STEMfit: Student Centric Innovation to Improve STEM Educational Engagement Using Physical Activity, Wearable Technologies and Lean Methodologies †

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Abstract: School-based education programmes are increasingly focused on the teaching of skills thought to be more suitable for an increasingly technological society. These STEM (Science, Technology, Engineering and Mathematics) skills are often seen as enablers for the workforce of tomorrow. This paper utilises wearable sensors during prescribed physical activity as a vehicle for student engagement through their direct involvement in the creation of personalised data sets, direct questioning about their physical activity and the development of a nexus between what they do and fundamental physical properties such as the laws of motion. Results demonstrate the technical challenges, including the selection of appropriate monitoring technologies and development of appropriate technology tools suitable for school cohorts, together with sample results obtained through field trials in metropolitan and remote schools to demonstrate the utility of such technologies.

Keywords: STEM; inertial sensors; education pedagogy; innovation; business model canvas

1. Introduction

In many educational systems around the world today, there is an increasing focus on the technical disciplines of Science, Technology, Engineering and Mathematics (STEM) [1], often beginning in the early years of schooling (primary) and continuing through to secondary and tertiary levels. It is thought that these skills are critical for an increasingly technologically based society. Research has found that the early years of education represent a window of opportunity for engagement, where there is a curiosity and an appetite for learning [2]. In the primary context this is particularly challenging as there are many barriers to learning, such as the level of skills in students, availability of resources that are engaging at that level and a need to develop the primary educational skills of students as a first priority. This is further compounded in areas of disadvantage, such as lower sociodemographic as well as rural and remote communities where access to specialist

educators is more limited. In such communities, the level of STEM literacies and implicit support in the home environment are further compounding factors [3].

The adoption of technology in society is a strong juxtaposition to this, where the appetite for consumer-grade technologies and electronics continues to grow. Society is indeed a heavy user of technology for convenience and lifestyle choices, such as for recreation. Young people in particular are enthusiastic adopters of technology for gaming, social connectedness and—increasingly—wearables. Here, the trends of technology convergence, miniaturisation and downward pressure on costs through mass market production have led to the growing popularity of devices such as mobile phones and wearable technologies for fitness [4], in particular with young people.

The central focus of this paper is to use wearable technologies to engage students in the learning of STEM skills. Wearable technologies as biomechanical and physiological sensors [5] have been widely used in the assessment of athletes and are today popular consumer-grade electronics. The use of these sensors is comparatively straightforward and they lend themselves well to inspection-style analysis [6] suitable for young people, together with the opportunity for deeper analysis [7–9].

Whilst the application of the technologies to primary education pedagogy was the desired outcome, the path to development and best educational fit was less certain. Thus, the research approach was based on the Lean method popularised by Blank [10] and had adopted the Business Model Canvas developed by Oestenwalder [11] throughout the development cycle. This allowed the consideration and significant input from the various stakeholders to create a demand-driven, customer-centric solution rather than pure pushing of technology.

The vision of the reported research here was to determine whether wearable technology could be used as a vehicle to enhance student engagement through: (1) direct involvement using their own movement patterns in sporting settings and based on fundamental physical properties such as the laws of motion, and (2) gathering into datasets and delivering in a meaningful manner to learn STEM-based subjects.

2. Materials and Methods

Utilising the Lean startup method was essential to the success of the project. One of the strengths of the methodology was the focus on a customer-centric approach and contact with the identified customers. These were used as the major pivot points in the project. In a research context, customer segments were identified as the major stakeholders in this project, namely, students, teachers and schools. Developing a good fit with each of these stakeholders, meeting their 'pain points' (Value Proposition) and pivoting the research appropriately ensured that the iterative development process maintained and honed a clear focus on educational outcomes.

Lean methods have been increasingly utilised in research contexts [12], as the needs of research and business often have similar objectives in that they seek to solve a problem. The canvas is a visual design tool that can be utilized by populating various elements by design and refined through contact with stakeholders. The main elements of the Business Model Canvas (BMC) are the key activities, key resources, key partners, value propositions, customer relationships, customer segments, channels, revenue streams and cost streams. This research focused on the customer segments and value proposition (benefits) to develop the key activities. From this, key resources, including the technical aspects of the project, were developed. While other elements were identified as less critical to the research undertaken (such as revenue), they are important in the future for the sustainability and further development of the project.

Thus, the Business Model Canvas and Lean methodology process facilitated the iterative development of the technologies utilised within the research, representing a demand pull rather than technology push approach to develop the findings and educational resources [13].

Activities were carried out in accordance with the Charles Darwin University Human Research Ethics Committee (Approval H18089) "Using convergent technologies to enhance engagement, STEM and literacy education via physical activity and sport". A snowball convenience sample was utilised with n = 10 participants. Semi-structured interviews and reflective practice adopting a previously used methodology [13], encompassing baseline technical literacy, attitudes to technology

and the experience of the developed programme, were used to develop and iterate the activities technology development. Performance data for timing and height measurement were made using standard sports science equipment including light gates (Swift®), Vertec®, video and timing equipment. Time series data were collected using standardised inertial monitoring sensors previously described and accompanying processing techniques [6]. Participation was through informed consent (individuals or institutionally as guardians). Numerical computation was undertaken using the Matlab® high performance environment and Microsoft .NET environments.

3. Results

Activities for the research and design utilised three pivots focusing on the student experience, the learning environment and technology development. Each pivot involved development, then delivery of trials with student cohorts, which are described linearly, though the process had nonlinear elements.

3.1. Lean Methodology

Three segments were identified, with distinct needs and attributes to which trials were targeted to develop the value proposition.

3.1.1. Student Experience

The reflective process highlighted a self-reported strong sense of identity with physical prowess along with, at times, a diminished sense of intellectual capacity. The cohort significantly exceeded national benchmarks of physical literacy. In some of our cohort, English was a second language and education was not strongly supported at home.

Interviews showed that the students exhibited an interest in technology, physical activities and an intrinsic desire to compete with themselves during the activities (Figure 1). Amongst a range of activities, there was a strong interest in wearable technologies that personalised performance data. Utilising this interest in technology to establish how good they are physically is a good potential 'hook' for participation whilst imparting STEM skills.

The value proposition for students is that by doing something they enjoy they are more likely to be engaged in STEM-based learning.
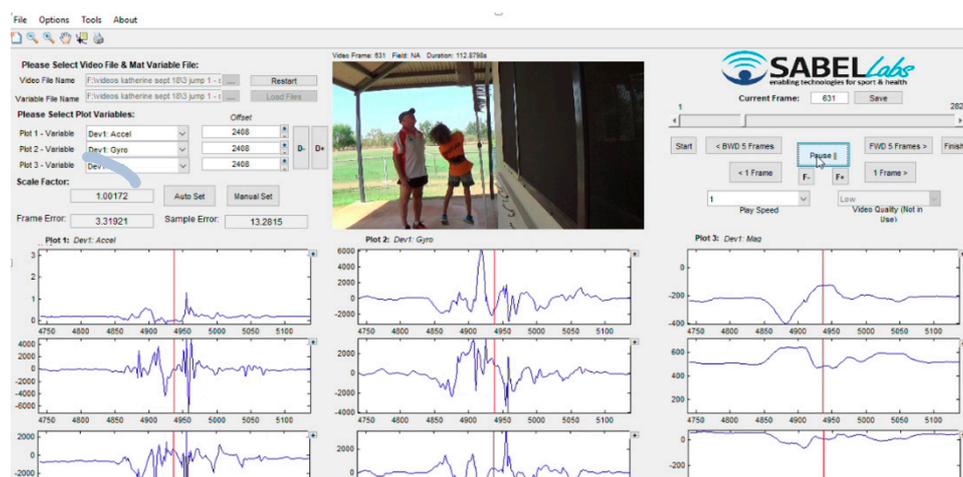
Figure 1. The student experience: A jump and reach task together with inertial sensors developed a strong sense of achievement and positive competition.

3.1.2. Learning Environment

Primary school teachers are generalist tertiary qualified professionals. In today's curriculum, many feel that it is overcrowded and there is great difficulty in covering even the basics to a sufficient depth [3]. The introduction of any new activities for STEM education needs to be mindful of the

existing STEM skills base and the need to not further crowd the classroom already struggling to deliver the basic curriculum. Developed technologies would need to be packaged together with educational resources.

For many, they would have had limited exposure to science education beyond their own secondary education. The value proposition for education is that any new activity needs to replace and improve on existing syllabus requirements and do so more efficiently.

3.1.3. Technology Development

The availability of classroom resources, in particular computers and specialist expertise, can represent a significant barrier to the successful deployment of technology-based STEM education. Technology only adds significant value to the learning environment when it does not introduce additional barriers such as resource requirements or literacy required to access it (for educators and students), and when it is a helpful consideration for the projects educational goals.

3.2. Educational Programme

The developed educational programme consisted of an informational module and experiential modules based on simple running and jumping protocols. Key technologies available at all schools as part of education department's SOE (Standard Operating Environment), such as Microsoft Powerpoint, Excel and video projection equipment, were leveraged as the learning environment, with a single low-cost inertial sensor [6] being the only additional requirement.

The student experience was centered around prescribed physical activities encompassing timing, measurement and data recording. Classroom analysis through visual inspection of their personalised performance data utilised an interactive Excel spreadsheet (Figure 2) with prewritten customized scripts (VBA) to incorporate signal processing elements for ease of interpretation. The activities were scalable such that a 'point and click experience' could be augmented to the manipulation of data and enquiry-based learning of data sets.
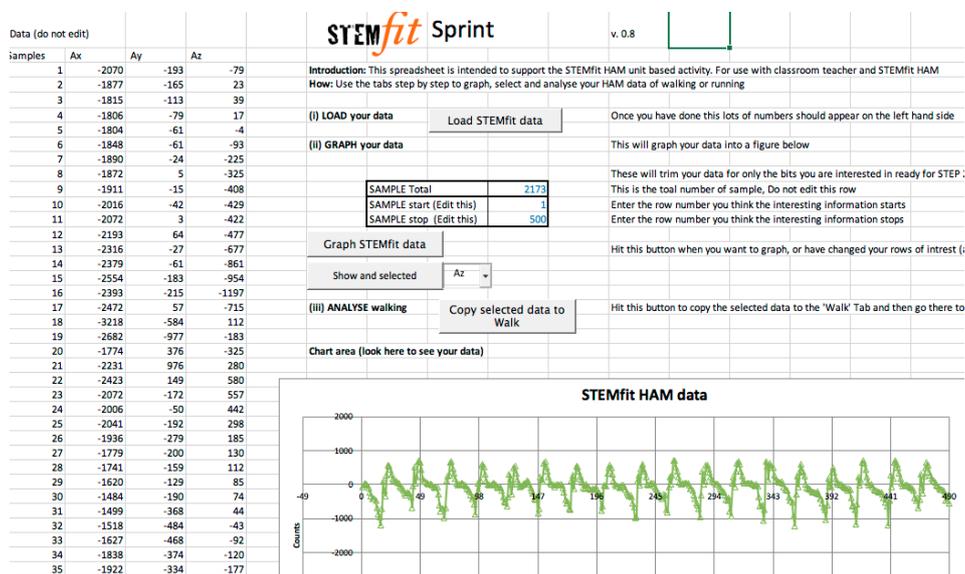
Figure 2. A sample education spreadsheet showing raw inertial sensor data and student-led inquiry process. Additional 'tabbed' sheets (not shown) show processed data with metrics such as jump height and stride time that can be used to compare performance across the classroom and with other cohorts.

4. Discussion

With primary school students, in the midst of great developmental changes comprising social and intellectual capacity, physical activity is a primary driver of engagement. The relevance of STEM

subjects requires delayed gratification and is not seen as an enjoyable activity. However, there is appetite for consumer-grade electronics. Variability in expertise means that activities need to be open-ended and progressive from point-and-click through to analysis and further curriculum extension for high-ability groups.

This research paper at its outset adopted an agile, discovery-based research, where a need was identified. By harnessing methodologies from entrepreneurial literature, specifically the Lean startup and the Business Model Canvas, rapid iteration led to the development of cost-effective technologies. Combined with the leveraging of existing resources in the classroom, it was able to equip generalist teachers to deliver STEM-based activities that were engaging for students. Specifically, it targeted those students who might not normally be receptive to learning STEM. For the research team, this orientation from subjects in an experiment to customers was challenging.

The translation of several decades of research into wearable sensors for a school-based education environment was also found to be challenging. The utilisation of Lean methods greatly facilitated the transformation of complex research knowledge and systems into something more accessible. The adoption of interview techniques greatly facilitated this, and whilst the sample size was small, it was essential to the task. This aspect of the project is preliminary and was primarily to ensure engagement with the participants.

Future work on the programme will look to integration with secondary and tertiary education programmes, the incorporation of other sports technologies and delivery methods, and the adoption of educational instruments to assess engagement and learning outcomes, along with control groups.

Whilst elements of the Business Model Canvas were utilised, the peripheral (to this project) elements around costs and revenues were not investigated in detail. There exists great potential to develop a social enterprise around the developed concept, which will be considered in the future.

5. Conclusions

By using a demand-driven approach, which was to improve education outcomes in rural and remote school communities, this research project has trialed an appropriate technology and educational programme that was applied to children through physical activity and sport, to draw them back to the classroom and solve problems based on their own personal data. This comes at minimal cost to their teachers in terms of additional work overheads. Because it combined elements of STEM with those of physical activity, even those such as half-day focused activities resulted in multiple learning objects within an engaged classroom.

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