engagement, and practices of teachers seeking professional development in place-based integrated STEM. *Teacher Education and Practice*, *26*(2).

Nokes-Malach, T. J., Richey, J. E., & Gadgil, S. (2015). When is it better to learn together? Insights from research on collaborative learning. *Educational Psychology Review*, *27*(4), 645–656. https://doi.org/10.1007/s10648-015-9312-8

Overby, K. (2011). Student-centered learning. *ESSAI*, *9*.(32)

Palincsar, A. S. (1998). Social constructivist perspectives on teaching and learning. *Annual Review of Psychology*, *49*(1), 345–375. https://doi.org/10.1146/annurev.psych.49.1.345

Pedaste, M., Mäeots, M., Siiman, L. A., de Jong, T., van Riesen, S. A. N., Kamp, E. T., Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educational Research Review,* 14, 47–61. https://doi.org/10.1016/j.edurev.2015.02.003

Pieterse, V., & van Eekelen, M. (2016). Which is harder? Soft skills or hard skills? *Communications in Computer and Information Science*, *642*, 160–167. https://doi.org/10.1007/978-3-319-47680-3_15

Porfeli, E. J., & Skorikov, V. B. (2010). Specific and diversive career exploration during late adolescence. *Journal of Career Assessment*, *18*(1), 46–58. https://doi.org/10.1177/1069072709340528

Potvin, P., Riopel, M., Masson, S., & Fournier, F. (2010). Problem-centered learning vs . teaching-centered learning in science at the secondary level : an analysis of the dynamics of doubt. *Journal of Applied Research on Learning 3*(5), 1–24.

Przybilla, J., Vinerean-bernhoff, M., Brandl, M., & Liljekvist, Y. (2021). *Rooms of learning: A conceptual framework for student-centered teaching development in a digital era.* [Manuscript in Preparation]. Department of Mathematics and Computer Science, Karlstad University.

Rainsbury, E., Hodges, D., Burchell, N., & Lay, M. (2002). Ranking workplace competencies: Student and graduate perceptions. *Asia-Pacific Journal of Cooperative Education*, *3*(2), 8–18.

Robles, M. M. (20). Executive perceptions of the top 10 soft skills needed in today's workplace. *Business Communication Quarterly*, *75*(4), 453–465. https://doi.org/10.1177/1080569912460400

Rocard, M., Csermely, P., Jorde, D., Walberg-Henriksson, H., & Hemmo, V. (2007). A Renewed pedagogy for the future of Europe. *Economy and Society*, 29.

Rutledge, S. A., Cohen-Vogel, L., Osborne-Lampkin, L., & Roberts, R. L. (2015). Understanding effective high schools: Evidence for personalization for academic and social emotional learning. *American Educational Research Journal*, *52*(6), 1060–1092. https://doi.org/10.3102/0002831215602328

Sacerdote, B. (2011). Peer Effects in Education: How might they work, how big are they and how much do we know Thus Far? *Handbook of the Economics of Education*, *1*(3). Elsevier B.V. https://doi.org/10.1016/B978-0-444-53429-3.00004-1

Saçkes, M., Trundle, K. C., Bell, R. L., & O'Connell, A. A. (2011). The influence of early science experience in kindergarten on children's immediate and later science achievement: Evidence from the early childhood longitudinal study. *Journal of Research in Science Teaching*, *48*(2), 217–235. https://doi.org/10.1002/tea.20395

Saroinsong, W. P., Saroinsong M. (2023). *Developing global collaboration skills in the era of unlimited learning.* [Manuscript submitted for publication]. Universitas Negeri Surabaya, Surabaya, Indonesia. https://doi.org/10.1201/9781003366683-24

Schwab, J. J. (1960). Inquiry, the science teacher, and the educator. *The School Review*, *68*(2), 176–195.

Shih, J.-L., Chuang, C.-W., & Hwang, G.-J. (2010). International forum of educational technology & society an inquiry-based mobile learning approach to enhancing social science learning effectiveness. *Source: Journal of Educational Technology & Society*, *13*(4), 50–62.

Skagen, D., McCollum, B., Morsch, L., & Wentzel, M. (2019). *Impact of international online collaborative learning on global perspectives of chemistry*. [Unpublished manuscript]. Mount Royal University, Calgary, Canada.

Slavin, R. E. (2015). Instruction based on cooperative learning. *Handbook of Research on Learning and Instruction*, 388–404. https://doi.org/10.4324/9780203839089.ch17

Slavit, D., Nelson, T. H., & Lesseig, K. (2016). The teachers' role in developing, opening, and nurturing an inclusive STEM-focused school. *International Journal of STEM Education*, *3*(1). https://doi.org/10.1186/s40594-016-0040-5

Susilawati, Aznam, N., Paidi, & Ngadimin. (2020). Teachers' perspectives toward soft skills in science learning. *Journal of Physics: Conference Series*, *1460*(1), 0–7. https://doi.org/10.1088/1742-6596/1460/1/012111

Sweller, J. (2021). Why inquiry-based approaches harm students' learning. *Centre for Independent Studies*, *24*, 1-10. Retrieved from https://www.cis.org.au/publications/analysis-papers/why-inquiry-based-approaches-harm-students-learning/

Taraban, R., Box, C., Myers, R., Pollard, R., & Bowen, C. W. (2007). Effects of active-learning experiences on achievement, attitudes, and behaviors in high school biology. *Journal of Research in Science Teaching*, *44*(7), 960–979. https://doi.org/10.1002/tea.20183

Tolmie, A. K., Topping, K. J., Christie, D., Donaldson, C., Howe, C., Jessiman, E., Thurston, A. (2010). Social effects of collaborative learning in primary schools. *Learning and Instruction*, *20*(3), 177–191. https://doi.org/10.1016/j.learninstruc.2009.01.005

Turiman, P., Omar, J., Daud, A. M., & Osman, K. (2012). Fostering 21st century skills through scientific literacy and science process skills. *Procedia - Social and Behavioral Sciences*, *59*, 110–116. https://doi.org/10.1016/j.sbspro.2012.09.253

Wahl, H., Kaufmann, C., Eckkrammer, F., Mense, A., Gollner, H., Himmler, C., Slobodian, R. (2012). Soft skills in practice and in education: An evaluation. *American Journal of Business Education*, *5*(2), 225–232. https://doi.org/10.19030/ajbe.v5i2.6826

Walker, E., Rummel, N., & Koedinger, K. R. (2009). CTRL: A research framework for providing adaptive collaborative learning support. *User Modeling and User-Adapted Interaction*, *19*(5), 387–431. https://doi.org/10.1007/s11257-009-9069-1

Warsah, I., Morganna, R., Uyun, M., Hamengkubuwono, H., & Afandi, M. (2021). The impact of collaborative learning on learners' critical thinking skills. *International Journal of Instruction*, *14*(2), 443–460. https://doi.org/10.29333/iji.2021.14225a

Weingart, P., Muhl, C., & Pansegrau, P. (2003). Of power maniacs and unethical geniuses: Science and scientists in fiction film. *Public Understanding of Science*, *12*(3), 279–287. https://doi.org/10.1177/0963662503123006

White, B. Y. (1998). Inquiry, modeling, and metacognition: Making science accessible to all students. *Cognition and Instruction*, *16*(1), 3–118. https://doi.org/10.1207/s1532690xci1601_2

Williams, B. T. (2005). Standardized students: The problems with writing for tests instead of people. *Journal of Adolescent & Adult Literacy*, *49*(2), 152–158. https://doi.org/10.1598/jaal.49.2.7

Xu, D., & Jaggars, S. S. (2013). *Adaptability to online learning: Differences across types of students and academic subject areas.* [Unpublished Manuscript]. Columbia University, New York, NY. Retrieved from http://ccrc.tc.columbia.edu/media/k2/attachments/adaptability-to-online-learning.pdf

Zan, R., & Di Martino, P. (2009, July 19-24). *Different profiles of attitude toward mathematics: The case of learned helplessness.* The 33rd Conference of the International Group for the Psychology of Mathematics Education, Thessaloniki, Greece.