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Multistakeholder analysis of a novel STEM intervention using physical activity and play

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ABSTRACT

CONTEXT

Understanding the success of any teaching program often needs to look wider than just metrics. This is particularly true for STEM disciplines where the metrics of unqualified success are clear. However, for students who struggle in class it can remain something of a mystery, or worse, it becomes demotivating resulting in failure to engage. Thus by looking beyond performance metrics towards engagement and mitigating attitudinal changes, barriers to learning may be uncovered.

PURPOSE OR GOAL

A previously reported successful multidisciplinary STEM program using physical activity was examined to identify statistically relevant indicators for its success. This was to aid in translational opportunities to other STEM areas that are of a national priority. Success to improve student engagement in STEM subjects was the underlying objective, especially for student cohorts that have been identified by various agencies as typical non-engagers.

APPROACH OR METHODOLOGY/METHODS

This study using a 360 degree stakeholder analysis of technology of a short term STEM intervention to determine measures of its success and failures. It uses semi structured interviews to capture feedback from students, educators and educational system administrators. Traditional hard measures of scholastic of performance was also be used. Measures of academic records is an example of scholastic performance that were used.

ACTUAL OR ANTICIPATED OUTCOMES

Based on earlier work, we anticipate that changes in attitudinal experience of STEM and higher engagement with the education system will be a short term outcome. Reflective analysis from the stakeholders (educators) will likely provide longitudinal information about the efficacy of the program. If the anticipated outcomes are shown as accurate, collaborations with key stakeholders will be established to develop novel curricula based on what has been found, while still fitting the established education curriculum requirements.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

From the earlier research and what is anticipated to be found in this study, greater student engagement in STEM based learning is possible. This will lead to further collaborations in order to develop novel teaching methods built on each student's own physical and play activities.

KEYWORDS

STEM education, technology innovation, student engagement

Introduction

Science, Technology, Engineering and Mathematics (STEM) are subjects given increasing priority in the developed world, from schools through universities to equip our workforces for tomorrow (Gonski et al., 2018). Despite this, the uptake of STEM courses at universities remains low. One reason is the attractiveness to traditional STEM careers appeals to only a limited subset of students. Critically, this is only after their formative years in primary school where the necessary prerequisite STEM orientated skills must first be developed. Earlier work by the authors has found that STEM subjects are typically 'things' focused, appealing to those that enjoy solitary activities (Su and Rounds, 2015) and comes at an opportunity cost of other activities that may be more desirable to adolescent bodies such as sport (Miller, Vaccaro, Kimball & Forester,2020). Students who are disengaged with STEM have varied reasons, they might find STEM difficult, boring, of little perceived relevance and therefore, do not actively engage when in these classes (Holmegaard, Madsen & Ulriksen, 2014). This can have a significant impact on academic performance and ultimately choice of career and education pathways. For example, entry to many engineering programs requires high level mathematics completed in senior school, which is in turn, only available to those that do well in junior high school, which is often based on primary school engagement in the fundamentals.

Furthermore, in a traditional sense, STEM subjects are typically taught in isolation (McComas & Burgin, 2020). This possibly contributes to what is being taught as perceived relevance. Being able to tie concepts across STEM subjects as well as the relatable activities or experiences may assist in meaningful lessons. Furthermore, it may provide opportunities for teaching efficiency in the classroom with multiple curriculum requirements being met.

Typically, there are cohorts that appear to be at greater disadvantage than others with regard to education in general and in particular STEM. It has been reported that Aboriginal and Torres Strait Islander students, students with disabilities, rural and remote locations, language based (English as a second language) issues, and low socio-economic backgrounds have greater disadvantage in STEM related learning (Gonski et al., 2018). Engaging students from these cohorts may address identified shortcomings in STEM education. Specifically, the declining student numbers in STEM subjects and increasing the numbers of girls involved in STEM areas (Gonski et al., 2018).

After several years of looking at physical literacy in school children, in 2018 a concept was developed to see whether the use of technology in combination with activities where children produce their own data may benefit the learning process of STEM subjects. The technology was developed as a proof of concept. The concept was named "STEMfit" (Lee, Parker, James, 2019). This original phase was to determine what technology could be developed with properties useful for teaching in the classroom. Taking a student centric view, a program that harnessed students' interest in sport as a vehicle to STEM education emerged (James, Parker, Willis & Lee, 2020) using wearable technologies that linked physical activity to classroom STEM activities.

To move past the original STEMfit proof of concept of the technology, we looked at what interested students at a remote and very remote schools. A thorough review of the literature was undertaken to look at why this approach to disengaged STEM students had traction. The literature review found significant drivers around relevance to daily life, play based learning, the inate competitiveness in adolescents (Lee, Willis, Parker, Wheeler, & James, 2020). This had been further extended to examine the pathways of decision making and enablers for the development of STEM careers (James et al, 2021)

For this paper we aimed to seek perceptions from all stakeholders involved in the program, to examine specific areas of success as well as areas to improve. Specifically, the participants (students), principals & teachers, and facilitators & developers.

Methodology

Multistakeholder analysis is a useful tool to examine issues associated with technology innovation (Ringuet-Riot, Hahn & James, 2013). This was combined with a case study approach using semi structured interviews and reflective practice in the educational environment during a STEM intervention.

In this paper we examined the STEMfit educational program (James et al., 2020) in two school communities from the points of view of the educational management team, teachers, facilitators (including a technical innovator) and students. This was based on visits made to a remote school and a very remote school. Both situated in the Northern Territory, Australia. The research was intended to test whether the approach of technology based data collection of school children's movement activities created interest and engagement in STEM in general. It also included insights from teachers and facilitators. Fifteen groups of children participated in the program and were arranged by their grade which ranged between Transition to Grade nine. The facilitators were the researchers and technical personnel who participated in the pilot by overseeing and assisting in the data collection for the program. The number of students to teachers was dependant on the class attendance on the day with an average of 13.0 (±4.0). Ethical clearance was given for the research (HREC clearance: H18089) and approval for the questions used (HREC clearance: H20094) by the Charles Darwin University Human Research Ethics Committee.

Activity design

Outdoor activities chosen for testing were based around running and throwing. These are both typical and popular movement activities. The run was set for 40 metres (m) and the throw was a tennis ball throw. The run was timed using lightgates (Speedlight, Swift Performance, Brisbane Australia) where three gates were used: a start gate; a 20 m split; and a 40 m final gate to record times automatically. Stopwatches were used as a backup to the electronic system. For the throwing, a radar gun (Bushnell Velocity Radar Gun, Bushnell Outdoor Products, Overland Park USA) was used to measure speed and stopwatch to measure flight time.

To generate scientific thinking, the children were asked to make predictions. For example, whether the first 20 m or the second 20 m would be faster in their 40 m run. This could be used later in class by demonstrating hypothesis testing and developing critical thinking on why their predictions were correct or not.

Younger children were given pedometers and asked to count steps manually (Figure 1). Class population data was collected, using steps for a known distance. Open ended questioning around who took the most and least steps were compared and the concept of average was introduced. Higher order thinking, around the relationship between height, leg length (longer legs take less steps) and steps introduced the participants to the meaning of numbers, instrumentation issues (don't hit the reset button) and relationship to physical quantities

The intention was that students could use the data generated in these activities during their regular STEM classes. For example, use the time a ball was in flight multiplied by the speed to estimate the distance thrown. During the physical activities, statements and questions were put to students in order to elicit thoughts that may be used later in critical thinking during classroom activities. While not directly tested in this study, it assisted students responding to questions surrounding this study.

Indoor activities included interactive group discussion based on the biology associated with physical activity including the energy systems of the body, the anatomy and function of the heart and lungs (Figure 1). Physical anatomical models were used for students to take apart and reassemble. Links were made for physiological functions such as lung and heart relationships. A physical model of lung function was utilised to demonstrate concepts like pressure difference and the importance of maintaining proper function of the body.

Kinaesthetic engagement was ensured through the use of plasticine model construction by students. Co-delivery of public health messaging emerged informally as a part of this education.

Figure 1: Classroom and Sports Field STEM activities

Data collection and analysis

Qualitative data was obtained from the participants through focus groups (students) and semi-structured interviews (teachers, early learning Directors and Principals) post intervention to enable participants to describe their experiences and aspirations and relate them to their current achievements. The collection and analysis of these subjective data followed a phenomenological approach, since the impact of the STEMfit program was examined through the eyes of the participants (Ary, Jacobs & Sorensen, 2010). The focus groups and semi-structured interviews explored the experience of participation in the STEMfit program and (the possible) resulting self-esteem, self-concept and self-reflection.

The phenomenological analysis was conducted by examining significant statements iteratively, where specific themes emerged they were tagged with a meaningful code and ascribed to a node (Bassett, 2012). In responding to the question relating to the impact of the STEMfit program word frequency queries to explore what words are used in each context from each theme (node). Deidentified direct quotes were used to demonstrate the context and validity of the analysis, to directly address the research questions and to give further depth to the study.

Results

Results are grouped into students, teachers, and facilitators. The teacher group includes those with administrative and management responsibilities, the facilitator group includes those doing the face to face delivery of the program together with program developers. Whilst the student responses are a snapshot of the program, teacher and facilitator group includes those with longitudinal views of the program owing to multiple deliveries and iterations of the program.

Students

Analysis of the survey data asking students about their learning experience around STEM to date found that while one student (Student 3) was "interested in science", most reported commonly that they were disengaged and "not interested" in the topic area (Students 2, 3, 6, 7, 8, 9). In comparison, following the STEMfit program students were engaged through the physical movements and activities. Students cited that their most memorable part of the STEMfit program was the "running and throwing" (Student 1, 4, 5, 7, 8, 9). Student 2 reported that the STEMfit approach was "more interesting that normal school" and that the facilitators provided "good tips on how to learn and move more effectively." This was supported by Student 3 who enjoyed exploring "different ways to run faster" using biomechanics. Student 6 recalled the strong interactions with "friends made me excited" to be part of the program.

Some students described the apprehension during the first time they participated in the STEMfit program (Student 1, 2, 3, 4). Student 1 stated "I did not think it was easy", while Student 3 described feeling "nervous". Four of the students reported feeling "good" and having "more energy" and this was summed up by Student 6 who described that they were "excited, grateful because I wanted to run". When asked to reflect on how STEMfit compares to how the students' might normally feel about STEM learning they replied that they "enjoyed going outside, with one child simply saying "less boredom" (Student 3). This was supported by Student 9 who reported "enjoying class outside." Student 7 reported that the STEMfit program "made me learn" and Student 8 reported that STEMfit made them "happy to do maths."

It was identified by the students that they would like to "run more" during the STEMfit sessions (Student 1, 2, 5, 7, 8). Physical activity was a central feature of what the students wanted more of in the program. Student 9 highlighted that they wanted "soccer, more throwing and doing activities" for future iterations of the STEMfit program. Another student identified that they would like "people to cheer and be happy for each other" during their activities. When the students were asked about what impact the STEMfit program had on their identity and self-belief they typically responded that they "don't know", but Student 1 responded "yes, interesting".

Teachers

Analysis of teacher responses found that Teacher 1 reported that they had experience "interpreting Australia Government STEM policy and frameworks relevant to state/territory strategic directions." This resulted in employing specific STEM based teachers with their remote school and allowed the school to "develop whole of NT initiatives to support school to develop understanding of STEM and STEM programs." When they reflected on what they found interesting in these STEM experiences they responded that "when learning about STEM people start with a strengths-based approach. Starting with what they know best and branching out from there. A good example is those people who enjoy and use computers and devices competently. They have engaged in STEM through the vast range of resources that can now be added to a computer."

When asked about what they remembered most about the STEMfit program they identified that the "use of everyday movement activities to develop key concepts and thinking" was an important factor. Along with the "use of a wide variety of technology from simple through to complex to gather data and the richness of the data that is produced through simple activities." The same teacher identified that they were "curious as to how to link human movement to a range of curriculum areas" during their first encounter with the STEMfit program.

Teacher 1 talked about the development of data entry tools that enable the manipulation of data easy for teachers and students to learn about STEM is something that could be done differently to be more effective in increasing educational outcomes for students. They believe that STEMfit needed to provide "model lesson plans and units of work so that teachers can start to work easily with the concepts and build capability in the area of STEM.” Teacher 1 concluded by saying that “the use of basic everyday technologies linked to everyday activities helps students understand the world” is one way to increase participant educational aspirations.

Facilitators

The standpoint of the STEMfit facilitators varied and when asked about their own experience in STEM, Facilitator 1 described “my learning experiences revolved around typical classroom activities. At the time (mid 1970s), there was little or no technology or engineering taught in high schools. Furthermore, there was no science taught in my primary schooling.” Whilst Facilitator 2 described how they had “been a tertiary educator in STEM for 13 years, both as a laboratory supervisor and as an academic. “I also discuss STEM in primary schools as a part of STEM Professionals in Schools”, run by the CSIRO.” Facilitator 3’s standpoint was they had “been a STEM professional developer for over 30 years, the last 20 in cross disciplinary areas, bringing STEM into them. The challenge of translating STEM talk and thinking to other disciplines has been one of the major challenges. What I think of as small and what others thing of as small are 2 different things. Something that an end user thinks will be difficult - invariably is easy to do. Something an end user thinks is easy might be almost impossible to do”.

What these STEMfit facilitators remembered most about the STEMfit program was “the enthusiasm by the children and their willingness to engage. “The lines of questioning were clearly due to the desire to find out more” (Facilitator 2). Facilitator 3 recalled how they “heard the girl students played with a female facilitator’s hair at the second school was very interesting and this says there is a STEM acceptance and relevance of the delivery of the program through relationship based and student centric activities.” Facilitator 1 remembered that the strengths of the program to be “children getting to see technology/models that they might not have had previous access too, getting excited about using the technology and as a side effect, learning something new. Students getting to touch, explore and ask questions; the BIG smiles especially from the junior students”.

When asked about the activities in the STEMfit program that facilitators thought had a positive impact on them*,* Facilitator 3 reported “the conversation based activities like playing with models. A focus based on starting with building rapport, then an activity, then STEM.” In a follow-up question, the facilitator was asked about which activities has a negative impact. They reported that “in my role as technology developer I am a few steps removed from the end-user …its a frustration…but its Ok too.” In comparison, Facilitator 2 when asked about the positive impact on them reported that “it was easy to get excited about the program when you could see the positive impact it had on students. I had some teachers saying that they had never been able to get their students to stay engaged for that length of time before. Also, recognising that every class/experience is different and modifying on the fly one set of students might be really enjoying an activity, so let them go longer, then next group not so much, so move onto something else...” “Loved how the students called out across the school and out in the community to say hi and give a hug.”

When asked about improvements to the STEMfit program, Facilitator 1 remarked that an area of improvement is “for students to design the activities to challenge critical thinking. Plus for teachers’ involvement in curriculum development.” In contrast, Facilitator 3 highlighted that “STEMfit and sensors is a beachhead to engaging students through physical activity and play, broadening the scope to biology and diet and personal health is a natural extension and can really capture student interests as well as deliver across the ACARA curriculum.” Facilitator 2 emphasised that “conducting STEMfit in an Aboriginal community really showed how necessary it is to make content relative to the student's context so that they can see how the knowledge is beneficial to improving their own lives.” Facilitator 2 then went on to explain that “I identify as a female scientist and I think that it is good for young students, especially girls to have that type of role model come into their schools. I like to think I made a positive impact and if nothing else, gave them a fun way to learning even just one thing new."

Discussion

The aim of this study was to determine the impact that the initial proof of concept had on stakeholders. Specifically, whether the initial development enabled interest and what may possibly be used or altered in going forward with curriculum based development. Student centric outcomes revealed a high level of engagement and interest in the activities. Teachers reported that moving from prior knowledge to something new held great promise but needed to be better aligned with curriculum tools. Facilitators reported as tertiary educators struggled with shifting focus of knowledge dissemination to facilitating. It is felt that overall alignment with ACARA curriculum elements will aid in future delivery for all.

Activities

Distance and time for the running, as well as speed and flight time for the tennis ball throw was recorded in the activities. Additionally, in the running, the 40 m runs had the 20 m split time recorded also. These basic data sets offer considerable classroom use in at least three of the four STEM areas. For example: students can take the distance and time data and calculate their average running velocity (maths). From this they could hypothesise how they may be able to run faster (science). To test the hypothesis, how to measure outcomes, students can be given to various options to collect data such as: timing gates, stop watches, wearable devices/pedometers (technology). This approach may enable teachers to address multiple curriculum requirements and in an engaging and meaningful way. Limited innovative teaching activities was highlighted as a deficiency in the Through Growth to Achievement Report (Gonski et al., 2018).

In discussions after the running and throwing sessions, students demonstrated interest in what they had just participated in. For example, one group asked what where their speeds. The facilitator said that he did not know. However, metrics recorded could be used to find out. Questions were put to the children about what was the distance (40 metres), what was recorded (time), what was the time measured in (seconds). This led to questioning about what was speed and what it was measured in (km/hr). With this set as a backdrop, little prompting the children began to see how they could work out their speed. The conversation lasted 15 to 20 minutes with almost every student (approximately 15) participating. The facilitator took the opportunity of the engagement and left the children with the challenge of working out their own speed.

Survey feedback

Student feedback focused on the outdoor activities and little on the physiological sessions. This may have been due to the facilitator who took the running and throwing also surveyed those who volunteered to answer. However, the facilitators reported engagement in this area also. This included positive feedback from teachers. Therefore, engagement with the children was evident to those involved (teachers and facilitator) reflectively. In many of cases, student feedback was limited to one or two word responses. The intent was for open ended questions to let each child genuinely say what felt or wished to say. Therefore, the facilitator did not prompt or lead any questioning. The minimal responses may have been due to factors such as English not being the primary language (Kriol was the language of the area) and the perception that quick answers were required. How the open-ended question approach may need to be carefully considered when moving forward into curriculum development. This is especially the case if co-development principles are to be followed. The use of school interpreters should be considered for effective communication (Taylor & Guerin, 2019).

Opportunities

At one of the schools, the lightgates failed to function correctly. Stopwatches were used as timing alternatives. The failure of the lightgates may often be considered as a negative. However, in the case of providing opportunities for children to learn STEM subjects, it provides an opportunity to discuss why the technology did not work as there is a reasonable chance that the technology may have been influenced due to the school's location in an approach zone for a military airport and Radio Frequency interference. Therefore, the likelihood of radio blocking technology impacting on the wireless components of the timing system. This could lead to even further discussion in regard to technology e.g. potential impacts on other systems. This demonstrates the versatility of STEMfit in that many scenarios can be offered up for children to learn from. And having directly experiencing the technological shortcoming, would be providing an opportunity to make more sense than giving a "what if something went wrong" scenario.

Looking forward

What is possible in the future, is to combine various activities in order for students to make connections between concepts that are taught. For example, after looking at biology models of the heart and lungs, have students walk a lap of a designated area e.g. the school oval. Taking heart rate measurements pre and post the walk and also noting how they feel exertion wise. Then repeat but instead of walking, the students run. Then carrying out the same measurements and observations. Tying together the use of the models, followed by physical activity that demonstrates physiological changes, increases understanding of the science of how their body works, in this case the need to breath harder and increase heart rate due to physical activity. It also provides multiple data sets that can be used. This is in line with our earlier observations where the relevance of the activity creates greater interest (Lee, Willis, Parker, Wheeler & James, 2020).

Helping children transition smoothly from early childhood learning to school is also crucial (Gonski et al., 2018). The need to develop partnerships between the key stakeholders is important for effective primary school and beyond learning. STEMfit represents an open ended tool and framework that assists in early introduction in STEM education. Specifically, at this point, the implementation of STEMfit is to provide teachers with opportunities and professional development to engage children in STEM subjects that is open ended. Whether teachers wish to continue using STEMfit, or create their own teaching curriculum will be their choice. The initial phase has been largely led by the researchers. Progressing the project from here, will be a process of transitioning from "research-led" via "teacher-led" curriculum design to "teaching-focus". Therefore, the level of autonomy will be at the discretion of individual teachers.

Only a small number of students and adults were surveyed, and this intent was to attain an idea whether the pilot program was heading in the right direction, without telegraphing and possibly influencing future outcomes. What was clear from the surveys were that for the next phase, the construction of questions and how the interview is managed will need to be carefully designed. Some of the responses may have been due to children guessing what the facilitators might have wanted to hear. At this stage of the research, it is difficult to measure direct educational outcomes, growth in educational measures requires a longitudinal approach, however engagement and relationship building is a key to enabling this next stage of research. The educational intervention at one site was the first and was the second intervention at the other site. Repeat visits are planned as well as student field trips to the university (a 7 hour journey), the project will continue to monitor engagement and with school principals and staff, utilise the schools' scholastic measures longitudinally to measure the educational efficacy in the future.

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