A Twinkle in Their Eye: Factors that Influcence Motivation in Remote Student Instructors and Co-located Students

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Abstract—This research paper discusses pedagogical and instructional approaches for K-12 education. As demand for engineers and computer scientists continues to increase, it is important to nurture a passion for STEM in high school students. However, a significant obstacle to contend with is low student motivation in rural and economically disadvantaged areas, which in turn may cause a lack of student success. In this paper, we examine students' motivation by using a STEM curriculum in which students from rural and economically disadvantaged schools are taught remotely using Zoom and a telepresence robot.

Over the course of 11 weeks—approximately one semester—a curriculum that included a mixture of programming, engineering, and manufacturing was taught to 11th and 12th grade students in three different classes. Remote teaching was done by college students with a background in engineering (e.g., student instructors). These schools were used because of their remote location and underrepresentation in research.

To measure student motivation in a teaching environment that uses telepresence robotics and Zoom, researchers collected the following data: a daily class progress document filled out by student instructors; weekly discussions between student instructors and researchers; and the submissions of student projects. Data on student instructor motivation was collected with surveys that had a mix of Likert scale and free response questions. The ratio of phrases about amotivation to phrases about motivation of the students was collected from surveys, discussions, and progress documents and analyzed.

We found that the three classes exhibited varying levels of interest in the program, and that differences in class motivation fluctuated over the course of the semester. Classroom motivation may be influenced by the curriculum or technical issues unique to a remote course with co-located students. Finally, we found that the traditional relationship between student motivation and instructor motivation is not disturbed even though the students were co-located and the student instructor was remote.

Keywords—STEM, Motivation, Zoom, Education, High School, Engineering, Remote Learning, Telepresence Robot

I. Introduction

There is an increased demand for engineers within the United States, meaning more students must pursue engineering degrees in college to fill this resulting job vacancies. As such, high school students in the United States are a potential target for interventions to increase interest in engineering fields [1]. By cultivating an interest in engineering at this age, students may be encouraged to select an engineering degree and become engineers in their professional lives.

But a large factor to contend with is high levels of student and instructor amotivation, factors which contribute to negative consequences such as higher dropout rates [2]. Furthermore, there is a direct link between student motivation and teacher motivation: When the student is motivated to learn, the teacher is more motivated to teach [3], and when the teacher is more motivated to teach, the students' academic outcomes improve [4].

In this paper, researchers focused on rural and economically disadvantaged schools, which are underrepresented in research and are, according to Hardré et al., "at risk for low motivation and lack of school success" [5]. Because these schools do not have equitable access to STEM professionals, a Career Technical Education (CTE) program was used to virtually teach co-located students an engineering curriculum [6] and to examine how motivation fluctuated over the course of a semester. This instruction was done remotely because Zoom can be an effective teaching tool for rural areas [7], and more research needs to be conducted examining the dual use of Zoom and a telepresence robot.

Because underfunded schools typically lack STEM professionals and the funds to supply them [8][9], college-aged "student instructors" were used to mentor high school students on engineering topics such as mechanical engineering, electrical engineering, and computer programming. Factors which potentially contributed to changes in motivation were also examined. Finally, student instructor motivation was examined, as there is a lack of literature about whether the relationship between student and instructor motivation persists if the educational role is assumed by a student instructor instead of a teacher and the students are co-located while the student instructor is remote.

This information was collected to answer following research questions:

1) *What factors influence student motivation when taught remotely through Zoom and a telepresence robot?*
2) *Is student instructor motivation linked to student motivation when students are co-located and the student instructors are remote?*

II. Revelant Background

A. Motivation Theories in the Classroom

According to Ford and Roby, "a large number of high school students across America lack academic motivation". The causes of amotivation can be attributed to perceived irrelevancy, difficulty, lack of autonomy, and lack of approachability. When these causes are present, students may not feel a sense of control in their studies and are more likely to feel amotivation [2]. In Vennix et al.'s study, researchers found that when students feel a high level of autonomy and they believe the material is personally relevant, their motivation increases [10]. Furthermore, self-determination motivation theory supports these findings by drawing a connection between internalized motivation and feelings such as competence, autonomy, curiosity, and relatedness [11].

Other factors, such as a student's relationship with their teacher, also have a large impact on motivation [12]. Social-cognitive motivation theorists argue that this is because "human learning and performance result from reciprocal interactions among personal, behavioral, and environmental factors" [11]. The more a teacher is motivated to teach, the more effort this teacher will put into educating their students, which has been shown to directly improve students' academic outcomes [3][4]. When considering social-cognitive motivation theory, it is important to note that "self-efficacy beliefs are the primary drivers of motivated action". Self-efficacy belief is defined as someone's belief in their ability to accomplish something [13].

A. STEM Motivation in Practice

Julia et al. studied the effectiveness of an after-school program for 6th and 7th grade students. The program lasted the entire academic year with each session lasting an hour each week. To measure the motivation of students, researchers surveyed the students and separated motivation into four categories: attention, relevance, confidence, and satisfaction. They found that the students were motivated by the hands-on learning approach and the engineering construction kits [14].

For adolescents, STEM motivation can also be improved through STEM programs. In Master et al.'s study, they examined the interest of six-year-old girls in STEM, particularly robotics. Using a control group, they were able to evaluate the effectiveness of this program. The girls who designed and programed a robot using a smartphone showed higher technology interest and self-efficacy [15].

These are just two examples of STEM programs finding success. In recent years, there have been many others that have worked with secondary education classrooms to provide students with in-school and after-school STEM activities. These programs have been implemented with the goal of encouraging students to pursue a career in STEM, and they have yielded positive results: students' perceptions of the outreach learning environment were overall very positive [10].

Remote teaching was an integral tool during the Covid-19 pandemic. Indeed, in certain situations it was proved to be as effective as in-person teaching. For example, when comparing students' knowledge on the subject they studied for both in-person and remote classes, the scores were similar [16]. Remote teaching can also be an effective tool of education for students from rural areas [7]. But there is a lack of research examining the relationship between remote STEM education and motivation. And there is even less research on instructor use of telepresence robots with co-located students, as most research that exists typically focuses on human-computer interaction [17] or learning outcomes [18].

B. The Curriculum in Relation toPedagogy

A Horizontal (HL) approach prioritizes breadth over depth when introducing students to new topics. This gives students the opportunity to touch upon multiple subjects while slowly building complexity [19]. Project based learning (PBL) is also a key component to curriculum building, as it can be used to test how much information students absorbed during instruction. Many argue that there is a link between PBL instruction and positive student outcomes [20]. HL and PBL are related to one another in that in both learning approaches, student learning is typically driven by student-originated inquiry of a subject [19]. This relationship allows for both HL and PBL to be used in the creation of a curriculum which gives students an opportunity to exercise autonomy within their learning, thereby increasing motivation [10].

III. Methodology

The following section describes the recruitment of student instructors, the participating schools, and the organization of the interventions, the creation of the curriculum, and data collected.

A. Recruitment of Student Instructors

Researchers recruited college students as student instructors based on two criteria: their educational background (e.g., engineering students who demonstrated an understanding of circuits, programming, and 3D design) and their previous experience mentoring grade school children and teenagers. The demographics of the student instructors can be found in Table 1. Student instructors received $11/hour and they signed a consent form approved by the researcher's Institutional Review Board.

TABLE 1: Demographics of Student Instructors.

Student Instructor	**Age**	**Sex**	**Degree Program**	**Year**
Instructor 1	21	F	Electrical Engineer	Junior
Instructor 2	20	F	Multidisciplinary Engineering Technology	Sophomore
Instructor 3	20	M	Electrical Engineer	Junior

Instructor 4	21	M	Electrical Engineer	Junior
Instructor 5	21	M	Electrical Engineer	Senior
Instructor 6	20	M	Electrical Engineer	Sophomore
Instructor 7	23	M	Aerospace Engineer	Sophomore

B. Participating Schools and Responsbilities

Two high schools from underfunded school districts in rural areas were recruited for the program. These school districts will be referred to as School-1 and School-2. School-1 was 313 miles from the location of the student instructors and School-2 was 226 miles away. There were three classes total, two from School-1 and one from School-2. Class A and Class B belonged to School-1 and Class C belonged to School-2. Class A, Class B, and Class C had 12, 12, and 7 students, respectively. A total of 31 students—6 girls and 15 boys—all of which were juniors and seniors, participated in the program. These students and their parents signed a consent form to authorize inclusion in the study.

Within each class, students were divided into groups. These groups sometimes changed composition based on classroom dynamics, such as a student refusing to work with another student because they weren't friends anymore. There was one teacher and two student instructors, when availability allowed, in the classroom. The teacher's purpose was to 1) distribute materials to the students, 2) turn on Zoom and the telepresence robot, and 3) manage student behavior. The student instructors' responsibility was to 1) teach new material to the students and 2) reinforce any concepts learned.

There were seven student instructors who either taught through Zoom or through a telepresence robot [21]. When a student instructor taught using Zoom, they presented a slide deck with new material to the students. When a student instructor taught using the telepresence robot, they did not present new material. Instead, student instructors communicated with students individually to reinforce topics the students had previously learned.

Each class was 45 minutes, allowing for 35 minutes of teaching (five minutes was lost in the beginning of class due to setting up and five minutes at the end of class was lost for cleanup and class dismissal). The schools were taught as depicted in Table 2. Various school conflicts, like a pep rally or an absent teacher, led to the cancellation of the class session. This explains the differences in total days taught.

TABLE 2: Educational Days.

School	Weeks Taught	Days Taught	Educational Minutes
Class A	11	41	1435
Class B	11	35	1225
Class C	8	24	840

C. The Creation of the Curriculum

Teaching engineering disciplines opens many possibilities for students, ranging from aeronautics to robotics to computer programming. However, despite the sheer number of engineering disciplines, an introductory course only affords teachers and student instructors time to educate students on a select number of topics. To address this concern, a curriculum was designed with a focus on computer programming, mechanical engineering, and electrical engineering in order to give students the opportunity to learn basic concepts that stretch across multiple different engineering fields. More specifically, this curriculum was broken down into three streams of learning: microcontroller-based electronics; computer programming; and 3D design, 3D printing, and construction. This approach to learning is in agreement with the HL approach because it proceeds breadthwise across each of these areas. This approach also allowed for a slower introduction into computer programming. This can be beneficial because, according to Blanchard et al., students often view computer programming as "difficult, intimidating, and/or tedious in nature" and "the initial experiences students have while programming affect their perceptions of their own ability to program" [22].

The curriculum was organized into five units based on concepts of microcontroller-based electronics and computer programming. Student's learning outcomes and subject mastery were assessed with projects that were situated towards the end of each unit, which is consistent with PBL. The project included 3D design, 3D printing, and construction. For example, in Unit 1, students learned to wire and program multiple LEDs, a push button, and a potentiometer using an Arduino.

D. Data Collection

To answer the research questions, researchers collected the following data: a daily class progress document filled out by student instructors, student instructor motivation surveys, and notes taken by a researcher from weekly discussions between student instructors and researchers.

Student instructors filled out a daily class progress document in which they briefly summarized what lessons were covered, any technical issues that arose, and suggestions for the future. The weekly discussions were between student instructors and researchers, and student instructors were prompted to discuss the students' motivation. For the submissions by students, each group of students was prompted to submit their work to Google Classroom, resulting in one submission per group. Groups were instructed to submit a picture of their circuit, code, and structure.

For student instructor motivation, researchers took notes from their weekly discussions and student instructors filled out surveys with a mix of Likert scale and free response questions. The student instructors were prompted to discuss a positive and negative experience from the week at the weekly discussions. They were also given a chance to restate any issues they faced in the classroom that week.

IV. RESULTS

A. Student Motivation

a. From the Eyes of the Student Instructor

Two researchers examined the daily class progress document, creating two categories: motivation and amotivation. These categories were used to record the ratio of motivation phrases to amotivation phrases. Examples of phrases indicating students' motivation and amotivation include: the students were "engaged and actively participating"; "kids were uninterested"; and the students were "not actively participating in class". Occasionally the students were both motivated and amotivated with some students working and others not. The total ratio of motivated to amotivated phrases is as follows: Class A with 17:8, Class B with 10:13, and Class C with 7:1.

This is reaffirmed with the notes taken at the weekly discussions. Class A's results contained both examples of motivation and amotivation as seen in the following quotes:

- "Half the class was motivated".
- "If [the student instructor] indulged the student, their motivation increased".
- Some students "definitely work, they at least try".
- "If they are confused, they stay confused" because they "don't ask questions".
- The students "don't take [the] class seriously".

Class B's motivation was described as follows:

- Their motivation was "low, very low".
- The students were "unresponsive" and they "don't understand the material".

Student instructors from Class C stated the following:

- Engagement is "good, really good".
- The class was "very easy" to teach and "chill".
- The students "understood the material and if they didn't, they would tell [the student instructor]".

b. From Submission Rates and Material Covered in the Curriculum

Class A covered 14 lessons and completed two projects from the curriculum within 41 days. Class B covered 10 lessons and completed one project in 35 days. For Class B, after four weeks, the curriculum was restarted because the students did not grasp the material; they were unable to define variables in the coding platform of Arduino or wire up an LED. Class C covered eight lessons and completed one project from the curriculum and one alternate project in 24 days.

For comparison purposes, only the group submissions rates from the first project are examined, as this was the project that all three classes were assigned. The total number of groups per class and the number of components of the project they submitted to Google Classroom is presented in Table 3. There were three components to the first project: "Code", which is computer programming; "Circuit", which is electronics fabrication and assembly; and "Structure", which is 3D design, 3D printing, and construction. For example, some students opted to make a stoplight. In order to do so, the students had to wire up three LEDs (Red, Yellow, Green), code for these LEDs to turn on and off, and 3D design a structure to contain all of the wires and LEDs neatly. Some groups only submitted one of these components. For example, students would only design the structure component.

TABLE 3: Project One Components Submitted

	Class A	**Class B**	**Class C**
Groups	4	4	4
Project Submissions	2	4	4
Code	1	0	3
Circuit	1	0	4
Structure	2	4	4

In Table 3, it can be seen that Class A had four groups total, of which only two groups submitted work in any form. One group completed all three components, while another group only submitted the structure component. The other two groups did not submit any of their work to Google Classroom.

Additionally, not all the students in groups participated because sometimes amotivated students refused to work. Table 3 shows the percentage of students who submitted a component of Project 1 per class (e.g., 42% of students in Class A completed the Coding component of Project 1).

TABLE 4: Percentage of Students that Submitted a Component of Project 1

	Coding	**Structure**	**Circuit**
Class A	42%	%	42%
Class B	0%	67%	0%
Class C	43%	57%	57%
Average	28%	58%	33%

B. *Technical Issues Reported in the Classrooms*

During the interventions, a wide range of issues arose. Of these issues, this paper specifically looks at the issues that potentially affected motivation through the lens of a telepresence and Zoom teaching experience with co-located students. These issues are described in Table 5. A number of these issues remained unresolved across multiple class periods due to the distances involved between the researchers and the classrooms.

TABLE 5: Issues Reported in the Classrooms.

Issue	**Explanation**
School-Imposed Restrictions on Internet Access	The schools had web browsing restrictions. This was a multiple week issue for Class C. The online version of Arduino IDE was inaccessible to them. The school's IT department was

	eventually able to resolve this issue. Classes A and B experienced a week-long Zoom outage when their IT department updated the web browsing restrictions.
Misplaced Materials	There were multiple reports from the Class A and B teacher that materials shipped to them had not arrived. However, the issue was misplacement of received shipments. Researchers were often unable to resolve this issue in a timely manner due to the distance between the researchers and the students.
3D Printer Failure	The 3D printers in both schools failed. As with the misplaced materials discussed above, no one on-site was able to repair the printers, making them inaccessible until they could be shipped for repairs.
Failure of Classroom Setup	The class setup that was planned was to have a main screen at the head of the classroom. All the Zoom lessons were to be taught from this. But unfortunately, due to a loud A/C unit, Class A and B's students logged into the Zoom individually with no central screen.

C. Student Instructor Motivation

When asked in the survey to further elaborate on the relationship of student's motivation to the student instructor's motivation, the student instructors provided the following responses:

- "When the students weren't as interested in the lecture it was a lot harder to teach them".
- "The students' lack of motivation gets a little bit draining".
- "When they were interested, it was a lot more fun and eas[ier] to teach them".
- "[A student's] table was always active and working, which motivated me a lot".
- "Seeing her gradually understand the concepts I was teaching was motivating".
- "Them showing me their code and asking questions about how some systems work is encouraging because they are actively seeking information towards this curriculum".
- "The positive feedback and participation of the students to actively learn this material was encouraging and helped make teaching easier".
- "Almost half of the class did not seem to have interest in what we were teaching at some point. Honestly, I was demotivated when I was on robot and just watching students on the phone".
- "It's motivating when a student really understands or tries to understand".
- The students' "energy was very good and gave me a positive impact on teaching".

V. Discussion

A. Curriculum and Student Motivation

As seen in Tables 3 and 4, the students participated the most in 3D design, 3D printing, and construction (Structure) followed by electronics fabrication and assembly (Circuit). They completed the fewest submissions for computer programming (Code).

Students appeared to be most interested in completing the Structure component, which was evident from their more detailed and time-consuming submissions. Many students spent the bulk of their time in class decorating their structures, a task which was not necessary for the completion of the component, but which nevertheless demonstrates the students' motivation. Additionally, the student instructors noted that the students were less likely to be distracted by their phones when they were creating their structures. This attention to detail by the students could be explained by self-determination motivation theory, which states that curiosity or a desire for mastery drives the motivation to learn [11].

The coding aspect of the curriculum had the fewest submissions. Students would often state that coding was difficult and that they didn't understand it. In all of the classes, each group had a "designated coder" because none of the other students would want to do it. When this designated coder was absent, none of the students would step into this role, often halting the progression of their project. A potential explanation for the minimal coding submissions is that students could have perceived coding outside of their capabilities, thus resulting low self-efficacy [13]. As mentioned before in Section III, students often perceive programming as too difficult and are dissuaded from trying [22].

B. Impact of Technical Issues on Student Motivation

The remote and rural location of the schools presented an opportunity to study how remote education, and the practical problems associated with remote education, can impact student motivation. As previously stated in Section III, School-1 was 313 miles away from the student instructors and School-2 was 226 miles away. For this reason, student instructors and researchers could not easily fix many of the problems that arose causing these complications to persist longer than they otherwise might. Technical issues of this nature are another potential source of influence on students' motivation. As seen in social-cognitive motivational theory, the environment can influence an individual's motivation [11].

Due to complications of websites being restricted, certain lesson plans had to be altered or pushed back. This temporary solution was also put in place for Classes A and B when the materials for certain lessons were misplaced. This forced lessons in the curriculum to be taught out of order, which likely increased frustration for students who had not learned everything needed for a following particular lesson because a preceding lesson was skipped. At other times, students did not have materials to perform their own project work and were reduced to following along in a lecture. This likely decreased students' sense of autonomy, causing an increase in amotivation [11].

All the classes had 3D printer failures at some point during the study. Because the schools were in rural areas and economically disadvantaged, there weren't any STEM professionals on site that could fix these printers. This source of frustration for students is a likely factor in reducing student motivation; many were unable to see their 3D designs printed and their curiosity on the subject could have been reduced [11].

When using Zoom, the planned setup was not feasible due to an extremely loud A/C unit for Classes A and B, resulting in a less optimal remote teaching setup. This change shifted the focal point for the classes. Instead of the students all sharing the same focal point, they each had their own singular focal point [23]. This change in environmental factors could account for the difference in the motivation of Classes A and B when compared to Class C. Social-cognitive theory states that environmental factors, both physical and social, influence motivation [11].

C. Elements Impacting Student Instructor Motivation

The researchers observed that student instructor motivation levels varied between the different classes. Zoom and the telepresence robot may have played a role in the student instructors' motivation levels. For Classes A and B, due to the failure of the classroom setup, the students had to individually join Zoom. While the students were encouraged to turn on their cameras, none of the students did. This prevented the student instructor on Zoom from having a face-to-face conversation with the students. The student instructor could have felt that the student was unmotivated due to their lack of screen participation. This could in turn demotivate the student instructor as it is known to demotivate in-person teachers [3]. But the telepresence robot was able to directly communicate with the students and see the student's workspace, regardless of their Zoom screen. This may have helped to motivate the student instructor because they could see the student participating.

From the results, researchers observed that there is a relationship between the co-located students' motivation and the remote student instructor's motivation. When the class was motivated, the student instructor was motivated. Previous work in traditional classroom settings has shown that, for teachers, there is a direct correlation between student motivation and their motivation: When students are motivated to learn, the teacher is motivated to teach [3]. This result indicates that there is a similar link between student instructor motivation and student motivation, even though the students were co-located and the student instructor was remote.

VI. Conclusion

With the increased need for engineers, it is important to evaluate the motivation of students within engineering programs. Unfortunately, rural and economically disadvantaged schools—due to their distance from population centers and lack of funding—often do not have equitable access to STEM education and are at risk of amotivation. With Zoom being a useful teaching tool, student instructors taught remotely with the combined use of telepresence robots. Because of the known relationship between teacher and student motivation, it is important to examine if there is a relationship between the motivation of a remote student instructor and motivation of the co-located students.

In this paper it is seen that the three classes each had different levels of student motivation. The content of the curriculum was the same across all classes. The different components of the curriculum demonstrate the impact the varied levels of student motivation had upon student performance. The classes with lower motivation performed less overall work and performed fewer of the more difficult or daunting submissions. The curriculum could be changed by assigning easier tasks to the students, potentially building students' self-efficacy.

Student motivation was impacted by a number of technical issues. Issues with websites and materials forced reordering of lessons and decreased student autonomy, negatively impacting motivation. Additionally, equipment failures reduced positive reinforcement and environmental challenges reduced central focus, both likely resulting in reduced motivation.

Co-located student motivation correlated with remote student instructor motivation. As student motivation decreased, so too did student instructor motivation. The same holds true for increases in student motivation, which raised instructor motivation. This matches previous research about teacher motivation as it relates to student motivation.

VII. Limitations and Future work

There are several areas where the work in this paper can be extended. The study could first be expanded by offering other schools an option to opt in, increasing the sample size.

Direct surveys of the students would provide an additional avenue to gather information about student motivation and self-efficacy, providing more credibility to the observations of the student instructors. Additionally, if these surveys of students were done longitudinally across the school year, changes in motivation could be more granularly tracked to establish specific points of motivation change.

Longitudinal surveys of the student instructors could also be used to track not just changes in motivation but how long it takes for changes in student motivation to impact student instructor motivation.

This work looks solely at instruction done by remote student instructors—using Zoom and a telepresence robot—to co-located students. Future work could compare this remote setup to other remote programs to measure the impact of this program on motivational issues.

Future work could also do a direct comparison between students taught remotely via telepresence robot and those taught in a mixed remote/co-located mode.

ACKNOWLEDGEMENTS

This material is based upon work supported by the National Science Foundation under Grant Numbers 1949439 and 1917950.

REFERENCES

[1] Hirsch, Linda S., Siobhán J. Gibbons, Howard Kimmel, Ronald Rockland, and Joel Bloom. 2003. “High School Students Attitudes to and Knowledge about Engineering.” In *Frontiers in Education Conference*, 2:F2A – 7. STIPES.

[2] Ford, Valjeaner B., and Douglas E. Roby. 2013. “Why Do High School Students Lack Motivation in the Classroom?” *Global Education Journal* 2013 https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=65164011790d512f74da8969659247c4274a0d69.

[3] Börü, Neşe. 2018. “The Factors Affecting Teacher-Motivation.” http://acikerisim.nevsehir.edu.tr/handle/20.500.11787/2319.

[4] Oko, Orji Friday. 2014. “Impact of Teacher Motivation on Academic Performance of Students.” In *National Association of Mathematics Students’ Conference/Seminar Held at the College Auditorium, Nwafor Orizu College of Education, Nsugbe, Anambra State, Nigeria*.

[5] Hardré, Patricia L., H. Michael Crowson, Teresa K. Debacker, and Deborah White. 2007. “Predicting the Academic Motivation of Rural High School Students.” *Journal of Experimental Education* 75 (4): 247–69.

[6] Hordemann, Glen, et al. "Everybody needs somebody to teach: Embodiment, telecommunication, and telepresence in stem learning." *2020 ASEE Virtual Annual Conference* Content Access. 2020.

[7] Stenman, Saga, and Fanny Pettersson. 2020. “Remote teaching for equal and inclusive education in rural areas? An analysis of teachers’ perspectives on remote teaching.” *The International Journal of Information and Learning Technology* 37 (3): 87–98.

[8] Ejiwale, James A. 2013. “Barriers To Successful Implementation of STEM Education.” *Journal of Statistics Education: An International Journal on the Teaching and Learning of Statistics* 7 (2): 63–74.

[9] Rincon, Blanca E., and Casey E. George-Jackson. 2016. “STEM Intervention Programs: Funding Practices and Challenges.” *Studies in Higher Education* 41 (3): 429–44.

[10] Vennix, Johanna, Perry den Brok, and Ruurd Taconis. 2018. “Do Outreach Activities in Secondary STEM Education Motivate Students and Improve Their Attitudes towards STEM?” *International Journal of Science Education* 40 (11): 1263–83.

[11] Cook, David A., and Anthony R. Artino Jr. 2016. “Motivation to Learn: An Overview of Contemporary Theories.” *Medical Education* 50 (10): 997–1014.

[12] Johnson, Davion. 2017. “The Role of Teachers in Motivating Students to Learn.” *BU Journal of Graduate Studies in Education* 9 (1): 46–49.

[13] Pajares, Frank. 1996. “Self-Efficacy Beliefs in Academic Settings.” *Review of Educational Research* 66 (4): 543–78.

[14] Julia, Carme, and Juan Òscar Antolí. 2019. “Impact of Implementing a Long-Term STEM-Based Active Learning Course on Students’ Motivation.” *International Journal of Technology and Design Education* 29 (2): 303–27.

[15] Master, Allison, Sapna Cheryan, Adriana Moscatelli, and Andrew N. Meltzoff. "Programming experience promotes higher STEM motivation among first-grade girls." Journal of experimental child psychology 160 (2017): 92-106.

[16] Kawasaki, Hiromi, Satoko Yamasaki, Yuko Masuoka, Mika Iwasa, Susumu Fukita, and Ryota Matsuyama. 2021. “Remote Teaching Due to COVID-19: An Exploration of Its Effectiveness and Issues.” *International Journal of Environmental Research and Public Health* 18 (5): 2672.

[17] Hordemann, Glen, Francis Quek, and Gabriela Gomez. “In the Footsteps of Learning: A Comparison of Robotic and Human Instructor Movement in the Classroom.” *International Conference on Human-Computer Interaction.* Cham: Springer Nature Switzerland, 2024

[18] Okundaye, Osazuwa, et al. "Telepresence robotics for hands-on distance instruction." *Proceedings of the 11th Nordic Conference on Human-Computer Interaction: Shaping Experiences, Shaping Society*. 2020.

[19] Liu, Ting, Francis Quek, and Glen Hordemann. 2023. “Physical Computational Models for Horizontal Learning in STEM.” In *2023 IEEE Frontiers in Education Conference (FIE)*, 1–9. IEEE.

[20] Kokotsaki, Dimitra, Victoria Menzies, and Andy Wiggins. 2016. “Project-Based Learning: A Review of the Literature.” *Improving Schools* 19 (3): 267–77.

[21] Hordemann, Glen, Francis Quek, and Larry Powell. 2023. “Reaching Across the Communication Gap: Evaluating How Augmented Reality Shared Gestural Spaces Impact Gesture and Language Usage.” In *2023 IEEE Frontiers in Education Conference (FIE)*, 1–6. IEEE.

[22] Blanchard, Jeremiah, Chistina Gardner-McCune, and Lisa Anthony. 2019. “Effects of Code Representation on Student Perceptions and Attitudes Toward Programming.” In *2019 IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC)*, 127–31. IEEE

[23] Aspelin, Jonas. 2010. “What Really Matters Is ‘between’—Understanding the Focal Point of Education from an Inter-Human Perspective.” *Education Inquiry* 1 (2): 127–36.