

Developing General Capabilities through FLL

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Abstract: *FIRST[®] LEGO[®] League, or FLL[®], is an international program designed to promote STEM-related learning and work amongst middle-school aged children. In Australia a new nation-wide curriculum has recently been introduced which is based upon the development of seven so called General Capabilities. In this paper, a qualitative study that sought to ascertain FLL's efficacy in developing these capabilities at one FLL site is reported upon. This study sought the perceptions of FLL team coaches, typically classroom teachers with knowledge of the Australian Curriculum, in regards to the FLL's efficacy for developing these capabilities. These perceptions of FLL were compared to the descriptions of the seven General Capabilities as well as the broad intentions of FLL. From this study, implications are drawn regarding how the implementation of STEM-rich activities, such as FLL, might be aligned to the imperatives of the new curriculum.*

Keywords: LEGO, Robotics, Curriculum

1. Introduction

In the past decade, the focus on Science, Technology, Education and Mathematics (STEM) has grown significantly. More recently, STEM Education has gained momentum in the United States and a number of programs have been implemented which not only focus on education but also on the quality of teachers. In his speech on the Educate to Innovate program (The White House, 2009a), President Obama emphasized the importance of high quality education across the important STEM disciplines, stating that America's role on the world stage depended on how well the future generations were able to demonstrate their leadership in areas that paved the way for scientific discovery and technological innovation. Other countries also recognise this and as a consequence STEM Education is becoming increasingly important within education systems, as demonstrated by the United Kingdom's development of the National STEM Centre (<http://www.nationalstemcentre.org.uk/>).

While there is a lot of interest in STEM Education, there is substantial confusion regarding what the term means. For some, STEM Education means a greater emphasis on each of the four disciplines, which is an interpretation that is not substantially different to how school curricula have evolved over the past couple of centuries. Bybee (2010) believes that many still view STEM as mathematics and science only. Bybee (2010) also points out that "a true STEM education should increase students' understanding of how things work and improve their use of technologies. STEM education should also introduce more engineering during precollege education. Engineering is directly involved in problem solving and innovation, two themes with high priorities on every nation's agenda" (p. 996). Judith Ramaley (a former director of the National Science Foundation and who has been credited with coining the term STEM Education) suggested the creation of a meta discipline in which the teaching of mathematics and science could be revolutionized through the incorporation of technology and engineering (Fioriello, 2010). Elsewhere, STEM Education has been described as "teaching science and mathematics through design" (Morrison, 2006, p. 3). In a design-based approach to the learning of mathematics and science, the role of the teacher shifts to that of facilitator and the curriculum is "driven by problem-solving, discovery, exploratory learning, and requires students to actively engage a situation in order to find its solution" (Fioriello, 2010, para. 3). In the context of this study, the leaders of FLL discuss STEM in terms of the knowledges embedded in each of the disciplines (e.g., knowledge of the natural world vs. man-made world) and suggest that STEM Education, through programs such as FLL, should aim to develop in children the skills needed to solve the world's complex problems (Betsy Daniels & Scott Evans, personal communication, 26th June, 2012).

A design-based approach to the learning of mathematics and science necessitates equally innovative pedagogy.

Teachers need to find innovative approaches and sometimes this will involve learning that extends beyond the classroom. President Obama (The White House, 2009b) makes an important point about how this could be achieved: "I want us all to think about new and creative ways to engage young people in science and engineering, whether it's science festivals, robotics competitions, fairs that encourage young people to create and build and invent—to be makers of things, not just consumers of things" (para. 69). In this paper, *FIRST*[®] LEGO[®] League (FLL[®]), which is an example of such an innovative approach to design-based learning in mathematics and science, and its implementation at one geographical location will be presented and discussed in terms of the seven general capabilities that underpin the new Australian Curriculum.

2. The research context

FLL is an international program targeted to 9-16 year old children which, as promoted by the international organisers, "is designed to get children excited about science and technology – and teach them valuable employment and life skills" (FIRST, n.d., p. 1). It involves participants (under the guidance of a team coach, typically a teacher in the Australian context) engaging in two components: the Robot Game, which involves the design, construction, programming and testing a robot built using the LEGO[®] MINDSTORMS[®] NXT technology; and the Research Project, which involves the identification and solution of problem related to the program's yearly theme. The teams have a period of time (nominally 2 months) to complete the program's activities, at the conclusion of which they attend a tournament day where they demonstrate and discuss their robot and present their research findings. The authors of this paper have had experience as coordinators of a regional FLL Tournament in Australia. In addition to the research data presented in this paper, this experience has provided the authors with first-hand knowledge of FLL's potential capacity and actual achievement of promoting STEM amongst the target age group of children.

As noted, FLL is closely associated with the use of the LEGO Mindstorms product, the name of which is derived from Papert's seminal work *Mindstorms: Children, Computers, and Powerful Ideas* (Papert, 1980). Papert co-developed the Logo programming language at the MIT Media Lab specifically for children to use to develop their understanding of geometry. Mindell et al. (2000) explained that: "[the Mindstorms] book details the invention of Logo and the philosophical ideas that influenced the technical building of the language. Papert describes his thoughts on how computers can be used as teaching machines, and change the means by which students access knowledge. He takes from Piaget the model of children as builders of their own intellectual structures and describes how computers can be used to aid in the construction of knowledge" (p. 9). Closely aligned to the Piagetian notion of constructivism, this thinking is the basis for Papert's formulation of the theory of constructionism which argues that learning is a process of active knowledge construction and not of passive knowledge absorption. Specifically, learning is typically embodied by and articulated through an artifact or model. The Logo programming language has underpinned several educational applications including Logowriter and Microworlds as well as a range of LEGO robotics kits. The current Mindstorms NXT, upon which FLL is based, is a clear descendent of these earlier technologies. In the context of FLL, learning in the STEM disciplines (and also more generally) occurs as team members actively participate in the purposeful robot implementation and research project activities. FLL can thus be seen to be derived from two conceptual bases. The first is concerned with innovation in and positive dispositions towards STEM Education. The second is the educational philosophy from the MIT Media Lab summed up as being to "develop new computational tools and toys that help people, particularly children, learn new things in new ways" (Resnick, 2000 cited in Mindell et al., 2000).

Education in Australian schools is currently in a state of flux associated with the design and implementation of the new Australian Curriculum. The research reported upon in this paper was conducted in the second half of 2011, at which time the state of Queensland was preparing for its first year of implementing the new curriculum (i.e., 2012) in the learning areas of Mathematics, Science and English. As such, Queensland teachers were becoming familiar with the new structure of the Australian Curriculum. Common to each of the learning areas of the new curriculum is an overarching set of seven General Capabilities, which are: literacy; numeracy, information and communication technology (ICT) competence; critical and creative thinking; ethical behaviour; personal and social acceptance; and intercultural

understanding (ACARA, 2012). It is the intent of the new Australian Curriculum that these General Capabilities are progressively developed throughout a child's compulsory years of schooling (i.e., Preparatory Year – Year 10).

It was against this backdrop of FLL at a time of curriculum change that the research project was designed and conducted. The project aimed to interrogate how effectively FLL's conceptual bases of STEM promotion and constructionist-based learning were enacted at a regional tournament using the Australian Curriculum's General Capabilities as an evaluation framework. Specifically, the project aimed to address the following three research questions:

1. To what extent do team coaches (teachers) perceive the activities of FLL support the seven General Capabilities of the Australian Curriculum?
2. How are the General Capabilities observed in the actions, interactions and outcomes of selected team members (students)?
3. How does the rhetoric match the reality in terms of the educational benefits of involvement in FLL?

This paper provides a preliminary response to these research questions and some guidance regarding future activities.

3. Methodology

To address the projects stated aims, FLL in relation to the Australian Curriculum's General Capabilities was considered from three different but inter-related perspectives: the team coach (typically, but not exclusively, a school teacher) who has selected FLL as a vehicle for achieving intended learning outcomes; the team members (9-16 year old students), who through their varying engagement or participation in the different facets of the FLL program represent the enacted curriculum; and the organisers of the FLL program, as represented in associated web-sites and operational manuals.

To capture the team coaches' perspective, an anonymous qualitative survey, featuring continua-based responses (Lloyd & Masters, 2006) was used to establish a broad understanding of team coaches' perspectives regarding the FLL's alignment to the Australian Curriculum. This survey was administered on the FLL Tournament day. On that day there were 43 teams involved, each with (nominally) one coach. Of those coaches, responses were received from 25 coaches. The survey was in two parts: general demographic data and then questions related to the respondents perceptions of the FLL in relation to the seven General Capabilities. The demographic data collected included age ranges of team members, the reasoning for forming the team (e.g., Gifted and Talented program, special interest) and the normal role of the team coach (e.g., classroom teacher, teacher-aide, etc.). This general data enabled the broad comparison of perceptions within and between age ranges and school settings. The second part of the survey consisted of seven questions, all with the same common stem: *'To what extent does the FLL develop a team member's ...'*. This stem was then completed with each of the seven general capabilities to form a question such as *'To what extent does the FLL develop a team member's literacy?'* To respond to each question, a continuum was presented as a banded line interspersed with single word descriptors, namely, *nil*, *weak*, *moderate* and *strong*. A similar approach, that is, asking teachers to map perceptions on a continuum, was adopted by Lloyd and Masters (2006) in a study developing a tool to measure the integration of information and communication technologies (ICT) within a school. Their study showed that profiling the task in this way highlights what needs attention and celebrates what has been achieved. Additionally, the respondent was also asked to provide (where relevant) examples of how FLL developed each of the General Capabilities. To avoid influencing responses, the descriptions of the capabilities as provided in the Australian Curriculum were not included in the survey instrument.

To delve deeper into the team coach perspective, a case study methodology featuring semi-structured interviews (Lindlof & Taylor, 2002) was used to focus on one team participating in the 2011 FLL. An interview guide was prepared which had an informal "grouping of topics and questions that the interviewer can ask in different ways for different participants (Lindlof & Taylor, 2002, p. 195) that was similar to the seven sections of the qualitative survey provided to all team coaches. This type of interview was appropriate in this situation because the interview was flexible and allowed new questions to be brought up during the interview as a result of interviewee's responses. The team coach was interviewed twice during the two month preparation period before the tournament day.

Paralleling the team coach interview, observations (Creswell, 2008; Mulhall, 2002) of the students in the case study team were made to explore the team member perspective. Observations allow for the collection of open-ended, firsthand information by observing the participants at the research setting (Creswell, 2008). The observations were made in a naturalistic setting (a school) during the lead-up to the Tournament. Observations were recorded by the researcher as field notes using an observation guide that had similar structure to the survey and interviews.

Finally to capture the FLL organisers' perspective, documentation pertaining to the FLL program's design that is publicly available, such as the FLL website (www.firstlegoleague.org) and the challenge instructions (FIRST, 2011) was collected and analysed to establish of the intentions of the FLL program.

To analyse the aforementioned data sources, a constant comparative approach was used to compare and triangulate perceptions and to iteratively develop theory related to the alignment of FLL and the seven General Capabilities of the Australian Curriculum. In this paper, one aspect of that analysis is presented – the perceptions of FLL collected via the team coach survey and the comparison to the descriptions of each of the General Capabilities provided by ACARA.

4. Data analysis and discussion

In this section, each of the seven General Capabilities is discussed in turn. For each General Capability: The General Capability is summarised, as documented on the Australian Curriculum Assessment and Reporting Authority's (ACARA) website for the Australian Curriculum (ACARA, 2012); and the team coaches' perceptions gathered via the survey instrument are collectively summarized and comments are made regarding to the alignment of FLL activities to the General Capabilities are made.

4.1. Literacy

Students become literate by “listening to, reading, viewing, speaking, writing and creating oral, print, visual and digital texts, and using and modifying language for different purposes in a range of contexts” and through such activity they “develop the knowledge, skills and dispositions to interpret and use language confidently for learning and communicating in and out of school and for participating effectively in society” (ACARA, 2012, p. 9). As a consequence students demonstrate the knowledge and skills needed “to access, understand, analyse and evaluate information, make meaning, express thoughts and emotions, present ideas and opinions, interact with others and participate in activities at school and in their lives beyond school” (ACARA, 2012, p. 9).

Many team coaches indicated that FLL embedded literacy development, with 22 of 26 respondents rating literacy development at ‘moderate’ or higher on the continua. This development occurred in various ways beyond the read and writing of text. With regards to the Robot Game component, team members had to interpret instructions written in a technical genre, including text and diagrams. Team members also had to communicate their ideas in suitable technical language so as to be efficient and accurate. With regards to the Research Project, team coaches identified this component as requiring team members to develop and apply a wide range of literacy skills to gather, synthesise and present new information. These literacy skills covered all modes of communications across a variety of contexts including communication with ‘experts’ from outside the team members’ typical environment.

4.2. Numeracy

Students become “numerate as they develop the knowledge and skills to use mathematics confidently across all learning areas at school and in their lives more broadly. Numeracy involves students in recognising and understanding the role of mathematics in the world and having the dispositions and capacities to use mathematical knowledge and skills purposefully” (ACARA, 2012, p. 24).

Designing, developing and evaluating the robot is a mathematically rich activity for the team members. Team coaches identified some common mathematical concepts (such as measurement of time, distance and angles, fractions) as well as more complex mathematical ideas such as problem solving strategies, the development of multi-step solutions and

iterative refinement of answers. Whilst the majority of team coaches (17 of 26) rated numeracy development at a level of at least moderate, no team coaches provided specific examples of how the Research Project developed numeracy. This is a surprising result given the strong science-based content of the research activity and the program's desire for participants to base their research upon the analysis and/or synthesis of evidence.

4.3. Information Communication Technology (ICT) Competency

ICTs enables students to “access, create and communicate information and ideas, solve problems and work collaboratively in all learning areas at school, and in their lives beyond school” and as a consequence they adapt “to new ways of doing things as technologies evolve and limiting the risks to themselves and others in a digital environment” (ACARA, 2012, p. 41).

Team coaches reported both the Robot Game and the Research Project providing opportunities for team members to develop ICT competencies. The Robot Game not only developed fundamental computer use skills, but also developed the logical thinking (and a range of specific skills) associated with computer programming. As with numeracy, robot design, development and evaluation necessitated the use of problem solving skills i.e., engineering design principles. The Research Project component involved many team members searching information sources (databases, websites) and then using ICTs (including presentation and animation softwares) to articulate the presentation of their research findings. Also, from a teaching perspective, several team coaches noted that FLL provided a meaningful and substantive vehicle to integrate ICTs into the curriculum.

4.4. Critical and creative thinking

Within the General Capabilities framework students are expected to develop their abilities “in critical and creative thinking as they learn to generate and evaluate knowledge, clarify concepts and ideas, seek possibilities, consider alternatives and solve problems. Critical and creative thinking are integral to activities that require students to think broadly and deeply using skills, behaviours and dispositions such as reason, logic, resourcefulness, imagination and innovation in all learning areas at school and in the lives beyond school” (ACARA, 2012, p. 53). Students need to develop these attributes as they are considered critical to addressing some of the challenges of the 21st century.

Team coaches commented on the complexity of the task and the need for students to think carefully about how to solve the problem. This included strategy for the Robot Game and how to develop the Research Project. Both the Robot Game and the Research Project (including the presentation of findings to the panel of judges) provided opportunities for creativity and thus extended the opportunities for team members' contribution. Careful thinking was also required to manage the demands of the activity, i.e., the management of the team and the delegation of responsibility. It is evident from the team coaches' responses that FLL facilitated the development of creative thinking amongst students because they were “learning to generate and apply new ideas in specific contexts, seeing existing situations in a new way, identifying alternative explanations, and seeing or making new links that generate a positive outcome.” (ACARA, 2012, p. 53)

4.5. Ethical behaviour

ACARA (2012) describes ethics as “largely concerned with what we ought to do and how we ought to live” and so “students need to understand how people can inquire collaboratively and come to ethical decisions. They need the skills to explore areas of contention, select and justify an ethical position, and engage with and understand the experiences and positions of others. These skills promote students' confidence as decision-makers and foster their ability to act with regard for others.” (p. 75). Developing ethical behavior is an essential aspect of student development.

The dominant theme amongst team coaches' comments was that FLL required team members to act ethically towards each other and with other competing teams – this necessitated skills such as cooperation, collaboration, listening and valuing the opinions of others. This reflects the core values of the FLL program, including the notion of Coopertition™.

Ethical considerations related to the FLL theme (of food safety in 2011) and the conduct or implications of the Research Project were not identified in the team coaches' comments.

4.6. Personal and social competence

For students to develop personal and social competence, they need to engage “in a range of practices including recognising and regulating emotions, developing empathy for and understanding of others, establishing positive relationships, making responsible decisions, working effectively in teams and handling challenging situations constructively” (ACARA, 2012, p. 64). The benefits of well developed personal and social capabilities flows into other elements as well: “When students learn about their own emotions, values, strengths and capacities, the more they are able to manage their own emotions and behaviours, and to understand others and establish and maintain positive relationships” (ACARA, 2012, p. 64).

In response to the General Capability of personal and social competence, many team coaches' comments focused upon the intra-team communication and the development of a respectful and encouraging team dynamic. Secondly, coaches commented upon how FLL provided an opportunity for the team and its members to develop a sense of self-worth in their broader (predominantly school-based) community, noting that FLL promoted team members' inclusion in social and academic peer networks, some of which they had previously been excluded. Personal and social competence development was simply summarized by one team coach, who noted that “students develop confidence in their skills and abilities, learn to meet challenges and think creatively. They learn how to collaborate with their peers and relate to adults who are not part of their usual circle of known contacts.”

4.7. Intercultural understanding

FLL is an international program that is run in more than 60 countries. Central to the program is the promotion of STEM such that children are equipped with the skills and understandings needed to tackle the problems faced by the world. Key to solving such problems intercultural understanding, which “encourages students to make connections between their own worlds and the worlds of others, to build on shared interests and commonalities, and to negotiate or mediate difference” (ACARA, 2012, p. 84). Three dispositions – empathy, respect and responsibility – have been identified as critical to the development of intercultural understanding in the Australian Curriculum.

Some comments were made by team coaches regarding some teams' surface level awareness of theme-related issues in other cultures. But in general, the team coaches' comments suggested there was no strong sense of FLL promoting intercultural understanding. This suggests that teachers perhaps themselves only had a superficial understanding of the importance of intercultural understanding with regards to the solution of problems faced in the world. At a lower and more pragmatic level, the research project component does provide scope and specific opportunities for inter-cultural considerations of FLL's annual theme, but perhaps this too is not strongly promoted or scaffolded by the support materials given to teams (including to the team coaches).

5. Implications and Conclusion

The evidence collected via the survey instrument leads to the general conclusion that FLL supports the development of each of the seven General Capabilities of the Australian Curriculum. In terms of academic learning, FLL provides an authentic 'real-world' context to develop language, mathematics and ICT skills. That is, the true development of literacy, numeracy and ICT competency. The team-based nature of FLL provides numerous possibilities for team members to develop the 'soft' skills associated with working productively and constructively with others.

In the context reported upon in this paper, the predominant mode of FLL activity was as a school-based extra-curricular or 'extension' activity. However, anecdotal evidence gathered by the researchers suggests that teachers (especially at this time of curriculum change) face pressures of being time-poor and imperatives of addressing the content of the curriculum. Only a few teams reported upon in this paper integrated FLL into regular classroom instruction. Whilst

few in number, this demonstrates that FLL can become an integral feature of the curriculum, not an add-on.

To support the use of FLL as a vehicle for promoting STEM Education and for instilling a desire to engage in future STEM activity, it is the conclusion of this paper that further effort needs to be spent upon providing explicit support and guidance to team coaches (i.e., teachers in the reported context) such that they can realize the true potential of FLL. In the Australian context, this might include providing team coaches with specific materials and professional learning experiences that highlight the relevance of the various FLL activities to the development of the General Capabilities. More practically, resources could make specific connections between FLL and the Australian Curriculum in terms of the continuum of development in each of the General Capabilities across the years of schooling as well as to the specific content in each of the learning areas. This would not only support the teachers in their classroom activity, but would also aid in the promotion of FLL and other such STEM-rich activities to the school community.

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