Autonomy Relation to Student's Motivation in STEM

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Autonomy Relation to Student's Motivation in STEM

Halle Patton

HONORS PROJECT

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UNIVERSITY HONORS

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Introduction

Student individuality is an important factor for teachers to consider when in an educational environment. Examples of student individuality include student interests, learning preferences, and overall identity. Through tasks in which students are in control of both the product (how they show their learning) and the process (the steps they take to learn) students are able to create their own goals and develop agency in order to achieve them (Turner & Paris, 1995).

Teachers should use open-ended activities, as they encourage students to, “set goals, select and organize information, choose strategies, and assess the final results” (Turner & Paris, 1995, p. 664). With students taking ownership throughout the entire learning process, they become more actively engaged and motivated because of the personal responsibility they feel to learn. This is an example of a teaching practice known as autonomy-supportive teaching.

Reeve and Cheon (2021) describe this way of teaching as “the adoption of a student-focused attitude and an understanding of interpersonal tone that enables the skillful enactment of…instructional behaviors to serve two purposes—support intrinsic motivation and support internalization” (p. 1). Thus, when learning environments are catered to the students and their needs, students will be more motivated and able to understand the information they are taking in more clearly. Together, motivation and internalization create a more fruitful learning environment for students and a more manageable classroom for teachers. This can occur through decreasing negative behaviors and increasing intrinsic motivation (Vansteenkiste et al., 2020).

To better understand just how impactful autonomy can be on education, I conducted research to answer one central question: How does having autonomy-supportive teachers
influence student’s motivations in science, technology, engineering, and mathematics (STEM) learning environments?

The relationship between autonomy-supportive teaching and student’s motivation could greatly affect how learning environments are constructed and facilitated going forward. The purpose of my research is to help change how we teach— and for the better.

I will be using my own meaning of STEM to organize the supporting literature to clarify the purpose of my project. I have broken the acronym down to explain the components of Self-Determination Theory (S), Teaching Practices (T), Enrichment (E), and Motivation (M). Though Science, Technology, Engineering, and Math, still play a key component in this project, my version of STEM will help me to frame and analyze the educational environment that the original STEM is a part of.

Literature Review

Self-Determination Theory

Self-Determination Theory (SDT) is made up of three key components— autonomy, competence, and relatedness. Deci and Ryan (2008) suggest:

As a macrotheory of human motivation, self-determination theory (SDT) addresses such basic issues as personality development, self-regulation, universal psychological needs, life goals and aspirations, energy and vitality, nonconscious process, the relations of culture to motivation, and the impact of social environments on motivation, affect, behavior, and well-being (p. 1).

Deci and Ryan (2008) explain in “Self-determination theory: A macro theory of human motivation, development, and health” how self-determination theory affects the body and mind as a whole. One of the points that they emphasize is that using individual difference is impactful
when determining how to motivate a student. One way to focus on an individual and motivate that student is to give them autonomy in their environment.

Autonomy is a “basic human need and motivational drive” (Alrabai, 2021, p. 4). Fakieh Alrabai performed an investigation on autonomy and its relation to English as a Foreign Language (EFL) students. The article goes on to explain the benefits of autonomy in EFL learning environments and just how impactful it can be. In its simplest sense, autonomy means independence. When students are given independence in the classroom, they account for their own thoughts and actions. When one has responsibility over their own thoughts and actions, they are more likely to want to engage with their environment in a positive manner. One aspect of their environment is the relationships that the individual forms with others around them. The value that individuals place on these relationships is known as relatedness. (Vansteenkiste et al., 2020).

Relatedness comes from the relationships that one forms within one’s environment, and can greatly affect an individual. This effect can be positive or negative. When negative, Vansteenkiste et al. (2020) explain that, “Relatedness frustration comes with a sense of social alienation, exclusion, and loneliness” (p. 3). Being excluded and feeling alone are indicators of a student who is not going to want to participate in their environment. This creates a snow-ball effect: the engagement of an individual is known as their competence, and when the individual's relatedness is negatively affected, their level of competence will be too.

However, “[competence] becomes satisfied as one capably engages in activities and experiences opportunities for using and extending skills and expertise” (Vansteenkiste et al., 2020, p. 3). It is so important for an individual to have autonomy and a positive sense of relatedness because it has a direct correlation with engagement. Vanteenkiste et al. (2020)
worked to unpack the three components of self-determination theory to help better understand how the three affect one another, and how they affect motivation and engagement in students.

When the three components—autonomy, relatedness, and competence—are all positively affecting one another, students will feel more motivated and encouraged to learn. I studied and observed how allowing students autonomy, encouraging individual capability, and establishing strong teacher-student relationships can increase motivation.

This information will be beneficial for students and teachers alike, as students will internalize more from their learning environment and teachers will have learners that are more engaged and productive.

**Teaching Practices**

The environment, expectations, and instructional methods that a teacher chooses have a great effect on student learning and development. To make this a positive effect, teachers must foster an environment where students are the focus. Including student choice and interest will create the most beneficial environment for students. Jang et al. (2010) noted:

Autonomy-supportive teachers facilitate students’ personal autonomy by taking the students’ perspective; identifying and nurturing the students' needs, interests, and preferences; providing optimal challenges; highlighting meaningful learning goals; and presenting interesting, relevant, and enriched activities (p. 589).

Jang et al. (2010) worked to show how teaching practices that involve high structure and an autonomy-supportive foundation can work together to increase engagement in a student’s environment.

I focused on autonomy-supportive teaching from both the teacher and student perspective, specifically within STEM educational environments. The environment of the
STEM Summer Camp revolved greatly around choice—a key component of autonomy.

“Another crucial element of choice is that it can encourage students to take personal responsibility for their tasks by setting goals and deciding how to reach those goals” (Turner & Paris, 1995, p. 665). Turner and Paris dissect environmental factors and instructional choices and relate them to student motivation and engagement. Their findings showed that open-ended activities are more likely to improve motivation and engagement versus close-ended activities. The structure of the camp supports this by using open-ended activities to encourage students to apply the knowledge they gain to real world problems.

The framework allows for a gradual release of responsibility. It begins with the teacher, otherwise known as the Team Leader, who guides the students through literature, both nonfiction and fiction, and then poses a challenge to solve a problem shown throughout the reading. The students then are able to brainstorm individually three separate designs with sketches and explanations, before collaborating with their group (3-5 students) and deciding on one design. This framework also allows for legitimate peripheral participation to take place. This is when learning goes from students being on the peripheral—or edge—at first, but then gradually becoming confident enough to fully engage (Lave 1991; Lave and Wenger, 1991). I will observe how this kind of participation mixes with autonomy, then note how the correlation affects motivation.

In a similar STEM environment, Roberts et al. (2018) explained, “the community is an essential element of the meaningful context and is a powerful vehicle for transforming perspectives and understandings” (p. 3). The STEM Summer Camp puts emphasis on the aspect of community, motivating students to participate in STEM related activities in an enriched environment.
**Enrichment**

Enrichment refers to the opportunities outside of the traditional classroom where students are able to learn and grow in a low-stakes environment. “In an era of budget cuts and pressure to cover material that will appear in standardized tests, schools are often limited in the access they can provide to in-depth content and authentic settings” (Roberts et al., 2018, p. 11). The BGSU TIME STEM Camp that took place the summer of 2023 is exactly the kind of low-stakes environment that provides authentic enrichment where students can apply themselves without fear of falling-short or being graded. Similar STEM summer experiences have increased students’ interest in STEM” (e.g. Mohr-Schroeder et al., 2014). The low pressure settings have also been shown to increase student’s interest in future STEM careers (Kitchen et al., 2018; Kong et al., 2014). As a Team Leader in the BGSU TIME STEM Camp, I was able to experience the environment myself. Though the focus is on STEM environments, Autonomy Supportive Teaching is beneficial in a wide variety of environments as well. Evidence of this was found in a study done within a physical education environment. Leisterer and Paschold (2022) found that, “being autonomous and free in one’s choices supports the individual in being responsible for her or his own outcomes (e.g., affective-emotional, behavioral) in life” (p. 2). This is just one example of how autonomy-supportive teaching can elevate the educational process in another environment. **Motivation**

Motivation is the fuel that runs everyday life. Without motivation, nothing would get done. More importantly— learning would not get done. If one is not motivated to engage, or even observe, that person will not be able to take in information and the experiences that are happening around them. Jang et al. (2010) noted:
When autonomy-supportive teachers nurture students’ inner motivational resources, they create opportunities for students to take the initiative during learning activities by building instruction around students’ interests, preferences, personal goals, choice making, and sense of challenge and curiosity, rather than relying on external sources of motivation such as incentives, consequences, directives, and deadlines (p. 589).

The purpose of my project was to find ways to motivate students in learning environments. As previously stated, inner motivation occurs when a student wants to participate because they desire to, not because they are being told they have to. A way that this can be achieved is through using a student’s individuality to engage them with the material or activity. By knowing the student for who they are, their interests and likes can be incorporated in order to make the material or activity more appealing. An example of this would be if a teacher knows that a majority of their class enjoys crafting, instead of having the students show what they know through a quiz, they can create a diorama instead. Increasing motivation does not have to occur through sticker charts, detentions, or due dates— but instead can occur through connection between the student and the material or activity. Another way to increase student motivation is through choice. Leisterer and Paschold (2022) found that:

Motivation regulation processes can be described on a continuum reaching from external to internal motivation regulation. This continuum comprises external and introjected (i.e., external motivation regulation) and identified, integrated and intrinsic regulation (i.e., internal motivation regulation). Internal motivation regulation is seen as similar to the development of internal locus of control by providing individual autonomy and freedom (p. 2).
When given choice, it encourages students to take responsibility for their learning. Because they are not being demanded, but rather driven to make their own decisions, students may be more likely to participate.

**Methodology**

To investigate the relationship between autonomy and motivation within a STEM environment, I became a facilitator for STEM camps in my community. The STEM camps were carried out by the TIME tutoring program at my university—Bowling Green State University. The TIME (Tutoring in Math and English/Language Arts) program had one main goal— to provide content area learning in an enriched environment. The two STEM camps took place during the summer of 2023. Each camp was one week long and served approximately 60 students. The first camp served rising 5th and 6th grade students within an intermediate school environment. The second camp served rising 4th and 5th grade students within an elementary school environment. Both weeks of camp occurred in Northwest Ohio.

The same activities were completed during both camps. These activities followed the same general structure: read a piece of literature, receive a real-world problem, independently make a plan to solve the problem, collaborate and defend ideas, decide on a design, build a creation based on the design, test the creation, revise, test again, and finally, reflect on the experience. Each day there was a different real-world problem or situation that was presented to the students.

One of the real-world problems that was asked of the students was to build a helmet. This activity correlated with the book *My Papi Has a Motorcycle* written by Isabel Quintero and illustrated by Zeke Peña. Students were given a plastic egg filled with beads, and asked to create
a helmet that would protect the egg when dropped from a certain height. The students first thought about the problem. Then they made four drawings with labels and explanations that they came up with independently. Once the entire group had four drawings each, they came together and presented the one that they thought was best. Out of the four designs, the students had to come together using reasoning and problem-solving skills to decide on one design. After their design was chosen and agreed upon, the students began to build. Using the resources provided, students created their helmets and put them on their eggs. The facilitator in their room then measured the height, starting at six feet, for the students to drop the egg. After the egg was tested the students had to observe if their design was successful or unsuccessful. If successful, students were then challenged to create another design using less materials as an eco-friendly alternative. If the students were unsuccessful, they were asked to create a new design or decide on another pre-existing design. Students then were able to test again. Following the second trial, students were asked to reflect on what they thought was positive, negative, or important to note about their designs. Students then shared with the class what their group experienced throughout the activity and anything else that they wanted to share.

Another real-world problem asked was how to build a filtration system, connected to the book *The Unstoppable Garrett Morgan: Inventor, Entrepreneur, and Hero* written by Joan Dicicco and illustrated by Ebony Glenn. This piece of literature told the story of how the first fire-fighter mask was created. Another piece of literature, *Twenty-One Elephants and Still Standing* written by April Jones Prince and illustrated by François Roca, told the story of the creation of the Brooklyn Bridge. This book tied in with the experiment on building bridges.

The STEM learning camp also included a designated technology block. This robotics time occurred in the latter half of the day. The different technologies consisted of Ozobots,
Spheros, and 3D pens. The Ozobots were small robots that followed lines drawn on paper in correlation with different colors and patterns. The Spheros were clear spheres that rotated to move around on the ground in relation to the controls on a Bluetooth connected iPod. Lastly, the 3D pens were slightly larger pens that used colored plastic to melt and form the desired creations of the user. This use of technology was a key component of the STEM camp.

Participants

The facilitators of the STEM camp were the primary participants of my research project. Employed through the TIME tutoring program, these five tutors carried out their roles through the entire duration of both STEM camps. Four of the five facilitators were teacher candidates at Bowling Green State University in their fourth year. The fifth interviewee was a masters student at Bowling Green State University who had previous contracted teaching experience. I was able to connect with and interview these women in order to gather well-rounded data and an insight to other perspectives during the camp.

I also used my own experiences to reflect on and guide my research project. I am a fourth year teacher candidate at Bowling Green State University.

Data Collection

Data collection consisted of my reflections as a team leader and of virtual interviews with other team leaders. All facilitators who participated in the interview process were present at both STEM camps. During the interviews, facilitators were asked about their thoughts, feelings, and overall experience during the STEM camps through eight guiding questions.
Table 1

*Interview Questions*

1. Tell me about your experience with STEM before working in the informal learning experience.
2. Do you see STEM as useful in the classroom? How so or how not?
3. Most elementary teacher programs have courses focused on teaching math and science. How did you focus on the Technology and Engineering aspects of STEM too?
4. Thinking about standards in math and science—How did the ideas in those standards connect to what you facilitated in the informal learning experience?
5. How would you describe your approach to facilitating an integrated STEM lesson?
6. Most of the projects were very open ended. How did you balance giving students autonomy to make choices with being able to connect important ideas in science and math?
7. What connections, if any, do you make between problem solving from a STEM perspective and a social emotional learning perspective?
8. Thinking about your experiences facilitating the informal STEM learning experience, are there two to three specific experiences or things that happened that had the biggest impact on your thinking and development as a teacher?

These questions served as a chance for fellow Team Leaders to share what they experienced. Having other perspectives ensures a well-rounded collection of data to support my conclusions.
Data Analysis

I used a deductive approach (Miles et al., 2013) to analyze data. All interviews were transcribed to allow a more in-depth analysis of the interviewees' experience. A priori coding (Saldaña, 2021) took place based on ideas from the autonomy and motivation literature I reviewed. Then, through the self-determination theory framework as the guiding principle, the codes were applied in the deductive analysis process.

Table 2

Codes for data analysis

<table>
<thead>
<tr>
<th>Code</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motivation</td>
<td>The student’s desire to succeed rose or fell.</td>
</tr>
<tr>
<td>Communication</td>
<td>The student or teacher willingly communicated with others to work towards a shared goal.</td>
</tr>
<tr>
<td>Self-efficacy</td>
<td>The student or teacher believed that they could complete a goal. This can be relative to confidence level.</td>
</tr>
<tr>
<td>Creativity</td>
<td>Students came up with original ideas to solve a problem when given the opportunity.</td>
</tr>
<tr>
<td>Engagement</td>
<td>The student participation level rose or fell.</td>
</tr>
<tr>
<td>Challenged</td>
<td>The teacher challenged the student, or the student challenged themselves, to think critically and further understand or solve a problem.</td>
</tr>
<tr>
<td>---------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Metacognitive Practice</td>
<td>The learners became aware of their own learning process and ways of thinking. This can be done with teacher facilitation or independently. Teachers can make the learning process explicit to students and promote self-evaluative practices among students (ex. diaries, portfolios)</td>
</tr>
<tr>
<td>Power/Control</td>
<td>The student or teacher has power or control over a thinking process, decision, and/or action.</td>
</tr>
<tr>
<td>Self-Determined Learning (SDL)</td>
<td>The environment is student-centered with emphasis on students essentially creating/leading their own content, process, and product.</td>
</tr>
<tr>
<td>Self-regulation</td>
<td>Students take responsibility in their learning. This is done through planning, monitoring, and reflecting with little to no support from</td>
</tr>
</tbody>
</table>
the teacher (facilitator).

<table>
<thead>
<tr>
<th>Autonomy</th>
<th>Students experience volition (will) and self-endorsement (approval) in actions.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Competence</td>
<td>Students experience improvement and a sense of being effective in one’s interactions with the environment.</td>
</tr>
<tr>
<td>Relatedness</td>
<td>Students experience a welcoming, responsive, and reciprocal learning environment.</td>
</tr>
<tr>
<td>Intrinsic Motivation</td>
<td>Students want to participate in the activity successfully despite the absence of a reward.</td>
</tr>
<tr>
<td>Self-report</td>
<td>Students share their thoughts, feelings, or attitudes on specific occurrences.</td>
</tr>
<tr>
<td>Choice</td>
<td>Students were given the opportunity to choose in a situation.</td>
</tr>
<tr>
<td>Classroom Management</td>
<td>Teacher’s choice in instruction style and grouping arrangements.</td>
</tr>
<tr>
<td>Intervention</td>
<td>Teacher intervened in a student’s thinking, solving, or reflecting process.</td>
</tr>
<tr>
<td>Individuality</td>
<td>Refers to students personally/individually.</td>
</tr>
<tr>
<td>Informal Learning</td>
<td>Evidence of the informal learning environment is discussed: unplanned/unstructured learning, focuses on experiences, and flexible processes.</td>
</tr>
<tr>
<td>-------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Perception</td>
<td>Discusses what STEM means to the teacher or the student.</td>
</tr>
<tr>
<td>Real-World Connection</td>
<td>The situation or activity connects to a real life situation. Student’s are made aware of the connection.</td>
</tr>
<tr>
<td>Rationale</td>
<td>“Verbal explanation as to why putting forth effort during the activity might be personally useful.” Teacher offers a student's rationale or students offer rationale for their choices.</td>
</tr>
<tr>
<td>Behaviors</td>
<td>A student or teacher behaves in a certain way in response to a situation.</td>
</tr>
<tr>
<td>Teacher-student (TS) Relationship</td>
<td>The relationship formed between a teacher and a student is important. Evidence of a positive or negative TS relationship are the interactions, responses, and communication style.</td>
</tr>
</tbody>
</table>
Effectiveness

The effectiveness of the environment or a specific activity is discussed.

Importance

Response on the importance of STEM in education.

Responsibility

Student’s are specifically responsible for their learning or choices in a scenario or situation.

Expectations

This can be either the expectations that a teacher had for students or what the student/teacher expected for the STEM camp.

Literature

Literature connections were discussed.

Enrichment

This refers to the STEM camp environment and how it made learning more meaningful and impactful.

Persistence/Problem-Solving

Students or teachers put effort in repeatedly to reach a goal.

Internalization

The lesson or instruction stayed with the student past the classroom doors

After the first round of coding, I completed a second cycle of coding. At this time I added new codes to the list and applied those – and any I may have missed within the first cycle – to the
transcripts. A couple examples of these new codes were persistence/problem-solving and behaviors. I noticed that these were recurring through facilitators experiences and helped to explain times and ways in which students self-regulated when facing challenges. A very common time where this self-regulation took place was when students' creations did not immediately succeed. Facilitators expressed how students would become upset, but then were encouraged to problem-solve. With this simple scaffold, facilitators found that students were able to face the challenge and discover ways to move forward through the power of their own critical thinking skills.

As the second cycle took place, I also noticed many recurring codes. These patterns then took precedent, and within the patterns I determined a few themes: self-determination theory, self-regulation, classroom management, communication, and connecting to real-world ideas.

**Findings**

Communication and classroom management is one of the themes that I determined, along with relation to real world connections, self-determination theory, and self regulation. These main topics all play a role in student motivation and engagement. “I also think it's really good to help motivate kids because when I think of STEM I think of...um...like...kind of taking a problem and then building some physical thing and like doing experiments with it. I feel like that's really good for motivating kids in the classroom. I also think it's good because it gives kids like a manipulative and...like a hands-on approach to a lot of things,” says Marissa. The correlation between hands-on activities and motivation was very prevalent. Another very impactful piece of engagement is student choice and responsibility. These two factors are best explored through self-determination learning and self-regulation teaching practices.
Self-determination Theory and Self-Regulation

Self-determination theory (SDT) in combination with self-regulation was prominent during the STEM camp. Self-determination theory was evident when facilitators spoke of the competence, autonomy, and relatedness that occurred within the camp environment. When students experience the three components of SDT, they have to have the skill of self-regulation readily available. Because the self-determination theory relies heavily on student responsibility, students must be able to monitor their own thoughts, feelings, and behaviors. Students that are properly regulated are more able to focus on the task at hand.

Competence was shown when students had more control over their environment and what they were doing. The STEM camp is an informal learning environment. Because of this, the teaching practices and educational activities differ from that of a typical classroom atmosphere. Team Leader Marissa says, “I feel like we didn't do a ton with like computers like the traditional technology sense, but we used like technology through other ways. I feel like the egg drop thing could have been an example of technology—like a way to protect something—as well as the bridges.” Through the various experiments—building bridges, filters, helmets, structures, and vehicles—the students used their resources to apply what they know into scientific creations. This informal, hands-on approach seemed to increase student engagement with STEM. I believe this is because students were able to be in control of their environment throughout the entirety of the process. They created their designs independently, had to agree within their group on a design, and then built their object with little to no assistance from the facilitator. This made them responsible for their own learning and the outcome at the end of the experiment.

Through self-determination theory, it’s proven that having control over learning can motivate students. When asked if STEM is useful in the classroom Team Leader Janice said,
“Yeah, I think so. It definitely allowed students for like a lot more independence, which was really cool because they got to kind of guide their learning. Um, so it's very student-centered and I liked that because, you know, they were coming up with their own questions rather than me having to like…ask them questions. And of course, like I did ask them questions, but they came up with a lot more than what I would have expected at the beginning.” This provides evidence that allowing students to guide their own learning can promote higher-level thinking. As Janice expressed, students were able to come up with their own questions. Students then took these questions and used them to work in solving a given problem. Critically thinking and willingly engaging, students participated fully in the STEM environment.

Autonomy is also a key component of the self-determination theory. Autonomy was a perpetual force throughout the camp. Evidence of this was shown through how facilitators of the camp spoke of student choice. I found that a recurring example of student choice within the camp took place during the designated technology block.

Learning does not have to be simplistic, basic, or boring. Learning should be colorful, vast, and experimental. By using the Ozobots, students practiced attending to precision through the intricate patterns that needed to be created to make the device perform its many functions. Student engagement with Spheros allowed for time honing operational and directional skills that were very important to control the robot’s movement. For the 3D pens, it was crucial that students follow the process of using the tool in order to safely and effectively create physical objects. While interacting with each of these technologies, students got to choose how they spent their time. This ability to choose encouraged students to spend their time being purposeful and to engage with the task at hand however they felt was impactful for them.
However, tech time was not the only duration in which autonomous learning took place. “It was like…there's definitely math involved, but it wasn't traditional— like adding, subtracting, multiplying, dividing. They had to like…they did have to figure out…like they had a set number of like sticks and they had to figure out how much they're going to use on each side,” says Marissa. During an informal activity like this, students were able to choose how they were going to use materials. She then goes on to say “So, you know, that's math, kind of a little bit of division there. And then they had to also divide the supplies equally. So I would say there's like computing within that. But very informal. So maybe they're not really realizing what they're doing is math.” By having this responsibility to model and create without being told what they can use and what they can make, students had the freedom to think outside the box. I also believe the informality of the camp is an immense reason for increased engagement. As Marissa stated, at times during the STEM camp it can be perceived that subject area learning is not taking place. However, as she expressed, students are learning within many content areas— even if they don’t know it! Instead of working out of a workbook, students are participating in hands-on activities that enhance the power of choice and encourage them to think deeper.

Though the engagement is prevalent, many of the facilitators expressed that it was not always easy. This is when self-regulation comes into play. Lauren explained, “I mean, they had to understand what are we looking for in this experiment. Um, what's the best way to do this? I mean, it was tricky for a lot of the kids. They had to try and try again. There were multiple trials.” Giving students control of the environment meant facilitators had to take a step back and let students make mistakes. Though it would have been easier to stop the student if the facilitator saw they were making the wrong choice when selecting a material or missing a step when building from their design, it would not have been nearly as impactful for their learning. If they
were corrected, students would simply do whatever the facilitator said. However, when given the opportunity to choose and to fail, students had to think critically in solving the problem. Because they were guiding their own learning, students had to take responsibility for the mistake and know that it was their job to solve it. In this way, the camp helped to teach and provide opportunities for students to improve their perseverance skills. When it comes to learning, mistakes are inevitable. Within this low-stakes environment students could experience that failure and then experience self-regulation through problem solving. “It was a lot of, like, coping with that failure, but then realizing that they can improve if they sit down and think it through,” says Janice. Thinking it through is a life skill that will promote success for students beyond this informal learning experience.

The final component of self-determination theory that was evident was relatedness. Relatedness was shown through how students connected with their environment and the feeling of belonging that they felt when interacting with their peers and facilitators. I believe that relatedness is strongly connected to the atmosphere of the learning environment. Communication and classroom management play key roles in forming and maintaining the learners atmosphere.

**Communication and Classroom Management**

There were many factors that went into running a smooth STEM camp. Effective classroom management strategies and communication were just two of them. When determining themes, I found that classroom management and communication went hand in hand. To have effective and clear communication between both the students and facilitators, and the students and other students, it was important to have established expectations and support. To create and enforce these expectations, as well as relay the option for support, students and facilitators had to communicate effectively. Specifically, for the learning activities, it was important to employ
strategies that helped support transitions from one part of the lesson to the next. Because the STEM camp allowed for primarily student control, it was important to set the tone and introduce scaffolds early on. One strategy that various tutors used was modeling.

Lauren explained, “I think modeling is extremely important in both education as a whole and in STEM.” I found this quote to be impactful because it sheds light on how classroom management strategies do not have to be exclusively used in formal versus informal environments. Modeling is a great example of how thoughtful instruction can help a classroom run smoother. Here, modeling was used as a “spark” according to Lauren who continued on to say, “You could show them pictures of other designs people have done in the past. It kind of gives them that freedom, or spark, and then they can go on from there!” Using modeling within instruction allows for a visual support that not only supports student understanding, but engages students with the task at hand. An important point that Lauren is also making here is that you can use modeling, but then it’s important to hand that control back over to the students. Tina agrees, as she says, “I think that helps them think of ideas and connect to it and their experiences they have prior. So I think that's a good first step going from there, just letting the students facilitate it, letting them take the activity where they want to.” By transitioning the responsibility from teacher to student, Team Leaders were able to promote that autonomy. By using modeling and giving that autonomy, classroom management was easier to facilitate because students were engaged and motivated to do their work. A part of engagement that was relevant to the STEM camp is collaboration— specifically through the decision making process.

When it came to collaboration, Tina stated, “We wanted them to go through that full process of creating, collaborating with their peers and discussing what they wanted to create. Um, debating on why they should choose different things versus others, making sure they have
reasoning for what they're choosing.” Instead of having students in separate desks, facilitators were able to arrange the room in tables to promote continuous collaboration with peers. I found in my own classrooms that as long as I used effective classroom management skills, like appropriate grouping and attention signals, it was easy to promote order and organization.

Though there were times when I needed the attention of the whole room and the grouping made it seem challenging, I simply asked the students to turn their chairs and show with their bodies that they were actively listening. I established early in the camp that active listening meant their eyes had to be forward, body in the direction of the person speaking, and voices off. By reinforcing this through repetition and positive feedback, students followed directions quickly and effectively. This made the transition from independent to group time run smoothly. This smoothness allows for students to have more time dedicated to engaging with the STEM activities. Supplying this dedicated work time made it to where students were able to put in the time and effort to deeply think about what they were doing. This higher-order processing was important when students were asked to communicate with others about their own thoughts and perceptions.

Active listening was also enforced within group collaboration—specifically when it came to explaining and defending their models. In any collaborative environment, there are a variety of participants. For example there may be the person who is shy and whispers when they talk or the person who is nervous and rambles on when it's their turn. Through teaching students active listening, facilitators were able to teach respect within communication. This reinforced an atmosphere where students felt welcomed and comfortable.

While collaboration is a key component in the learning environment and autonomy-supportive practices, it can have its challenges. “There were never any issues with the
regrouping of like mixing it up. But I definitely did see differences and attitudes and maybe motivation, depending on who was in their group that day,” expressed Nadia. When the attitude towards learning changes, it's hard to maintain an autonomous environment where students have the power of control. With control comes responsibility, and if students are lacking that motivation they may be less likely to want to participate or apply themselves to the full extent. Though it can be hard to balance motivation and collaboration, it is not impossible. Nadia went on to say, “We kept the STEP posters up in our classrooms…um…just kind of as a visual reminder for students to refer back to….um…especially when building or communication got frustrating when there was disagreement in groups.” The STEP posters that Nadia was referring to was a part of the Second STEP Social and Emotional curriculum that was used during the STEM camp. By offering that visual and showing social and emotional support to the students, the Team Leader promoted an environment in which students understood that collaboration can be a challenge, but there are tools to positively and effectively work through it. This effective classroom management allowed for students to not only experience the sense of relatedness that they belong– even if disagreement takes place– but also that strong sense of competence that they are in control of their environment and it's up to them to help make it positive.

A student’s surroundings have a great impact on them and their learning. Janice explained, “I think it allowed a really safe space for them to do that while learning…like problem and solution, analyzing their steps and where they went wrong, and finding their errors. So I think tying in the steps of engineering and then just like the environment of like, it's okay, like we're not giving you an F or like a bad grade because you didn't do this right. Like, this is all just for you. You're just self-motivated to do this. So it was a very safe space for them to like…experience failure and success.” The key piece here is self-motivation. I like how Janice
stated that the camp is all for the students. This understanding is crucial to properly instill a student-led atmosphere. Through offering the assurance, students can feel free to explore and try things they might not have before. When the pressure of failing is lifted off their shoulders, creativity and confidence is able to take its place.

Similarly, Tina stated, “This was a summer camp and it's not like we were teachers that've been with them all year. Like, they didn't know us just as much as we didn't know them. So I think they felt, um, more comfortable just in a group setting and not being questioned one on one.” I found it interesting that Tina expressed how the teacher-student relationship also played a role in the informal environment. Recognizing and knowing how an individual student feels in an environment helps to guide the teacher in supporting and encouraging that student. The environment should promote opportunities to fail and the self-acceptance skills to cope when one does. This has to be communicated with students and reinforced. Personally in my own classrooms I often used the phrase “mistakes are proof that you are trying” that I learned from a mentor teacher of mine.

This positive reinforcement could also help students to self-regulate within their environment. Marissa explains, “I feel like all people—all kids especially—really struggle with failure and not getting something right and it can cause a lot of, um, social/emotional problems. It can cause a lot of anxiety and like...um...insecurity when you're scared to fail. So letting kids fail in a very safe, fairly neutral environment where they're in a camp like this, you know, where there's no grades associated.” Social and emotional aspects of education go hand in hand with engagement and motivation. I think it’s important that this informal environment gave students a chance to experience failure in a place where they didn’t have negative consequences because they were able to feel free to learn through successes and mistakes. This helped them to gain
confidence in their interaction with STEM because through communicating with students that failure is okay and fostering a classroom environment that is equable, student’s could focus on solving the problem at hand. In turn, students thrived in an autonomous environment where they were able to feel free to choose, whether it resulted in success or failure.

**Real World Connections**

The facilitators of the STEM camp expressed an emphasis between STEM learning and the use of real world connections and implications. A skill that was employed to promote this level of internalization was the use of literature. Janice said, “Let's go back to the book and let's see what her helmet looks like. So they were like, ‘Oh, her face is showing, we have to have the face showing.’ So it challenged them more, but like by being able to relate it back to something that they all were knowledgeable of.” This was a helpful guiding tool for the students, and shows how teachers can provide scaffolding while still letting students have autonomy in their learning.

Another scaffold that facilitators used was encouraging connections to prior knowledge. Lauren explained, “I think it helps them to make more connections too. Cause they could be like, ‘Oh, this reminds me of the bridge in Toledo that we went over one day.’ I think it helps bridge connections that kids are making to what we're learning in STEM, or like what they're trying to create when they're doing a STEM project.” Not only do these real world connections help students understand a topic, it also helps them to engage with the activity on a more personal level. Because of that connection that they made, students are more likely to connect their learning to their schema in order to internalize the content. Internalization is vital when building and fostering skills that students will apply in the future.

When asked if STEM is important, Lauren said “I think it definitely is. I like it because I think it makes kids think about things on a deeper level, and I think it's also helpful for them to
be able to use computers. I know STEM involves more computers than we did at the summer camp, but it's useful for them to be able to use computers and to think about how experiments work and to think about technology and know the latest technology for things because you never know what they might do when they grow up or this could spark an interest for them.” Because many students don’t get the chance to participate in an environment like this, it was important to us facilitators to make it engaging and fun for students. I also think that the recognition of individuality is important because not all students have the same interests. By creating an environment that is rich in all content areas, more students will be engaged and impacted.

When asked the same question, Tina said, “I think STEM is very important and it's something that needs to be increasingly…like…represented in schools, just with how careers are nowadays.” This way of thinking is helpful because it draws attention to the fact that the skills gained in this STEM camp and the experiences made can lead to something greater. In relation, the knowledge gained throughout the STEM activities can lead to greater connection within the students real world environments. One example is described by Tina. She said, “They had to create a building that could withstand a tornado and just thinking about the architecture and how much time and effort goes into building structures. I think it's important because, like, they see construction or when new things are built around them, they know more of what has to go into that and how structurally sound the base has to be.” Connecting to the real-world makes the content that students learn more concrete in their brains. Marissa promoted this idea when helping students think more abstractly. She asked and followed the question, “Would your idea realistically work in this car that we're making?” She then expressed that it was all about “connecting it to the real world.”
In the end, the findings supported that a student-centered environment encourages both student engagement and motivation. Though there may be challenges to face in this new kind of learning environment, there are also many positives that outweigh the negatives. As Team Leader Marissa said, “Once they get there and realize it, it can get so cool and so fun. But it's definitely from my experience, a very student-led process. Because if you take that out of the equation, I've seen it to not be as effective of a learning experience if it's not pretty heavily student-led and student based.”

**Discussion**

The qualitative results revealed that through the interviews with the five Team Leaders, themes were determined. The consistency in which these themes arose suggests that though each facilitator and student is unique, there were many shared experiences within the informal STEM learning environment. However, there were also experiences that I expected to occur that did not. Specific examples are intervention and behavior.

Within my codes for data analysis I included intervention. I defined intervention as the occurrence of when a teacher intervened in a student’s thinking, solving, or reflecting process. Because this was a new environment for both the Team Leaders and students, I thought that it was going to be necessary for facilitators to intervene at times. However, through my findings it was seen that instead of intervening, facilitators offered support and redirection. Instead of saying “Maybe it would be better if you used two pieces of cardboard instead of one.” Facilitators used phrases like, “I see that your bridge fell down with not as much weight as you might have expected. Do you have a reason for why you think that happened?” This scaffold allowed for students to analyze the problem themselves and determine their own solution. Because of this, students were able to feel more sure of themselves and their ability to carry-out a
task (Deci & Ryan, 2008). So while there was a lack of intervention mentioned in the interviews, I believe that it is a positive thing— as it allowed for a more student-centered environment.

The other code for data analysis that seldom appeared was behavior. I defined behavior as occurring when a student behaved in a certain way in response to a situation. Though in my findings it was expressed that facilitators had to teach and reinforce self-regulation when students experience failure, I had believed that more negative behaviors would have been present. To me, being upset with failure is not a negative behavior. One should be allowed to be disappointed that what they put time and effort into did not succeed. However, that is when self-regulation is important to show students that they can prevail and solve the problem if only they try again (Reeve & Cheon, 2021). Because autonomy-supportive teaching allows for primarily student control, I had thought that more evidence of students being off task, unwilling to work with others, and refusal to participate, would have been prevalent. I believe this is due to the classroom management strategies and effective communication that the Team Leaders put in place.

From the themes that were apparent, a solid argument could be formed on why moving from teacher-centered to student-centered learning is the best decision for students and teachers alike. Whether it be through the self-determination theory— proving that autonomy, competence, and relatedness (Deci & Ryan, 2008) push students to their full potential, within teaching practices— the facilitation of effective communication and classroom management, or enrichment— allowing students to thrive in an untraditional environment full of real-world connections (Roberts et al., 2018), the research and interviews I conducted show that autonomous learning increases motivation and engagement in STEM.
The self-determination theory was a guiding principle in my research. The STEM summer camp experience reinforced why competence, relatedness, and autonomy are important within a classroom environment (Vansteenkiste et al., 2020). Team Leaders spoke of students feeling like a part of the environment through their engagement and collaboration within a group. They spoke of competence, when even though it was different to give control to students, it allowed for students to use their own desire to learn to carry out STEM procedures. This even made classroom management easier for facilitators, as students were engaged with their learning and focused on only the task at hand. Team Leaders emphasized the importance of choice throughout the entirety of the STEM camp. Admitting that at times it may have been more difficult to regulate student emotions in correspondence with failures, students internalized and learned more by leading their own learning.

Another key piece of autonomous learning that my research was based heavily around was teaching practices. The atmosphere, expectations, and way material was taught all went into the way students engaged with material. The Team Leaders expressed that during the STEM camp the teaching practices were different– as the learning environment was informal– but effective. A challenge that the facilitators faced was students’ self-efficacy. Because this environment was different, the students faced new challenges– some of which deterred them from confidence. Facilitators had to scaffold and emotionally support the students to set new goals and persevere through any roadblocks that they faced within the STEM activities. This helped them grow as learners and equipped them with skills that will be useful beyond the summer camp.

Because the summer camp was an informal learning environment with many untraditional components, the experience was classified as enrichment. The Team Leaders that
participated in this enrichment camp spoke highly of normalizing new ways of learning. One that was greatly supported was the use of robotics in the learning environment. In relation to this, Marissa expressed, “Well…they had the…um…those little balls [Spheroes] during the...like…tech time at the end. I think that was really cool for the kids, but I think they saw that more as like a playtime, which they definitely still like…learned from and got good experience from that.” Within this perspective, the informal technology is referred to as “playtime.” When I think of play I think of enjoyment, freedom, and student individuality. For example, centers in an early developmental classroom—such as preschool or kindergarten. During these levels, students have a lot of time that is dedicated to free-play. Whether free-play is choosing an activity within the classroom, or participating in imaginative play—such as classroom theater, self-regulation and self-determination are two huge factors in play. Within these free-play times, students are able to decide, based on their own interests, how they would like to spend their time. In this state, students are more likely to be fully engaged with the task at hand due to their intrinsic motivation level (Turner & Paris, 1995). Instead of aiming for approval, a reward, or an end goal, student’s are experiencing something for themselves through kinesthetic activities.

Based on that, I believe that this “playtime” that students were given during the camp to participate in STEM activities, is more likely to raise the student’s interest and motivation to participate in the learning experiences. By being given the freedom to use the technology how they see fit, student’s are taking personal responsibility in their learning. Though I do not believe Marissa meant “playtime” in a negative light, it's important to me that these student-centered learning experiences are not perceived as ineffective. Leisterer and Paschold (2022) expressed:

Internal motivation regulation can be observed in children during free play when they follow their inner desire to run, jump, move simply for enjoying themselves. Hence,
being autonomous and free in one’s choices supports the individual in being responsible for her or his own outcomes (p.1).

The free-play allowed students to explore in a low-risk environment. There they could be inquisitive and unafraid of failure. By stepping back and allowing this freedom, facilitators were able to observe how students were interacting with the STEM environment. This helped facilitators by giving insight to the students' individuality and what they find interesting. By incorporating the students' interest into the instruction—drawing back to the main idea of autonomy—students will be more likely to engage with content (Jang et al., 2010).

The STEM summer camp experience also revealed how autonomous learning can take place in an informal environment and still reinforce the learning of formal content. “When we think about like a school day, it's nice that they can get some technology and other things that might be more interesting to some students who may not be super interested in math or English,” relayed Team Leader, Lauren. As important as it is that students were able to interact with technology and other factors that may not be as prevalent in typical school environments, I believe it is also important to note that math and English were also very evident during the camp. This reinforces the idea that science, technology, engineering, and math can go hand in hand with other core subjects.

With activities that supported creativity, problem-solving, and reflection, the STEM camp incorporated a variety of subjects into just a few lessons. For example, students had to design a car after reading the book If I Built a Car by Chris Van Dusen. After reading, students created four of their own designs for a car. During this process they had to think about environmental factors, realistic function, and cost, encouraging them to think about the science behind their design. Students then had to use the materials they were given to bring their designs
to life. Within this portion of the process students also had to pay attention to the amount of materials they were using. This allowed them to look at the engineering piece of the process to figure out what works and what doesn’t, as well as the mathematical aspect of rationalizing materials and adding up total use for their design. After that, students used different technologies to test their device. The most used tool during this trial was a hairdryer to mimic a wind-powered automobile. Finally, students reflected on the entire process through a guided reflection page in their booklets. Within their booklets they also labeled designs, made note of materials, and jotted down thoughts during trials. Though the only properly constructed response was the 3-5 sentence reflection, English was a consistent factor throughout the activity.

**Conclusion**

The research, findings, and my personal experience all point to one central idea– giving students autonomy increases their motivation in STEM. The goal of education is to reach all students in hopes that they internalize content and aspire to continue learning. If students were given the opportunity to make their own choices and guide their own learning, they would be more motivated to participate and succeed. In a STEM environment, full of hands-on activities and analytical learning, students can use the power of choice to discover new ways to solve problems. If autonomous learning was encouraged not only in informal learning environments, but in all educational environments, students could succeed– and by their own will and way.
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