Learning Programming with VEX Robotics: Influence on Student Motivation in International Secondary School from Teachers' Perspective

Iek-Chong Choi
School of Education
City University of Macau
Macao SAR, China
M23091200226@cityu.edu.mo

Wan-Chong Choi
Faculty of Applied Sciences
Macao Polytechnic University
Macao SAR, China
& CISUC, University of Coimbra, Coimbra, Portugal
wanchong.choi@mpu.edu.mo

Biyun Huang
School of Education
City University of Macau
Macao SAR, China
byhuang@cityu.edu.mo

António José Mendes
Dep. of Informatics Engineering, CISUC,
University of Coimbra
Coimbra, Portugal
toze@dei.uc.pt

***Abstract*—This Research Full paper explores teachers' perceptions of how VEX robotics programming courses influence secondary education students' programming learning motivation. Educational robotics is increasingly recognized as an effective teaching tool for enhancing students' interest in and proficiency in STEM (Science, Technology, Engineering, and Math).**

VEX Robotics is one of the most well-known, practical learning tools that allow students to showcase their programming abilities and creativity. However, little research has been done on how VEX robotics impact teaching practices and students' learning motivation from teachers' perspectives. While VEX robotics is widely utilized in educational environments for teaching robotics and programming concepts, more detailed research is needed to understand how its implementation influences student learning motivation, and overall teaching effectiveness.

This study was conducted by interviewing teachers, who were experienced in using VEX in this pedagogical context at an international secondary school in Macao. In particular, the study focused on teachers' opinions about the impact of VEX robotics on students' learning motivation. Qualitative data was obtained through semi-structured interviews with robotic teachers, providing deeper insights into students' motivation and participation in the robotics environment.

The study employed the ARCS model as a theoretical framework. The teachers' interview outputs were examined considering the model's four dimensions: attention, relevance, confidence, and satisfaction. The findings highlighted that teachers valued the use of VEX robotics and believed that it increased students' motivation in all the dimensions of the ARCS model.

Keywords—K-12 education, Learning Motivation, STEM, ARCS model, VEX Robotics, Educational robotics

I. Introduction

Educational robotic competition leagues for schoolchildren experienced a significant surge in popularity across the United States in the early 1980s [1]. Many students participated in various international robotic competition programs. The VEX Robotics Competition (VRC) stands as the world's largest and fastest-growing competition tailored for students in secondary school, and over 20,000 teams from 50 countries play in over 1,700 competitions worldwide [2], [3]. Given the substantial number of students engaged in competitions in educational robotics, particularly VRC, it is pertinent to inquire about the educational impacts stemming from the investment of resources facilitating student involvement in these programs.

The reason for the increasing adoption of robotics in education was its capacity to capture the interest of both kids and adults. This fascination often arises from their human-like appearance or role in performing various tasks that simulate human actions. Robotics is frequently used as resources for teaching science, technology, engineering, and math (STEM), developing a wide range of learning skills, such as problem-solving, creative thinking, engineering design, scientific inquiry, and teamwork, and raising students' motivation for studying science and technology [4], [5], [6]. Moreover, robotics provide students with a fun learning experience that could enhance their cognitive and hands-on abilities, social skills, and emotional well-being [7].

Integrating block-based programming into VEX robotics helps secondary school students start with an accessible and engaging way to learn programming, allowing them to develop fundamental skills. When they enter high school, students may switch to text-based programming languages, like Python. The progressive transition from simple to more complex programming activities equip students with the skills to handle advanced concepts, establishing a solid programming foundation.

To comprehensively understand the elements influencing student motivation, we conducted interviews from the teachers' perspective. By gathering insights directly from teachers with firsthand experience interacting with students, we aimed to gain valuable insights into student motivation within the classroom environment. Through these interviews, we sought to uncover teachers' observations, experiences, and strategies for fostering motivation among their students. This approach allowed us to explore the various elements influencing student motivation from the unique vantage point of those responsible for guiding and supporting their learning journey. This study examines the following research questions:

(1) What were the advantages and limitations of VEX robotics from teacher perspectives?

(2) What were teachers' perceptions of VEX robotics in enhancing students' learning motivation based on the ARCS model?

The remaining part of the paper is structured as follows: Section II reviews the literature, Section III covers the study methodology, Section IV reports results, and Section V provides a conclusion and discussion.

II. Literature Review

A. STEM and Educational Robotics

Integrating robotics and STEM into classrooms is primarily based on the hands-on theory of constructivism [8]. Knowledge is a perception constructed by interaction with the environment [9]. The primary objective is cultivating advanced intellectual skills and knowledge by emphasizing problem-solving, discovery, and collaboration [10]. Educational robotics is a teaching technology that supports learning and helps students develop cognitive and social abilities [11]. It is also a practical learning tool that allows students to express their ideas and imaginations by creating basic or complex mechanisms and robotic entities. Significantly, the connection of robotics with play and enjoyment is an essential factor that encourages children [12].

Over the last few years, robotics and STEM programs have penetrated numerous schools worldwide. The multidisciplinary approach to teaching science, technology, engineering, and math is known as STEM education, enabling students to combine academic theory with practical applications. Research has shown that robotics is an excellent learning environment for applying STEM [6]. Researchers have looked into using robotics as a platform to teach various courses, such as physics, math, programming, engineering design, and problem-solving, and have outlined the specific mathematical, scientific, and technological knowledge students should acquire in a robotics program [6].

B. Learning Motivation

Motivation significantly influences learning [13], encouraging people to take or refrain from particular actions [14]. Understanding the impact of human-robot interaction on student motivation was crucial for understanding how robots can effectively enhance the learning process. Based on the behaviorist paradigm, early theories associated rewards and punishments with motivation. Current research tends to prefer a social-cognitive framework, which believes that motivation is influenced by the interaction of objectives, interests, attributions, and self-perceptions [15]. Therefore, enhancing student motivation and engagement in programming can be achieved by employing diverse methods that address the various dimensions of the ARCS model [16].

This study adopted the ARCS model, which integrates motivation and learning. The model posits that individuals are motivated to engage in activities if they perceive them as satisfying personal needs and if there is an expectancy for success [17]. It aims to stimulate and sustain students' motivation to learn [18], with numerous research studies affirming its validity and efficacy [19], [20], [21]. The ARCS model comprises four key dimensions, each vital to enhancing learning motivation:

Attention: This dimension highlights the importance of piquing students' interest and curiosity, which are fundamental to motivation [18]. Multiple studies have indicated that the presence of a robot in the classroom elicited excitement among children [22], [23]. Students showed keen interest and enthusiasm toward the robot's captivating and distinctive learning stimuli. According to Hsiao et al. [24], the robot effectively enhanced children's motivation and attention during educational activities while mitigating distractions such as talking, sound-light effects, and hand gestures.

Relevance: This dimension revolves around rendering the educational content meaningful and applicable to students' lives, making the learning experience personally significant. To accomplish this, robotics have to establish effective connections between the educational material and the students. According to goal-setting theory, students engage more fervently in academic pursuits that contribute to their objectives [25]. Chin et al. described a robot-based learning system that customized lessons and activities according to learners' specific learning goals [26]. Their research findings indicated that most learners interacted with robots with a heightened level of motivation.

Confidence: This dimension is centered on cultivating students' self-assurance and belief in their capacity to comprehend the material [27]. Confidence correlates with self-efficacy and expectations of success [28]. Enhancing self-confidence involves employing techniques that bolster self-efficacy, such as providing opportunities for successful experiences. Platforms like VEX foster a supportive learning environment by offering a block-based programming language tailored for younger children and beginners, presenting progressively challenging tasks and opportunities for success.

Satisfaction: This dimension encompasses enjoyment and positive learning experience [29]. The student's favorable attitudes toward the educational experience are closely tied to their level of satisfaction. Positive learning experiences foster students' enduring motivation to study [30]. While extrinsic consequences such as high grades and compliments serve as examples of material benefits, intrinsic consequences like a sense of accomplishment and the joy of overcoming challenges contribute to personal fulfillment and happiness [31].

These components stem from a synthesis of research on human motivation, offering a suitable theoretical framework to delineate the learning strategies of educational robots. Previous studies in robotics have incorporated the ARCS model into their experimental designs or utilized it as a guided instructional strategy within the learning process [32].

C. Overview of VEX Robotics

VEX robotics provides flexibility in mechanical design [33]. The VEX robotics kit includes a controller, basic sensors, metal frames and shafts, gear trains, motors, and program modules. Students are inspired by the excitement of engaging in active, hands-on STEM education and the satisfaction of using technology to create something.

VEXcode is a coding environment adapted to each student's level, appropriate for elementary, middle, and high school students. Its straightforward structure enables students to get started quickly. VEXcode is compatible across three coding languages: Block-based (Fig. 1), Python, and C++ (Fig. 2). The block-based programming language of VEXcode prioritizes dragging and dropping code blocks to enhance accessibility and comprehension, allowing beginners to manipulate and arrange code blocks visually instead of complex text input [34].

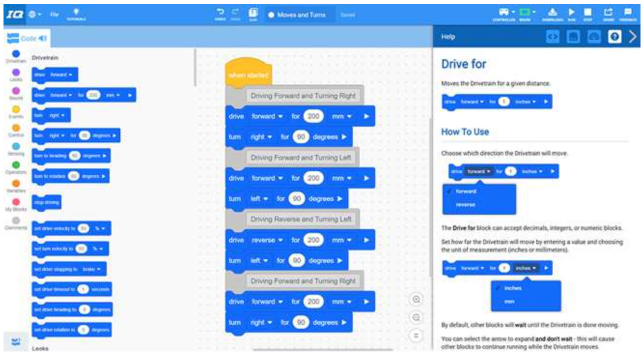

Fig. 1. VEX Block Coding language

Additionally, they encourage interactivity and offer enough visual assistance to aid students in experimenting and confidently exploring coding concepts. This would enhance their computational thinking and learning attitudes towards block-based programming [35].

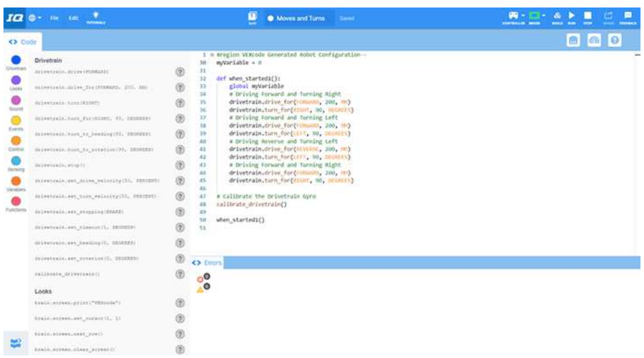

Fig. 2. VEX Python, and C++ Coding languages

III. METHODOLOGY

This qualitative study intended to explore the experiences and perspectives of robotic teachers through one-on-one semi-structured interviews [36]. People are inclined to express their opinions honestly in one-on-one individual interviews [37]. Moreover, semi-structured interviews usually start with specific, established questions [38] but can evolve to topics not foreseen in advance.

A. *Participants*

Two robotic teachers experienced using VEX in this pedagogical context at an international secondary school in Macao were selected to participate, each engaging in an individual interview session. One is a foreign teacher with 8 years of experience teaching computer science and robotics, while the other is a local teacher with four years of experience in the same field. They teach computer science and robotics at the school and participate in robotic activities and competitions. The two participants are depicted using the pseudonyms of David and Eason.

B. *Teaching Materials*

Students in grades 9 through 12 took the robotics course, powered by VEX robotics, three times a week for an hour each lesson. In the course, students assemble the hardware and then move on to programming. Since VEX robotics supports both, students can choose block-based or text-based programming languages. Specifically, students explored Python programming in their grade 10 computer science curriculum.

Furthermore, the VEX robotic competitions offer unique challenges and opportunities for students to demonstrate their robotics, programming, strategy, and teamwork skills. Students must work together effectively to achieve success.

In the VEX IQ Robotic Competition Full Volume, two robots ally and work collaboratively to score points. The objective is to score higher by completing tasks or challenges within the given time frame. The overall goal remains the same: to work together as a team to outscore the opposing alliance (Fig. 3).

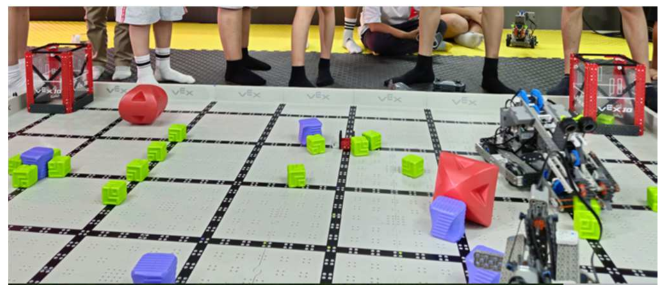

Fig. 3. VEX IQ Robotics Competition Full Volume

In contrast, the VEX Robotics Competition Over Under contains two alliances, each comprising two robots. Matches consist of two periods: autonomous and manual driver-controlled periods. During the autonomous period, robots operate autonomously based on pre-programmed instructions. In the driver-controlled period, human operators take control of the robots. The objective is to score Triballs in goals placed strategically around the field, aiming to outscore the opposing alliance (Fig. 4).

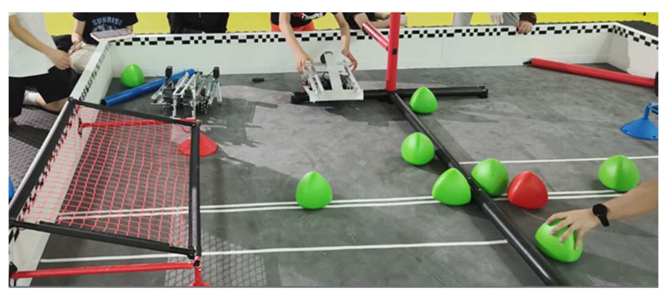

Fig. 4. VEX Robotics Competition Over Under

C. *Data Collection and Analysis*

Keller's ARCS Model of Motivation [18] was adopted as the guiding framework for analyzing the data. The interviews were audio recorded and transcribed verbatim to ensure accuracy [39]. This comprehensive approach enabled a thorough examination of the nuances and insights shared by the robotic teachers.

IV. Results

A. Advantages and Limitations of VEX Robotics

1) Advantages of VEX robotics in education

With a comprehensive learning experience of the K-12 continuum, VEX robotics provides a smooth educational transfer between elementary and secondary students. Additionally, a well-developed curriculum stands out as a significant benefit. By reducing the need to develop new curricula, teachers' workloads are lightened, allowing them to concentrate on teaching.

"I really like VEX robotics because they have that K–12 continuum." [David, 2:40]

"As students develop in the grade levels, they're gaining skills and doing more complex things… and still using the same skills." [David, 2:56]

"Their curriculum has been developed and can be applied to our school for the entire school year." [Eason, 2:51]

"Convenient, no need to create a new lesson plan or teaching content from scratch." [Eason, 3:05]

2) Limitation of creativity

Both participants revealed the potential restriction of creativity due to its well-designed structure and educational continuity, and this might have prevented students from exploring and utilizing their imagination and creativity completely.

"I can't quite do more interesting things like, you know, create a factory. So, I guess it would need to be supplemented by other things for them to start applying the robotics differently." [David, 3:12]

"The brand has been developed and taught according to a fixed model." [Eason, 3:23]

B. Teachers' Perceptions of VEX Robotics in Enhancing Students' Learning Motivation

1) Attention

The interactions with robots captivate students' attention and spark their interest in programming.

a) The hands-on physical experience captured attention. The significance of immersive physical interactions with robotics components offered students a tangible and dynamic learning environment. Additionally, there was a more substantial connection to knowledge through the active operation of the equipment, realizing the impact of their programming effort.

"They physically see it do something. Even when we use the robotic simulator, the stimulation for the kids is very low. But if the robot in real life is doing the same thing, they are amazed. I think that it brings interest in programming. [David, 4:31]

"Robotics is a combination of hardware and software, so students can touch and feel the real thing and realize what they are programming." [Eason, 4:06]

"The hardware itself has to be assembled, and so on, to get the students interested in the subject." [Eason, 4:25]

b) Drewed attention on competitive and game-based elements. The game-based structure introduced specific challenges and objectives, allowing students to focus on learning goal-oriented. This simulated real-world scenarios, facilitating practical applications in the field. The competitive aspect fostered a drive for achievement and attracted students to learning programming.

"Create a scenario, such as when the car goes to a wall or an obstacle, with some action to provide the students with a goal or assignment to complete the learning." [Eason, 5:38]

"Anytime the robot is doing something interesting, like that basketball drill, a little mini competition, or a challenge where they collaborate." [David, 3:40]

"Anytime the students are like the robots are racing to complete something, like it's gonna change something, and they do." [David, 3:59]

"Setting up an event or something like a small tournament. Everybody will want to beat another team." [Eason, 7:09]

c) Summary. Hand-on interaction with robots and engaging in elements of competition and game-based activities captivated students' attention and sparked their interest in programming.

2) Relevance

Established effective connections and meaningful experiences between robots and students.

a) Integration of practical application and programming. One participant revealed that advances in students' programming skills highlighted the transformative nature of robotics. Additionally, robotics comprises mechanical components and sensors, providing students with a versatile platform to experiment with programming.

"Because if only hardware exists, the machine can't move by itself. So, students must think about how to program it to make it move." [Eason, 6:07]

"This shows the improvement of their programming capabilities. From what may have started to build up a robot at the beginning, they are slowly giving life to their robots [move by compose command]" [Eason, 06:31]

"It is a mechanical car kit, which the program can move around. Also, it will have many different sensors so that the students can complete some tasks purposefully when they program." [Eason, 4:44]

Furthermore, the correlation between code and robotic operations helps solidify students' understanding of coding concepts.

"Where they make the robot drive forward, drive back, and… you can instantly teach them loops.… we do similar things to teach them functions and variables. [David, 1:46]

b) Diversity in programming languages for user-friendliness. VEXcode allowed students to apply coding abilities across multiple programming languages, offering flexibility that enhanced their comprehension of programming. Moreover, block-based programming languages provide a wealth of visual aids, especially for beginners.

"With younger kids, we start with block-based coding and do simple tasks to develop different control structures for them." [David, 1:36]

"The younger kids use the VEX codes platform for block-based coding. and the older students also use VEX code, but they're using either Python or C++ depending on their level." [David, 2:22]

"I think they do show programming skills. Sometimes, it is hard to get them to develop as a programmer. So, they're going to do it the easiest way for them rather than what would be the best code structure for them to learn." [David 5:22]

c) The real-world relevance of application. Examples assisted students in understanding the practical applications of their studies and better appreciating the relevance of their learning by connecting classroom experiences to practical problems. Both participants have revealed the importance of this approach.

"I'm going to give the students examples of some of the international companies in the world. For example, Amazon's logistics classification of parcels uses big data. And some robots like robotic arms or conveyor belts to do some sorting or work." [Eason, 7:42]

"We will use some examples to discuss the basic logic and reasoning of the robots we have acquired knowledge about. Through this process, they will understand how the world functions." [Eason, 8:10]

"I constantly show them videos of real robots doing similar tasks. That way, they can see what they're doing is a real-life skill. Currently, they're learning how to do a PID loop."[David, 6:19]

"I show them how to use thermostats, so they see that the exact things they're doing are real job stuff." [David, 6:29]

d) Relevance of robotics in future development within the field. Programming proficiency was undeniably a valuable asset in today's technology-driven landscape, offering relevance and engagement for students poised for future growth. The evolving demands of technological literacy and programming expertise were progressively indispensable.

"I would say it's more of have rather than explaining or demonstrating. Having conversations with kids, and trying to figure out what they want to be, what they want to do, or what they want to study, and then finding ways to apply it for them." [David, 6:48]

"After they finish the secondary school program, they are looking towards the university, and usually they may be interested in science, technology, robotics or computers and so on. We will work with them on some directions like life planning." [Eason, 8:41]

e) Robotics cultivating problem-solving skills. Both participants revealed critical improvement in the students' practical problem-solving skills. Troubleshoot errors related to connections, sensors, and actuators. This approach fostered the development of resilience when confronted with unexpected obstacles.

"They've gotten much better at debugging, reading error messages, using the sense-think-act cycle, and seeing that they are misunderstanding by reading the censored data. I think that's been a huge improvement." [David, 7:31]

"The most immediate aspect is problem-solving ability. ... as robots constantly adapt and execute diverse programs to accomplish various tasks assigned to them, they inherently develop their problem-solving skills" [Eason, 9:22]

f) Summary. Students applied programming concepts to bridge the gap between theoretical knowledge and practical application. The flexibility of VEXcode enabled students to improve programming accessibility. Students are adapted to meet the evolving demands of technology while significantly enhancing their problem-solving skills.

3) Confidence

Students' belief in their abilities for achievement and success in programming.

a) Small achievements and milestones for outlined requirements. Dividing projects into smaller, more manageable tasks was fundamental for fostering student success and building confidence. By breaking down complex projects into smaller components, teachers could create achievable goals for students to succeed.

"Sending small goals for students to reach that way, they're constantly getting. If you ask them to complete a task, they can see they're improving. They see it as an achievable goal." [David, 8:26]

"Initially, due to their limited programming knowledge, we will prioritize assembling the hardware. This process generally poses no significant challenges." [Eason, 10:11]

"When transitioning to the programming phase, it is common for individuals to experience a slight loss of self-confidence initially. However, they often start performing well without encountering any significant issues with break-down goals." [Eason, 10:30]

b) Progress tracking and reflection to overcome challenges. Encouraging students to explore alternative solutions was crucial for cultivating a more profound comprehension and facilitating growth while tapping into their existing knowledge. This built students' confidence to tackle challenges while programming and enhanced their critical thinking abilities.

"When encountering program issues, I usually inform them of a problem with the program. Instead of directly providing the solution, I discuss possible solutions with them." [Eason, 11:07]

"Exactly, by prompting them to brainstorm and recall their knowledge, they develop the ability to recognize that problems can be solved in various ways" [Eason, 11:24]

"Let them explore or solve more problems independently. They will only learn a specific way if they are told the solution directly." [Eason, 12:41]

c) Responsibility for collaboration and conflict management. They created an environment where students collaborated on projects, sharing ideas, pooling strengths, and offering support to one another. Moreover, through communication and conflict resolution, students achieved shared successes and gained confidence.

"I see them learning a lot of teamwork skills." [David, 8:56]

"They've learned a lot of conflict management, so they're signing jobs, taking duties, and ensuring everyone's in check with that." [David, 9:06]

"Our class will have groups, and they must learn how to cooperate. Robotics involves hardware and software. In a group of four people, they must learn to distribute what they must do in a limited time and accomplish the goal." [Eason, 11:53]

d) Providing autonomy in project choices enhances responsibility. Allowing students to choose projects or subjects that inspire them was a powerful way to improve their engagement and confidence in their abilities to explore innovative solutions. Personalizing the learning process open-ended gives students more authority and encourages responsibility.

"I would say they're extremely confident. One of the students tries to get the robot to solve the game using AI rather than manual programming; he's very confident." [David, 7:51]

"I led them into an open-ended project at the end for both the computer and robotics course." [David, 9:26]

e) Summary. Building confidence by providing an enjoyable environment and achievable learning goals was crucial for students to overcome challenges, succeed, and explore innovative solutions.

4) Satisfaction

Students were driven to learn programming if they were satisfied with the outcome. One participant revealed the importance of follow-up actions through open discussions and a questionnaire.

"After the course, we will give them a questionnaire for the overall learning experience." [Eason, 13:31]

"I'm going to talk to them about what's happening in the classroom and how they think." [Eason, 13:49]

a) Recognition of achievements of extrinsic rewards. Students derived satisfaction when their hard work and success were acknowledged. One participant revealed striving for awards and publicly recognizing students' accomplishments. Moreover, peer recognition played a significant role in feeling a sense of validation and respect.

"They went for awards because they do competitions." [David, 10:35]

"We always congratulate them. I put any time they do anything I think is good in the school announcement."[David, 10:38]

"So, every other student sees how well they're doing; that way, they get pure respect from their peers. I guess they also get respect from their peers." [David, 10:46]

b) Celebrating team success for an enjoyable learning journey. Celebrating team achievements was essential for reinforcing that every member plays a valuable role in the group. This fostered a positive atmosphere where students felt valued to continue working toward their goals.

"They can cheer each other on as the robot does things; that's usually where I see the most successes" [David, 3:53]

"You just got to celebrate the small games with them, and you got to cheer them on. I think that anytime they're doing something, it's imposing." [David, 10:13]

c) Satisfaction through project-based learning. Students felt satisfied after completing projects and being recognized for their efforts and contributions to the team's success.

"After each project is completed, it's straightforward to see how happy they are … from the satisfaction of completing their assigned tasks." [Eason, 13:17]

d) Opportunities for continuous learning to extend the learning journey. Offering continuous learning and skill development opportunities was crucial for enhancing student satisfaction. One participant revealed the importance of staying updated with the latest competitions and technologies and encouraged exploration to focus on specific competitions.

"See what competitions or new technologies are out there, share with students, and ask if they are interested. We can help them learn more about it." [Eason, 14:04]

"Encourage students to choose one or two competitions, and we would prefer them to focus on one or two of these activities." [Eason, 14:47]

e) Prevent potential frustration. Both participants highlighted the importance of providing guidance and support to students when encountering challenges or frustrations. Observation of signs or reaching a point of frustration among students, engaging in a dialogue to redirect their thinking in the right direction.

"There's no magic bullet for that question; you must carefully observe. and when you see students going from the zone of approximate learning to frustration." [David, 11:08]

"You have to go get in there, and I guess you have to talk their thinking through with them to help them get thinking on the right track." [David, 11:20]

Furthermore, it is crucial to emphasize the importance of providing direct assistance to students, especially when hardware issues arise and impede progress.

"In situations where the hardware may not work, and the robot may not be able to continue programming, I always help by fixing the robot directly." [Eason, 15:41]

"Directly tell them the solution, to solve the problem first, let it back to the right track, then we can engage in open communication about what is the correct process to do" [Eason, 15:58]

f) Summary. Students were motivated when they felt satisfied with the rewards offered. Encouraging and enjoyable learning was critical for student satisfaction, while potential frustrations must be carefully addressed.

V. Conclusion and Discussion

This study employed John Keller's ARCS model [18] of motivation and revealed a high consensus among both teachers regarding integrating robotics in enhancing student learning motivation. According to teachers' perspective, students' learning motivation was influenced by four factors: attention, relevance, confidence, and satisfaction. The results of the study highlighted the significance of each ARCS model dimension.

Regarding the attention dimension, VEX Robotics allowed hands-on experiences with robotics components, providing students with a dynamic learning environment and a competitive and game-based element. These interactions with robots captivated students' attention and sparked their interest in programming.

Concerning the relevance dimension, VEX robotics courses effectively connected educational material and students through practical coding applications, bridging the gap between abstract knowledge and practical application, exposing students to different programming languages, and providing relevance for students' future development. Additionally, students developed problem-solving skills through troubleshooting hardware issues and code debugging.

Regarding the confidence dimension, building and maintaining self-confidence was crucial for student success, achieved through small achievements by breaking down complex projects into smaller components. Keeping progress tracking and guiding students to explore alternative solutions were essential for fostering a deeper understanding and discussions for further reflection.

The satisfaction dimension came from the recognition of achieving milestones and celebrating team success for peers' valuable role in the group's success. Furthermore, providing continuous learning opportunities was crucial for enhancing student satisfaction, and project-based learning emerged as a particularly effective approach. Potential frustration was addressed by offering guidance and support to create a positive learning environment. It's critical to keep looking out for signs of frustration and have a dialogue with them to help guide their thoughts in the right direction.

VEX Robotics offers a K–12 continuum that provides smooth educational transitions, supported by a well-developed curriculum that saves teachers time and ensures consistency and quality in teaching. However, the VEX robotics program has been criticized for potentially limiting creativity, as participants noted concerns about a predefined curriculum restricting opportunities for students to explore and apply their creativity fully.

References

[1] T. P. Robinson, "Investigating the Self-Efficacy of Students Participating in VEX Robotics Competitions," *Technology Education for the Future: A Play on Sustainability*, 2013.

[2] Robotics Education & Competition Foundation, "VEX Robotics Competition – The world's largest robotics competition," 2024, [Online]. Available: Retrieved from https://www.roboticseducation.org/competition-teams/vex-robotics-competition/

[3] G. A. Stewardson, T. P. Robinson, J. S. Furse, and M. L. Pate, "Investigating the relationship between VEX robotics and student self-efficacy: An initial look," *International Journal of Technology and Design Education*, vol. 29, pp. 877–896, 2019, doi: 10.1007/s10798-018-9461-4.

[4] H. Altin and M. Pedaste, "Learning approaches to applying robotics in science education," *Journal of baltic science education*, vol. 12, no. 3, p. 365, 2013, doi: 10.33225/jbse/13.12.365.

[5] C. C. Chung, C. Cartwright, and M. Cole, "Assessing the impact of an autonomous robotics competition for STEM education," *Journal of STEM Education: Innovations and Research*, vol. 15, no. 2, 2014.

[6] D. Darmawansah, G.-J. Hwang, M.-R. A. Chen, and J.-C. Liang, "Trends and research foci of robotics-based STEM education: a systematic review from diverse angles based on the technology-based learning model," *IJ STEM Ed*, vol. 10, no. 1, p. 12, Feb. 2023, doi: 10.1186/s40594-023-00400-3.

[7] P. Dorouka, S. Papadakis, and M. Kalogiannakis, "Tablets and apps for promoting robotics, mathematics, STEM education and literacy in early childhood education," *International Journal of Mobile Learning and Organisation*, vol. 14, no. 2, pp. 255–274, 2020.

[8] S. A. Papert, *Mindstorms: Children, computers, and powerful ideas*. Basic books, 2020.

[9] W. Huitt and J. Hummel, "Piaget's theory of cognitive development," *Educational psychology interactive*, vol. 3, no. 2, 2003.

[10] S. Blanchard, V. Freiman, and N. Lirrete-Pitre, "Strategies used by elementary schoolchildren solving robotics-based complex tasks: Innovative potential of technology," *Procedia-Social and Behavioral Sciences*, vol. 2, no. 2, pp. 2851–2857, 2010.

[11] D. Alimisis, "Educational robotics: Open questions and new challenges," *Themes in Science and Technology Education*, vol. 6, no. 1, pp. 63–71, 2013.

[12] T. Sapounidis and S. Demetriadis, "Tangible versus graphical user interfaces for robot programming: exploring cross-age children's preferences," *Personal and ubiquitous computing*, vol. 17, pp. 1775–1786, 2013.

[13] A. J. Elliot and C. S. Dweck, *Handbook of competence and motivation*. Guilford Publications, 2013.

[14] S. C. Broussard and M. E. B. Garrison, "The Relationship Between Classroom Motivation and Academic Achievement in Elementary-School-Aged Children," *Family & Consum Sci Res J*, vol. 33, no. 2, pp. 106–120, Dec. 2004, doi: 10.1177/1077727X04269573.

[15] S. M. Glynn, P. Brickman, N. Armstrong, and G. Taasoobshirazi, "Science motivation questionnaire II: Validation with science majors and nonscience majors," *Journal of research in science teaching*, vol. 48, no. 10, pp. 1159–1176, 2011, doi: 10.1002/tea.20442.

[16] W.-C. Choi, H. Lei, and A. J. Mendes, "Motivating the New Generation: Using Flipped Classroom and ARCS Model to Enhance Block-Based Programming Education," in *2023 IEEE Frontiers in Education Conference (FIE)*, College Station, TX, USA: IEEE, Oct. 2023, pp. 1–8. doi: 10.1109/FIE58773.2023.10342942.

[17] J. M. Keller, "The use of the ARCS model of motivation in teacher training," *Aspects of educational technology*, vol. 17, pp. 140–145, 1984.

[18] J. M. Keller, *Motivational design research and development*. Springer, 2010.

[19] S.-L. Feng and H.-L. Tuan, "Using ARCS Model to Promote 11th Graders' Motivation and Achievement in Learning about Acids and Bases," *Int J Sci Math Educ*, vol. 3, no. 3, pp. 463–484, Sep. 2005, doi: 10.1007/s10763-004-6828-7.

[20] K. Li and J. M. Keller, "Use of the ARCS model in education: A literature review," *Computers & Education*, vol. 122, pp. 54–62, Jul. 2018, doi: 10.1016/j.compedu.2018.03.019.

[21] J. Visser and J. M. Keller, "The clinical use of motivational messages: an inquiry into the validity of the ARCS model of motivational design," *Instr Sci*, vol. 19, no. 6, pp. 467–500, 1990, doi: 10.1007/BF00119391.

[22] H. Crompton, K. Gregory, and D. Burke, "Humanoid robots supporting children's learning in an early childhood setting," *Brit J Educational Tech*, vol. 49, no. 5, pp. 911–927, Sep. 2018, doi: 10.1111/bjet.12654.

[23] S. Lee *et al.*, "On the effectiveness of Robot-Assisted Language Learning," *ReCALL*, vol. 23, no. 1, pp. 25–58, Jan. 2011, doi: 10.1017/S0958344010000273.

[24] H.-S. Hsiao, C.-S. Chang, C.-Y. Lin, and H.-L. Hsu, "'iRobiQ': the influence of bidirectional interaction on kindergarteners' reading motivation, literacy, and behavior," *Interactive Learning Environments*, vol. 23, no. 3, pp. 269–292, May 2015, doi: 10.1080/10494820.2012.745435.

[25] G. Latham and E. Locke, "Goal-setting: A motivational technique," *Motivation and work behavior*, pp. 357–370, 1991.

[26] K.-Y. Chin, Z.-W. Hong, and Y.-L. Chen, "Impact of Using an Educational Robot-Based Learning System on Students' Motivation in Elementary Education," *IEEE Trans. Learning Technol.*, vol. 7, no. 4, pp. 333–345, Oct. 2014, doi: 10.1109/TLT.2014.2346756.

[27] A. Bandura, W. H. Freeman, and R. Lightsey, *Self-efficacy: The exercise of control*. Springer, 1999.

[28] A. Wigfield and J. S. Eccles, "Expectancy–value theory of achievement motivation," *Contemporary educational psychology*, vol. 25, no. 1, pp. 68–81, 2000, doi: 10.1006/ceps.1999.1015.

[29] P. H. Mirvis, *Flow: The psychology of optimal experience*. JSTOR, 1991.

[30] B. F. Skinner, "Operant behavior.," *American Psychologist*, vol. 18, no. 8, pp. 503–515, Aug. 1963, doi: 10.1037/h0045185.

[31] R. M. Ryan and E. L. Deci, "Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being.," *American Psychologist*, vol. 55, no. 1, pp. 68–78, 2000, doi: 10.1037/0003-066X.55.1.68.

[32] I.-C. Hung, K.-J. Chao, L. Lee, and N.-S. Chen, "Designing a robot teaching assistant for enhancing and sustaining learning motivation," *Interactive learning environments*, vol. 21, no. 2, pp. 156–171, 2013, doi: 10.1080/10494820.2012.705855.

[33] Y. Liu, "From Handy Board To Vex: The Evolution Of A Junior Level Robotics Laboratory Course," in *2009 Annual Conference & Exposition*, 2009, p. 14.641. 1-14.641. 11.

[34] D. J. Malan and H. H. Leitner, "Scratch for budding computer scientists," *ACM Sigcse Bulletin*, vol. 39, no. 1, pp. 223–227, 2007.

[35] W. C. Choi, "The Influence of Code.org on Computational Thinking and Learning Attitude in Block-Based Programming Education," in *Proceedings of the 2022 6th International Conference on Education and E-Learning*, Yamanashi Japan: ACM, Nov. 2022, pp. 235–241. doi: 10.1145/3578837.3578871.

[36] H. J. Rubin and I. S. Rubin, *Qualitative interviewing: The art of hearing data*. sage, 2011.

[37] J. M. Johnson and T. Rowlands, "The interpersonal dynamics of in-depth interviewing," *The SAGE handbook of interview research: The complexity of the craft*, pp. 99–113, 2012.

[38] A. Strauss and J. Corbin, "Basics of qualitative research techniques," 1998.

[39] G. R. Gibbs, "Analyzing qualitative data," *Analyzing qualitative data*, pp. 1–232, 2018, doi: 10.4135/9781526441867.n1.