Learning with FIRST LEGO League

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Abstract: Robotics is a valuable tool for engaging students in the hands-on application of science, technology, engineering, and mathematics (STEM) concepts. Robotics competitions such as FIRST LEGO League (FLL) can increase students' interest in STEM subjects and can foster their problem solving and teamwork skills. This paper reports on a study investigating students' perceptions on the influence of participating in a FLL competition on their learning. The students completed questionnaires regarding their perceptions of their learning during the FLL challenge and were also interviewed to gain a deeper understanding of their questionnaire responses. The results show that the students were engaged with the FLL challenge and held positive views regarding their experience. The results also suggest that students involved with the FLL challenge improved their learning about real-world applications, problem solving, engagement, communication, and the application of the technology/engineering cycle.

Introduction

There has been a growing interest in the use of educational robots in schools (Benitti, 2012). Using robotics can help create an effective constructionist learning environment that impacts positively on students' motivation, problem solving, and learning (Cejka, Rogers, & Portsmore, 2006). Robotics activities allow students to engage in hands-on learning and can help develop metacognitive and higher-order thinking skills (Cejka, Rogers, & Portsmore, 2006). Other skills that robotics activities can help develop include science process skills and teamwork skills (Benitti, 2012). A review of research studies on the use of educational robotics found that the results were concentrated into two main aspects: learning of concepts/subjects and skills development (Benitti, 2012). The hands-on application allows students to actively construct their knowledge, linking various concepts and developing skills as they work on the robotics activities.

The growing interest in robotics in schools is partly due to robotics competitions that have been established to promote science and technology to school students (Williams, Ma, & Prejean, 2010). Robotics has proved to be an engaging tool for motivating students to participate in Science, Technology, Engineering, and Mathematics (STEM) activities and students participating in robotics competitions have been shown to be more likely to pursue STEM based university pathways and careers (Ludi, 2012; Nugent, Barker, White, & Grandgenett, 2011; Welch & Huffman, 2011). Robotics competitions can encourage students' interest in technology-related fields and offer an engaging learning context for STEM subjects (Johnson & Londt, 2010). The competitions provide hands-on application of science, technology, and mathematical concepts and helps students to apply their learning to real-life problems (Rockland, Bloom, Carpinelli, Burr-Alexander, Hirsch, & Kimmel, 2010; Petrel & Price, 2004), promotes collaborative learning (Beer, Hillel, Chiel, & Drushel, 1999), and provides students with an authentic learning experience. The focus of authentic learning environments is on solving real-world problems in an interdisciplinary way (Lombardi, 2007).

One of the more popular robotics competitions is FIRST LEGO League (FLL), for students aged 9 to 16, "designed to get children excited about science and technology and teach them valuable employment and life skills" (FIRST LEGO League, 2012). FIRST stands for the 'Foundation for Inspiration and Recognition in Science and Technology' and was created by Dean Kamen to help engage students in meaningful learning while promoting science and technology through fun hands-on activities. In 1988, FIRST, through Dean Kamen partnered with Kjeld Kirk Kristiansen from LEGO® to form the FIRST LEGO League so student teams could have opportunities to be involved in the 'process of creating ideas, solving problems, and overcoming obstacles, while gaining confidence in their abilities to positively use technology' (2012).

Each year a FLL challenge is released worldwide to over 200,000 students from 55 countries (FIRST LEGO League, 2012) and student teams have until the competition day to work on the challenge. The challenge theme changes each year and past challenges have focused on topics such as nanotechnology (2006), climate

(2008), transportation (2009), bio-medical engineering (2010), and food safety (2011). During the challenge the teams of up to 10 students work with an adult coach, engaging in scientific research, teamwork, and hands-on robotics activities. During the competition day the student teams receive points for their scientific presentation, teamwork, robot design, and for the performance of their programmed robot completing 8-10 challenges on the FLL challenge mat. Each team works together to score points navigating around the current FLL challenge mat and they receive points for each challenge the robot completes. The team attempts as many tasks as possible in 2.5 minutes and has 3 attempts on the challenge mat during the competition.

Previous research on FLL has shown that participation in the competition can increase students' interest in science and engineering subjects (Welch, 2010). It also shows promise for improving spatial ability (Coxon, 2012), fostering problem solving, creativity, and teamwork skills (Petre & Price, 2004); and for providing an engaging authentic learning environment for STEM subjects (Ludi, 2012; Nugent, Barker, White, & Grandgenett, 2011). Research has shown that students' attitudes towards science subjects were more positive for students competing in robotics competitions than for those students enrolled in the same science classes not competing (Welch, 2010).

The Study

This research focuses on an Australian Regional FLL competition. The school students participating in the competition were invited to complete a questionnaire regarding their learning experience. A total of 24 students (9 female and 15 male) completed the questionnaire after they had competed in the FLL competition. The questionnaire consisted of 36 statements categorised into seven categories. The seven categories focused on students' self-appraisal of their learning and students were asked to respond to statements about: learning about the world, learning to solve problems, learning to engage, learning to apply knowledge, learning to communicate, learning to apply the technology/engineering cycle, and specific questions relating to the FLL activities. Students were required to respond on a five-point scale ranging from Almost Always to Almost Never. The majority of responses to the statements on the questionnaire were in the range of Sometimes to Almost Always. However, for the purpose of this study only the student responses from Often to Almost Always have been used. The students were also interviewed to gain a deeper understanding of their questionnaire responses and to triangulate the data collection with observations and the questionnaires.

Almost Never	Seldom	Sometimes	Often	Almost Always

Learning about the world

The use of robotics helps students relate their learning to real-world contexts (Casteldine & Chalmers, 2012). From the students' perceptions, it appears that they were able to link their learning to problems and contexts outside of school. Table 1 shows the percentage of positive responses to the statements relating to the connections students made between FLL and real world applications. The statements that received the highest number of responses (21) related to learning about science and technology and learning interesting things about the world. During the interviews students were asked: What are some of the things you learnt about the 'real world' by participating in this competition? The majority of students mentioned learning about science (13) and teamwork (7). One student commented: "Robots can help world problems".

Table 1: Learning about the world

Statement	% responses often or always	Number of students
I learnt about the world outside of school	75%	18
I worked on problems about the world outside of school	67%	16
I learnt how science can be part of my out-of-school life	87.5%	21
I learnt how mathematics can be part of my out-of-school life	75%	18
I learnt how technology can be part of my out-of-school life	87.5%	21
I got a better understanding of the world outside of school	75%	18

I learnt interesting things about the world outside of school	83.5%	20
I saw the connections between schoolwork and the real world	75%	18

Learning to Solve Problems

According to the students' responses to the statements about learning to solve problems during the FLL challenge 100% (24) responded that they had learnt that there could be more than one solution to a problem. This is an important understanding as real-world problems often can have vague or unclear goals, multiple solutions and multiple solution paths (Chalmers, 2009). The students also indicated that they had learnt how others solve problems (21), had experimented with new ways to solve problems (20) and found creative solutions to problems (20). During the interviews seven students commented on there being multiple solutions paths when asked: What did you learn about problem solving by participating in this competition? For example, one student stated: "There are lots of ways to solve problems, some easier than others".

Problem solving and persistence are crucial when working with robotics (Nugent, Barker, White, & Grandgenett, 2011; Petre & Price, 2004). Students need to be persistent as they problem solve when their robot or program does not perform as expected. Two students mentioned that they had learnt the need to keep trying when they were constructing and programming the robot to complete the FLL challenges. Nine students focused on the importance of teamwork and sharing ideas when their robot did not perform as expected.

Table 2: Learning to solve problems

Statement	% responses often or always	Number of students
I learnt how to solve problems	75%	18
I learnt how others solved problems	87.5%	21
I experimented new ways to solve problems	83.5%	20
I learnt that there can be more than one solution to a problem	100%	24
I found creative solutions to problems	83.5%	20
I showed others how I solve problems	62.5%	15

Learning to Engage

FLL was established to engage students in meaningful learning while promoting science and technology through fun hands-on activities. Twenty-three students in this study recognised that they were engaged in a hands-on activity with the FLL challenge. The students responded that they were busy (21), finding new ways to improve what they were doing (22) and were trying new ideas (21). When asked what ways FLL activities were different to normal school activities nine students indicated that the FLL activities were more fun. Five students stated that there was more teamwork involved in FLL compared to normal school activities while three students focused on the hands-on aspect of their learning. One student commented that the activities were: "More interesting, more engaging and more fun".

Table 3: Learning to engage

Statement	% responses often or always	Number of students
I did hands-on activities	96%	23
I was busy with activities	87.5%	21
I was trying new ideas	87.5%	21
I was finding new ways to improve what I was doing	92%	22
I was always engaged	87.5%	21

Learning to Apply Knowledge

Various studies have reported on the positive impact of robotics activities on students learning STEM concepts (Barak & Zadek, 2009; Nugent, Barker, White, & Grandgenett, 2011; Welch, & Huffman, 2011).

According to the responses from the questionnaire the majority of students in this study learnt to apply their knowledge in science (17), mathematics (19), and technology (20). When asked how they applied their knowledge in the FLL challenge ten students responded that they had learnt to apply their mathematical knowledge by measuring the rotations of the wheels and estimating and measuring distances. Five students commented that they had applied their knowledge of science while working on the project for the FLL challenge and five students stated that they applied their knowledge of technology during the building and programming of their robots.

Table 4: Learning to apply knowledge

Statement	% responses often or always	Number of students
I was able to apply my science knowledge to solve problems	71%	17
I was able to apply my mathematics knowledge to solve problems	79%	19
I was able to apply my technology knowledge to solve problems	83%	20

Learning to Communicate

Teamwork is an important aspect of the FLL challenge and students need to learn to work in a team and communicate their ideas effectively (Petre & Price, 2004). Students' responses from the 'learning to communicate' category showed that twenty-three students felt that they had the opportunity to talk to other students while completing the FLL challenge. The students talked with other students about how to solve problems (21) and asked other students to explain their ideas (22). The students in this study showed that they had learnt the importance of teamwork for the challenge and twelve students commented that they had gained new ideas or different perspectives when communicating with other students. Four students discussed gaining teamwork skills and four students discussed how communicating with other students during the competition helped them build their confidence. Students also commented on the benefits of communicating to gain new ideas (14). One student also commented on the importance of "gaining different perspectives on the same idea".

Table 5: Learning to communicate

Statement	% responses often or always	Number of students
I got the chance to talk to other students	96%	23
I talked with other students about how to solve problems	87.5%	21
I asked other students to explain their ideas	92%	22
Other students listened carefully to my ideas	66%	16

Learning to apply the Technology/Engineering cycle

Rogers and Portsmore (2004) recommend using the engineering design cycle for robotics activities in schools. The characteristics of the cycle parallel the process that engineers and scientists follow as they solve problems (Barak & Zadok, 2009). The cycle involves identification of a problem, designing and constructing a prototype, testing the prototype, and communicating and sharing of the results of the solution. The iterative nature of the cycle is also emphasised, as student teams may need to move back to earlier stages of the cycle as new problems are encountered. Students in this study were asked to respond to statements about the different stages of the cycle. Twenty-two students indicated that they had investigated the problem and had created their robot prototype. Students also indicated that they had checked their work (21). During the interviews students were asked to discuss a problem their group encountered and how they solved the problem. Thirteen students focused on the problems that occurred during construction of the robot. For example, one student stated that the robot was "falling apart" so the group "replaced pieces and changed the design". Other students (4) focused on the project, with one student stating: "Both plays for the project presentation were too long, so we had to combine them". The students (7) also noted the importance of teamwork as they solved problems and engaged in the engineering cycle. One student commented that the "balance of the robot" was a problem and the group "worked it over and fixed it with teamwork".

Table 6: Learning to apply the technology/engineering cycle

Statement	% responses often or always	Number of students
I was able to investigate	92%	22
I was able to design	79%	19
I was able to create	92%	22
I was able to check my work	87.5%	21
I was able to think about my work	83%	20

FLL Activities

Students were also asked to respond to statements regarding the FLL activities. All students (24) stated that the FLL activities were interesting and well designed. The students found the activities in the FLL challenge fun (23), challenging (23) and enjoyable (23). The remaining one student responded that they felt the FLL activities were only sometimes fun, challenging, and enjoyable. When asked what they had gained by participating in the FLL challenge and how it would help them in the future eight students focused on the team skills they had learnt. Ten students discussed the knowledge they had gained by participating in the FLL competition including knowledge about designing, building, and programming robots, and knowledge about science. Three students mentioned that the FLL activities would help them with future jobs including marine biology and jobs in design.

Table 6: FLL activities

Statement	% responses often or always	Number of students
FLL activities were interesting	100%	24
FLL activities were enjoyable	96%	23
FLL activities were fun	96%	23
FLL activities were challenging	96%	23
FLL activities were well designed	100%	24

Conclusion

The advantages of engaging students in robotics tasks to foster technological literacy, problem solving, teamwork and creativity have been reported by various studies (Barak & Zodak, 2009; Benitti, 2012; Castledine & Chalmers, 2011). The findings from this study also support students' participation in robotics competitions such as FLL for improving students' learning about real-world applications, problem solving, engagement, communication, and the application of the technology/engineering cycle. The results show that FLL can provide a positive learning experience for students. Further research should include a larger portion of the students competing in the FLL challenge. It is also possible that the different FLL challenges may affect the results so studies could investigate students' perceptions of their learning in future FLL challenges.

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