Research Article

The Impact of Design Thinking and Steam Learning on Student Engagement

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Abstract

Global opportunities in steam-related employment have contributed to the need for students to engage in developing skills of critical thinking, collaboration and problem solving. This need aligns well with Design Thinking, where students are encouraged to address big picture problem solving (Ideaco, 2013). Student engagement is strongly linked to achievement. It has long been the focus of educational researchers and is of increasing importance as educators grapple with preparing students for an emerging future (Fredricks et al., 2004). This research evaluates the impact of steam learning and Design Thinking on student engagement. The participants were a focus group of Year 4 students, plus students and teachers (Years 0–6), in a junior school environment. The findings of this project suggest that steam learning provides an excellent platform for students to use Design Thinking, be creative and feel successfully engaged in their learning. Furthermore, many students found collaboratively constructing learning in a personalised way using digital tools was very engaging.

Introduction

With our constantly changing educational landscape, there has never been a greater need for students to engage deeply with learning. Emerging challenges such as providing flexible learning opportunities whilst keeping pace with changes in technology have provided the impetus for pedagogical change. As educators, providing real and relevant learning that will help students thrive in their world is of paramount importance (Hannon, 2017). Davis (1998) alludes to the gaps in current pedagogies that fail to develop 21st-century skills for students.

So how are New Zealand schools dealing with these gaps? Is it possible that incorporating steam learning and Design Thinking into classrooms is a way to provide enriched understanding and engagement for learners?

In New Zealand, steam education is a relatively new concept within the New Zealand curriculum. It sits within the technology curriculum which was revised in 2017 to include the technological areas of computational thinking, designing and developing digital outcomes, designing and developing material outcomes, designing and developing processed outcomes, and design and visual communication (Ministry of Education, 2018). With these modifications to the curriculum, teachers are looking for the means to which they can be implemented into inquiry and project-based learning authentically (Bolstad et al., 2012).

Literature Review

Student Engagement

Teachers have often considered that students who show purposeful effort in their learning activities are engaged learners. However, there is much more to consider when defining student engagement.

Christenson et al. (2012) note three types of student engagement. They stated that behavioural engagement is positive participation, cognitive engagement refers to an eagerness to learn, and emotional engagement is positive or negative reactions to teachers, classmates and the learning activity. All of these factors contribute greatly to student outcomes and impact academic achievement.

Additionally, Groccia (2018) describes student engagement in the more simplified terms of doing, feeling and thinking. For the purposes of this project, student engagement was defined as what students think, feel and do in the context of steam learning and Design Thinking.

Extensively reviewed research on student engagement by Fredricks et al. (2004) also indicated three main characteristics of student engagement: behavioural, emotional and cognitive. These characteristics describe a range of student actions during learning, from students simply being compliant and extrinsically motivated to engage, to students who are intrinsically motivated to engage.

Steam Learning

Defined as an educational approach that uses Science, Technology, Engineering, the Arts and Mathematics, steam learning is a means for guiding student inquiry (Bertrand & Namukasa, 2020). However, by fostering engaging steam practices, Sousa and Pilecki (2013) found that engagement, creativity, cognitive growth and long-term memory capabilities increased when taking part in steam learning. Similarly Rich (TKI, 2019) identified that students are multifaceted, so steam learning can tap into this by leveraging students' strengths to develop new learning.

Challenges faced by teachers when implementing steam learning include developing a deeper understanding of how steam differs from their current practice, to resourcing and planning. In a study by Taylor and Lowe (2021) it was found the integration of steam was challenging for teachers, as it involved learning about new topics requiring extra planning and resource development time. Additionally, adjustment to this new pedagogy is necessary, as the teacher's role is to guide and advise, "both the student and the tutor have to tolerate great risk along the journey to a solution" (Shreeve, 2015, p. 83).

Design Thinking

Alongside steam learning, Design Thinking was initially used in the 1960s and developed further in the 1980s. It continues to be a relevant way to collaborate and generate new thinking around problems (Rowe, 1987). It is used widely, in many secondary schools, tertiary institutions and workplaces.

There is some evidence that it is being developed in primary schools in New Zealand (TKI, 2021), however, it is yet to become an integral part of teaching and learning practice. This may be because of the lack of understanding surrounding Design Thinking and its practical use in primary schools. However, in Australia, there is significant support and resource material for teachers in New South Wales to implement Design Thinking processes (Taylor, 2020).

Davis (1998) refers to Design Thinking as an innovative way to problem solve, allowing students to be at its centre and providing a platform for divergent thinking. It refers to the cognitive, strategic and practical processes by which design concepts are developed. This thinking originated as a way of teaching engineers how to creatively solve problems, like designers do. In this capacity it was used to work through highly complex, "wicked" problems.

Moreover Kelly (2012) highlights that Design Thinking is a means for students to address real-world problems in a systematic way. Through its five modes, the students are able to *Empathise*, *Define*, *Ideate*, *Prototype*, and *Test*. These modes of thinking are all interconnected and students may cycle in and out of each mode, making refinements.

With an emphasis on empathy, Design Thinking is a valuable social emotional commodity for all individuals. Empathy is a skill that is needed not only for students to collaborate and work well with others, but is a crucial skill in many work environments.

A study by Chen (2015) affirmed that through experience with Design Thinking, children will be able to grow into empathetic adults who can be successful in their life.

In addition, Davis (1998) states that the use of design thinking to deliver existing learning content would help improve academic outcomes for students. Davis found that the social and collaborative nature of learning through Design Thinking created a shared ownership of learning and contributed greatly to students' making of meaning. This is a key finding as it is fundamental that students understand their learning. Engaging collaboratively with Design Thinking could therefore be a means of supporting meaning making for learners.

Steam Learning, Design Thinking and Differentiated Learning Needs

Steam learning removes barriers to higher level thinking involved in risk taking because multiple solutions to problems are possible. This coupled with Design Thinking allows for a heutagogical pathway where students have the opportunity for learning what they need to know when they need to know it (Hase & Kenyon, 2007). The transdisciplinary approach of Design Thinking has the potential to develop improved literacy in the technologies (TKI, 2018). Steam gives multiple entry points across contexts and therefore does not discriminate against students because of learning needs (Klyn, 2018). By understanding that steam learning allows for personalised and differentiated learning, teachers adopting new pedagogical approaches may be able to engage students further and empower them to think critically.

Teacher scaffolding of learning is an important consideration when teaching Design Thinking (Muramatsu et al., 2019). A study by Groccia (2018) also found that providing structured fun in learning activities resulted in engagement and therefore made lessons memorable and well understood and that teachers who praised learning processes saw increased confidence in thinking shown by students. Students therefore showed a willingness to engage and be open minded to new learning experiences.

Research Questions

1. What is the impact of steam learning and Design Thinking practices on student engagement?
2. What factors contribute to improved student engagement when utilising steam learning and Design Thinking practices?
3. What factors contribute to teacher collaboration when delivering steam learning?

Specific goals for this research project aimed to:

1. Increase student engagement through steam learning and Design Thinking processes
2. Co-construct learning enabling collaborative use of digital tools and a culturally responsive approach
3. Create a community of practice with teachers to enable the implementation of steam learning across the school.

Methodology

The methodology chosen for this project is Action Research because it is a practice-based method of research (McNiff & Whitehead, 2005). It has an iterative approach to evaluation and allowed me to build on cycles of activity to improve practice.

In order to obtain a clear picture of student engagement across the project, mixed methods of data collection were implemented. Real-life situations, such as teaching and learning, may be best described by using a mixed methods approach (Cohen et al., 2018).

When dealing with younger students, interviews helped me to tell their story about how they engaged with learning (Cresswell & Clark, 2011). Teacher interviews and discussions consisted of questions that were open and allowed for critical feedback/feed forward and a flow of ideas that could be shared. Quantitative data was also used to inform practice during each iteration of the project. This was gathered by means of student surveys. The surveys served the purpose of creating response data and were a means to measure levels of engagement. The instruments used for collection of data were interviews of participants, Google form surveys, observational field notes and reflective journaling.

During observations, the Leuven Well-being and Involvement scale was used to indicate student engagement (Laevers,1997). This scale proved to be a useful tool to show how students adapt to new activities and environments. Snapshots of involvement and well-being were taken as field notes and reflected upon.

A dual approach was developed to address the goals of this project. Firstly, with the focus group of Year 4 students, two iterative cycles of the International Baccalaureate Primary Years Programme (PYP) concept-based inquiry were implemented. Secondly, a new collaborative pedagogy for delivering steam learning was developed for Years 0–6 students across the school. The makerspace in the junior school was utilised as a resource and learning space for staff and students.

These goals were measured through gathering qualitative and quantitative data by means of observations, interviews, surveys and discussions with participants and stakeholders to inform practice.

Initially, the focus group participants were interviewed. This was an important phase of the project as it was an opportunity for the students to talk about who they are and how they see themselves as learners. The students were able to describe how they liked to work and what strengths and barriers to learning they had experienced.

During the first iteration, my role was to work with the Year 4 team to introduce the science and technology elements of our unit of inquiry. In this inquiry about Innovations and Inventions, students were introduced for the first time to Design Thinking. This process would be used to solve the problem of designing an invention, a fast America's Cup boat. Design Thinking would provide a framework for students to anchor their ideas and processes to. Making this pedagogical change, I hoped to deliver content in a different way to improve understanding and academic outcomes (Davis, 1998).

The focus group used a hands-on experience with an optimist boat as a provocation to think like a designer. Students looked carefully at the technology used on this boat and began researching ideas for their own boats by framing their learning with the five Design Thinking modes. They engaged fully with this process and were able to use this to design prototypes to test.

Students followed the process well, however, I was mindful of this being the students' first exposure to Design Thinking. I felt the Design Thinking modes needed to be worded in a way to be more suited to primary-aged students. I also learned that there is a gap in the research, with no Design Thinking model specifically for primary-aged students. Students co-constructed research and learning around student ideas structured by the Design Thinking modes. This learning was recorded in a slides presentation modelling book and was used as a guide for teachers and students. Documenting the learning process for students was in the form of a book creator book. Students were scaffolded to write or take photos to reflect on their learning. This iteration also demonstrated culturally responsive practice where the students' cultural funds of knowledge were incorporated (Siilata, 2015), as students recorded introductions about themselves and their families in their mother tongue.

Although students had influence on the construction of their learning in this first iteration, my role was more of a facilitator. Upon reflection, I would move on to eliciting students' ideas further, to devise more detailed success criteria for their tasks. Using the 21st-century learning design rubrics, I redefined learning, so students are more actively constructing it.

The collaborative delivery of steam learning to several classes across the school was occurring alongside work with my focus group. To start with, my aim was developing relational trust with teachers (Robinson, 2010). This occurred quite naturally, as we had the opportunity to plan collaboratively at PYP planning meetings across several year groups. Regular check-ins were made to see which directions student inquiries were taking them and how connections could be made to this learning. I had begun to develop a community of practice with teachers to enable the implementation of steam across the school (Wenger, 2002).

A pedagogical change was needed to deliver steam learning collaboratively and make it more engaging for students. This was initially challenging as teachers had in previous years come to "Do" science and technology in the makerspace. A shift in thinking and methodology was required. To support the change in pedagogy, shared slides documents and resources were created that supported students and teachers to help deliver PCK (pedagogical content knowledge) (Nixon & Lizaire, 2007). Initially there was a range of uptake from teachers depending on their comfort with teaching science and technology.

The purpose of this collaboration was to enable teachers to explore new ways to design, implement and evaluate knowledge construction through inquiry-based steam learning. Students brought their prior knowledge to sessions then both students and teachers collectively built on this through concept-based activities and discussion.

Initially teacher efficacy was limited by their confidence and lack of experience teaching science and technology (Aydin, 2020, as cited in Bassachs, 2020). This explained for me how some teachers were more readily able to work collaboratively with steam lessons than others. Through modelling open-ended, hands-on activities, students were able to develop practical knowledge of phenomena. Subsequent units of inquiry involved teachers working as guides to student-led learning relating to key concepts. Teachers worked together to plan and promote a heutagogical approach allowing for students to explore anytime, anywhere learning (Hase & Kenyon, 2007).

Data was collected throughout the first iteration and was used to inform the second iteration of this project. To gain further knowledge of the Design Thinking process, a rubric was developed to help students gauge how they were going in each of the modes. It was a way to break down skills and thinking to support students' learning.

The second unit of inquiry with the focus group was Sharing the Planet. Students were delving into the real-world concept of the impact of how humans dispose of waste. During this inquiry, students were guided to construct their learning. More emphasis was placed on unlimited creative thinking, as students planned to solve their real-world problems. Students used their newly constructed Design Thinking modes and were asked to think about, how might I solve the problem of waste around the junior school? The focus group *empathised* by interviewing members of the school community about the school waste problem. From this, students *defined* the problem and began researching possible solutions. Their research included auditing school rubbish and learning about alternative waste solutions such as composting and bokashi systems. In the *ideate* phase students used sketching and annotating to think of unlimited creative solutions. In the *prototyping* phase students chose how and what they would create. Students worked their way through Design Thinking modes. They produced and tested prototypes. These included making a 3D-printed hand, a rubbish claw hand, rubbish sorting machine complete with sensors, and themed scratch games that highlighted solutions to the school waste problem. They *tested* their prototypes and sought feedback about them, making necessary changes. Students then revisited their end users to *share and evaluate* the solution to the problem of school waste.

Focus group participants used a variety of digital tools to enhance their learning including, book creator journals, Tinkercad drawing, 3D printing and Scratch Junior coding.

Artefacts produced were a series of slides modelling books for teachers and students. These books helped gather thoughts, methods and resources and were used to generate a Google site connected to the junior school cloud. This site was made to support delivery of steam learning and Design Thinking processes.

A Design Thinking model has been developed for the junior school in collaboration with teachers which included an exemplar rubric to be used to guide students and teachers with the process.

Results and Analysis

Through analysing data, it was found that there were many contributing factors to increased student engagement in this project. These factors have been categorised into the three characteristics of engagement, cognitive, emotional and behavioural (Table 1) as discussed in Fredericks & McColskey, (2012).

Key factors impacting student engagement in steam learning and Design Thinking processes
Cognitive (Think) - encouraging curiosity - asking relevant open-ended questions - open-ended activities provided - teaching more explicitly, modifying to meet the needs of students - breakdown of individual skills - clarifying ideas for students through discussion - age/pace appropriate - journaling to justify and record ideas

Emotional (Feel) - establishing trust - allowing for students' preferred modes of learning (utilising cultural funds of knowledge) - learning is structured fun - encouraging students to make meaning through questioning - students being agile developing a mindset for trialling through new processes - articulating learning to whānau, enabling following on with learning at home - involving whānau – experts + support - establishing perceived success from students - enabling connectedness so students feel value for learning - student support – personalising, modes of learning/engagement - confidence and resilience encouraged when the problem solving
Behavioural (Do) - students constructing learning using prior knowledge - moving with students' ideas - creativity – no limitations on original ideas for finding solutions - connecting to real-world problems - hands-on scientific making and constructing - collaborating with others to confirm and support learning - valuing the process of learning not just the outcome - making connections between class learning and physical construction - engaging open-ended activities - student led, student driven, agency, CHOICE - teachers guiding and empowering students to find solutions

Table 1 Teacher Factors impacting student engagement

Through observation, it was evident that the level of engagement for students began to lift because of the hands-on nature of sessions. Many students were achieving success as teachers were emphasising the process of learning rather than the end product. Because steam learning instructional practices have a constructivist approach that impacts directly on metacognition, students felt more involved and began to show a more intrinsic motivation to engage. This is a significant finding as the physical construction of learning enabled students to engage because they could see and understand what they were doing (Prince, 2004).

Students were able see their thinking in action by building understanding through reflective journals, thus connecting thoughts and making learning coherent.

They linked new experiences with existing knowledge and skills, thus building metacognition and feelings of success (Aydon, 2020, as cited by Bassachs, 2020).

Perceived Success Influencing Student Engagement

From the analysis of data, discussions and interviews, it was found that students who felt successful and thought they were making progress were influenced to feel more engaged. The factors in this study that led to students perceiving success were understanding the tasks, feeling like they were making progress, and a connection or relationship to the teacher and students in the focus group.

Although there is limited research to connect perceived success with student engagement with steam learning and Design Thinking in primary schools, Howard and McInnes (2012), found that students who perceived they were doing "fun play activities" were more engaged than when they were using the same equipment to do "learning activities."

Parallels can be drawn from this research and how students' perceptions of learning positively affected their engagement and well-being. In this project students perceived they were having fun and felt good about what they were doing. Students thought steam learning and Design Thinking was fun, and they felt successful and engaged. They experienced flow when students were so engrossed in their work that they lost track of time (Nakamura & Csikszentmihalyi, 2014). As students adjusted to new methodologies, they felt more secure and gained more intense interest in learning (Figure 2).

Student engagement through being involved in hands-on learning grew, with clusters of high and extremely high involvement evident as students made and trialled prototypes (Figures 1 and 2). Levels of student *well-being* and *involvement* were observed and recorded to track engagement of students in iterations 1 and 2.

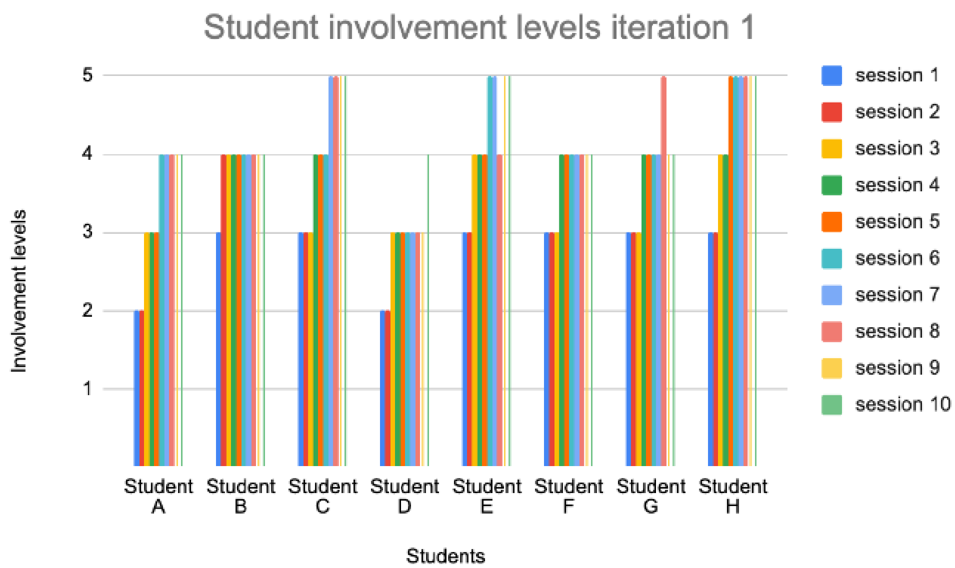

Figure 1. Leuven Scale Involvement levels iteration 1

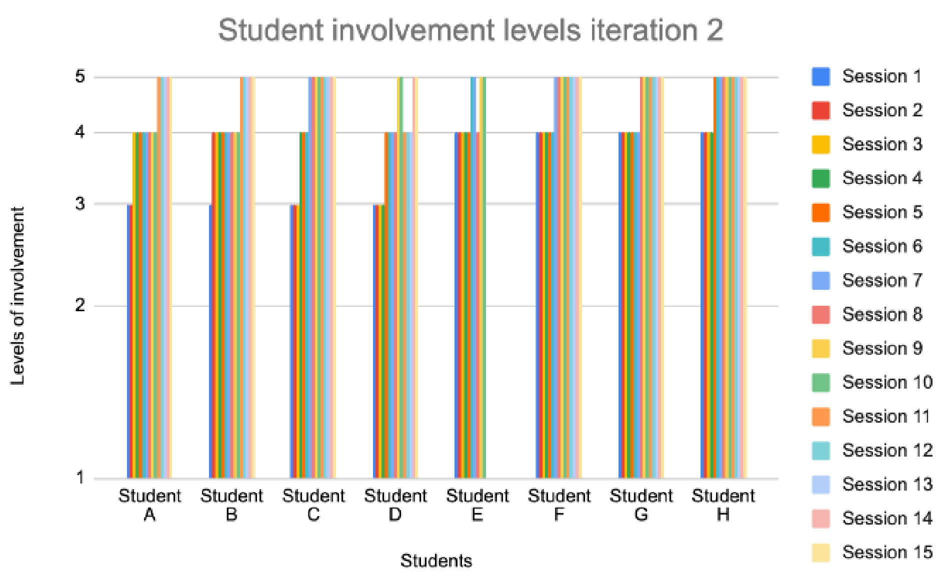

Figure 2. Leuven Scale Involvement levels iteration 2

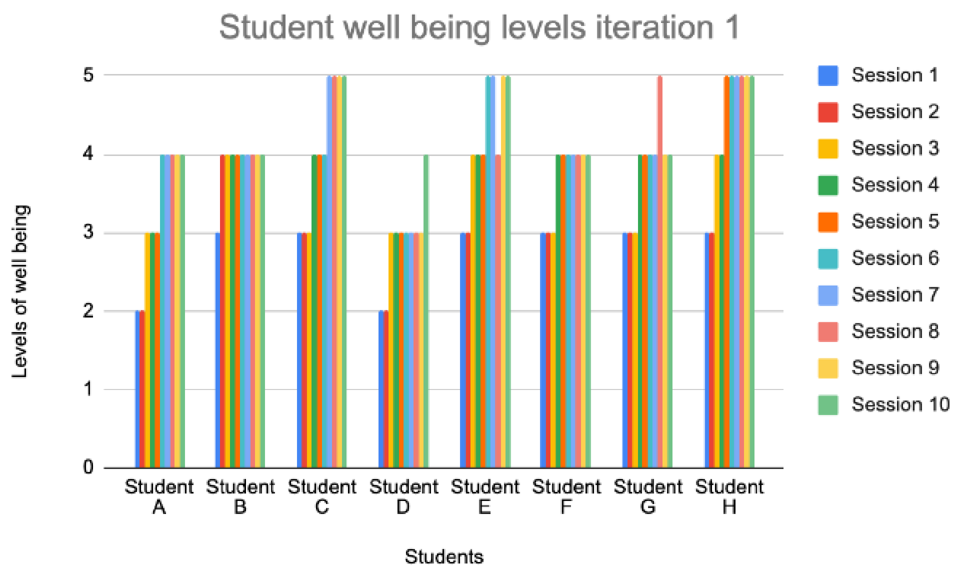

Figure 3. Leuven Scale Well-being levels iteration 1

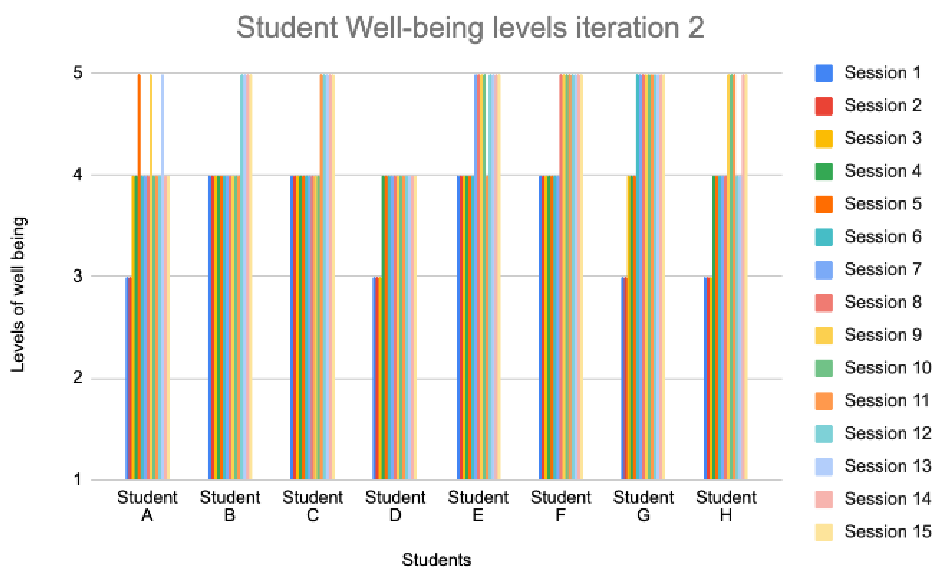

Figure 4. Leuven Scale Well-being levels iteration 1

Key: (1 = Extremely low, 2 = Low, 3 = Moderate, 4 =High, 5 = Extremely high) (adapted from Laevers, 2008).

In iteration 2, prior learning was built on and improved instructional strategies were implemented (such as more explicitly teaching, journaling and rubrics) to support learning. This impacted students' learning as they showed a marked improvement in emotional, behavioural and cognitive engagement. This is likely to be because the changes implemented had an impact on outcomes. Particular excitement and more active involvement was noted as students completed and tested prototypes seen in Figures 1–4.

Outliers in well-being data can be explained by understanding the differentiated learning needs of focus group students and the time these students took to settle into new learning. Many students showed increased engagement and involvement in learning because of the choices they had in sessions and the increased value they felt towards Design Thinking.

Through informal interviews with teachers, it became evident that many key characteristics of collaboration were validated in our community of practice. Examples of this were, having a shared vision, feelings of inclusiveness and good communication. Fullen (2015) confirms that relationships are key to collaborative teaching and learning.

New pedagogical strategies were trialled, these included co- construction of learning with students and using a range of digital tools to create learning. Teachers found that improved questioning techniques were developed and learning sessions were dynamic and fun for them also.

For most students, Design Thinking modes supported cognitive engagement as they were able to make meaning from their learning experiences. The modes also helped provide a systematic framework for students to find solutions for problems posed through their inquiry learning. Observed student behaviours that demonstrated increased engagement through steam learning processes were: continuous activity, students being excited about next steps, and intense moments where students were involved and not easily distracted from learning (Laevers, 2008).

When students had choice and had unlimited opportunities to be creative, they felt empowered by this. Allowing for students to become aware of their creativity in the classroom includes "Fostering open ended activities, accepting students as they are and boosting self-confidence" (Fleith, 2000, p. 150).

Recommendations

This project identified several noteworthy factors to demonstrate that steam learning and Design Thinking processes had a positive impact on student engagement.

One factor that supported improved engagement was the co-construction of learning, enabling students to think critically and creatively to solve real-world problems in innovative ways. Additionally Design Thinking has provided a framework for thinking and has challenged the way students felt about failure because students were constantly revising their thinking. It has encouraged out-of-the-box thinking to resolve problems (Dweck, 2016). The impact of hands-on learning experiences combined with students’ perception of learning being fun increased, leading to increased involvement and engagement.

An essential component of leading the collaborative teaching in this project has been developing relationships with teachers and enhancing their practice through building on their strengths. As a result of the project and its findings, many teachers found they have improved their practice to include greater student involvement in learning processes.

Limitations

Student surveys were used to get an insight into engagement in this project. However, with younger students there are variables that could bias their accuracy; the ability to read and understand questions, and students wanting to please the teacher to name a few (Christensen et al., 2012). I found measuring student engagement is challenging during active hands-on steam learning situations. The primary tool used was teacher observation. The Leuven Scale indicators were useful but in reality, using these coupled with informal questioning enabled me to get a clearer picture of how well learners were engaged. For future reference, having an outside observer would also enrich data collection, allowing for uninterrupted observation of students.

Throughout this project many teachers have embraced new methodologies that have challenged their thinking. This has required my leadership to be supportive and adaptive to cater for the needs of individual teachers. The project has highlighted steps towards developing students' lifelong learning skills. It has provided a platform for future steam learning and Design Thinking collaborative teaching opportunities in our school.

References

Bassachs, M., Cañabate, D., Nogué, L., Serra, T., Bubnys, R., & Colomer, J. (2020). *Fostering Critical Reflection in Primary Education through Steam Approaches*.
Educ. Sci. 2020, 10, 384; www.mdpi.com/journal/education

Bolstad, R., Gilbert, J., McDowall, S., Boyd, S., & Hipkins, R. (2012). *Supporting future-oriented learning & teaching – a New Zealand perspective*. Report to the Ministry of Education NZ.

Bertrand, M. & Namukasa, I. (2020). *Steam education: student learning and transferable skills*. Journal of Research in Innovative Teaching & Learning Vol. 13 No. 1, 2020 pp. 43-56.

Chen, A., Kiersma, M., Yehle, K., & Plake, K. (2015). *Impact of an Ageing Simulation Game on Pharmacy Students' Empathy for Older Adults*. Retrieved November 14, 2015, from http://www.ajpe.org/

Cohen, L., Manion, L., Morrison, H. (2018). *Research Methods in Education*. Routledge.

Christenson, S., Reschy, A., & Wylie, C. (2012). *Australian Handbook of student engagement.* Springer.

Cresell, J. W., & Plano Clark, V. L. (2011). *Designing and conducting mixed-method research*. 2nd Sage.

Davis, M. (1998). *Thinking like an engineer.* Oxford University Press Inc.

Dweck C,. (2016). *What having a growth mindset actually means*. Harvard Business Publishing Education.

Fullan, M. (2015). Leadership from the Middle: A system strategy. Education Canada.

Fleith, D. (2000). Teacher and student perceptions of creativity in the classroom environment. Roeper Review 22:3, 148-153, DOI: *10.1080/02783190009554022*

Fredricks, J., Blumenfeld, P., & Paris, A. (2004). *School engagement: Potential of*
the concept, state of the evidence. Review of Educational Research, 74 , p59–109.

Fredricks, J., McColskey, W., Meli, J., Mordica, J., Montrosse, B., & Mooney, K. (2011).
Measuring student engagement in upper elementary through high school: A description of 21 instruments. (Issues & Answers Report, REL 2011–No. 098).

Groccia, J. (2018). *What is student engagement? New directions for learning and teaching.* Volume 2018, issue 154 Special issue: Student Engagement: A Multidimensional Perspective p 11-20.

Hannon, V. & Peterson, A. (2017) Thrive: Schools Reinvented for the Real Challenges We Face. Innovation Unit Press.

Hase, S. & Kenyon, C. (2007). *Heutagogy: A child of complexity theory*. Complicity: An International Journal of Complexity and Education, 4(1), 111-119.

Howard, J., McInnes. (2012). *The impact of children's perception of an activity as play rather than not play on emotional well-being.* Child: care, health and development, 39, 5. https://elearning.tki.org.nz/Teaching/Future-focused-learning/STEM-steam

Ideaco design thinking model http://www.ideaco.org/2013/07/standfords-design-process-for-kids-teaching-big-picture-problem-solving/

ITL Research. (2012). *21CLD Learning Activity Rubrics*. https://education.microsoft.com/GetTrained/ITL-Research

Kelly, D. (2012). *http://www.theagileelephant.com/what-is-design-thinking/*

Klyn, L. (2018). Steam Design Thinking And Innovation: A Collaborative, Interdisciplinary, Authentic Approach To Problem Solving In Mathematics. tone Projects. 212. https://digitalcommons.hamline.edu/hse_cp/212

Laevers, F. (2008). Making care and education more effective through wellbeing and involvement. *An introduction to Experiential Education. Research Centre for Experiential Education* – University of Leuven.

Mc Niff, J. & Whitehead, J. (2005). Action Research for Teachers: A practical guide. Fulton.

Ministry of Education. (2018). Technology in the New Zealand curriculum. http://nzcurriculum.tki.org.nz/content/download/167461/1235900/file/Techno logy%20in%20th e%20New%20Zealand%20Curriculum%202017.pdf

Muramatsu, K., Wangmo, S. & Wangchuk, Y. (2019). *e-Design Education Using a 3D Printer Based on Design Thinking at Primary School*. ECEL 2019 18th European Conference on e-Learning, 412.

Nakamura J., Csikszentmihalyi M. (2014) *The Concept of Flow. In: Flow and the Foundations of Positive Psychology.* Springer, Dordrecht. https://doi.org/10.1007/978-94-017-9088-8_16

Nixon, C., Lizaire, F.(2007). *Elementary Science Literature Review.* Alberta Education Publication.

Prince, M. 2004. *Does active learning work? A review of the research.* Journal of Engineering Education. 93: p 223-231.

Rich, C. (2019). https://elearning.tki.org.nz/Teaching/Future-focused-learning/STEM-steam#js-tabcontainer-1-tab-3

Robinson, Viviane. (2010). From Instructional Leadership to Leadership Capabilities: Empirical Findings and Methodological Challenges. *Leadership and Policy in Schools.* 9. 1-26. 10.1080/15700760903026748.

Rowe, P. 1987. *Design Thinking.* MIT press. Massachusetts.

Shreeve, A. (2015). *Signature Pedagogies in Design In Design Pedagogy* (p 83-94). Dorchester: Gower.

Siilata, R. (2015) https://nzcurriculum.tki.org.nz/Curriculum-resources/Media-gallery/Cultural-diversity/Cultural-diversity-in-the-classroom

Sousa, D., & Pilecki T. (2013) From STEM to steam: Using brain-compatible strategies to integrate the arts. Thousand Oaks CA: Sage.

Taylor, T. (2020). *Design thinking across the curriculum*. Scan, 39 (2) Resource: Website - Design thinking across the curriculum by NSW Department of Education 2019.

Taylor, S., & Lowe, P. (2021). *Steam integration.* Teachers and Curriculum, 21(2), 45–53. https://doi.org/10.15663/tandc.v21i0.382

Wenger, E. (2002). Cultivating communities of practice: a guide to managing knowledge. Harvard Business Press.

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