Shaping STEM Literacy Through Discourse: The Role of Engineering and Technology in a New Zealand Classroom

Abstract

STEM literacy is essential for preparing students to solve real-world problems across science, mathematics, engineering, and technology domains. However, the integration of STEM education especially in terms of its influence on student discourse and interdisciplinary learning remain underexplored. This study contributes to STEM education research by highlighting how discourse within technology classrooms mediates the integration of science, mathematics, and engineering concepts. Conducted in a New Zealand secondary school, the qualitative case study draws on classroom observations, student portfolios, interviews, and field notes. Thematic analysis revealed varied levels of interdisciplinary discourse, with some students integrating scientific and mathematical reasoning, while others relied solely on technological language. These findings underscore the importance of teacher scaffolding, structured reflection, and intentional strategies to support the development of interdisciplinary understanding. The study contributes to research on STEM integration and highlights the socio-cultural dynamics of technology education in fostering STEM literacy.

Keywords: STEM literacy, interdisciplinary discourse, technology education, design-based learning.

Introduction

At the secondary education level, the role of technology (T) and engineering (E) in Science, Technology, Engineering and Mathematics (STEM) is not often clear. While science and mathematics are well-defined school subjects and generally compulsory, technology as a school subject is often an elective, and technology is often confused with information technology (IT). This lack of clarity presents a challenge in defining how STEM education can be effectively structured to improve student learning outcomes (Williams, 2017; Honey et al., 2014). International research highlights that STEM education policies often focus on science and mathematics, while technology and engineering in STEM receive less emphasis, limiting students' exposure to authentic STEM integration (Marginson et al., 2013; National Academy of Engineering & National Research Council, 2014).

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This study examines how engineering and technology-based discourse contributes to the development of STEM literacy, highlighting the role of socio-cultural interactions in shaping students' conceptual understanding. The study examines classroom practices that view student learning beyond a purely cognitive framework into a socially constructed practice, emphasizing how discourse plays a role in shaping STEM literacy. The research focuses on how students and teachers design and construct an artifact in a technology classroom and how these interactions facilitate development of interdisciplinary discourse.

Research Questions

This study seeks to answer the following questions:

1. How does participation in technology and engineering activities shape students' discourse and understanding of STEM concepts?
2. What role does experimentation and investigation play in the development of interdisciplinary discourse in STEM?
3. How do students appropriate and integrate disciplinary knowledge from science, mathematics, engineering and technology into their learning experiences?

STEM Literacy

The potential goals of STEM integration include improving technological literacy, increasing interest and competence in mathematics and science, and enhancing problem-solving skills (Gattie & Wicklein, 2007; Rogers, 2005). Despite the widespread advocacy for integrated STEM education, literature lacks clarity on how these subjects can be effectively connected in classroom settings (PCAST, 2010; English, 2016). Research suggests that a design-based curriculum can bridge these gaps by engaging students in active learning through engineering and technology contexts (Lemke, 1990; Norton, 2006; Wendell & Rogers, 2013). It is well known that project-based and inquiry-driven approaches allow students to develop STEM literacy by engaging in collaborative problem-solving and real-world applications (Capobianco et al., 2013; Kelley & Knowles, 2016). However, effective measures such as such as integrating explicit scaffolding, structured reflection, and interdisciplinary links need to be understood which require a better understanding of practices of students and teachers in a classroom where the design process is at the heart with an aim to improve STEM literacy through a student-centered approach.

A student-centered approach that fosters authentic learning experiences, collaboration, and classroom discourse can support the development of STEM literacy. The technology curriculum requires students to negotiate meaning through interactions with teachers, peers, resources and materials, which shape their professional identities (Adams et al., 2011; Case & Light, 2011). This study argues that without opportunities for students to participate in the design process through experimentation and investigations, students may struggle to develop the interdisciplinary discourse necessary for STEM proficiency. A lack of exposure to design thinking and problem-solving strategies can limit students' ability to synthesize knowledge across disciplines, reinforcing the need for structured STEM integration models that emphasize collaborative and inquiry-driven learning environments (Kelley & Knowles, 2016; Lin et al., 2021).

The Role of Discourse in STEM Education

The term discourse, as per Gee (1999) refers to ways of knowing, doing, talking, reading, and writing. The term discourse refers not only to the stretches of language, but also includes both the context (i.e., engineering, mathematics, technology or science) and the cultural demands. Moje et al. (2004) argue that incorporating multiple perspectives and discourse in the classroom can support student learning and improve conceptual understanding in science and engineering. With this, students develop STEM literacies through social practices, by negotiating meaning through interactions with their peers and the learning environment (Adams et al., 2011; Case & Marshall, 2011). This paper argues that if students are provided an environment where experimentation and investigation are at the center of learning, this could assist students in their development of integrative STEM discourse- an ongoing process of meaning-making across disciplinary boundaries (Osborne, 2010; Yore et al., 2004)

To investigate this relationship, the study examines how students' engagement in a technological design context supports the development of integrative STEM discourse. In this study, *discourse* encompasses multiple classroom interactions which includes student-student exchanges, small-group discussions (teacher with students), and teacher led whole-class conversations and discussions. Small groups discussions facilitated exploratory reasoning, whereas teacher led whole-class discussions fostered information dissemination, consensus-building, and teacher scaffolding of key technological concepts related to the challenge. When students participate in design-based contexts, they engage in discipline-specific discourse, which can naturally integrate science, mathematics, technology and engineering concepts. The use of discourse occurs when students use language that is:

- Grounded in the discipline
- Metacognitive and reflective
- Consistently applied throughout classroom activities
- Socially embedded within peer interactions
  (Rogoff, 1995; Levrini et al., 2015)

Appropriation, in this study, implies that students' discourse is (a) an expression of personal signature ideas, (b) grounded in the discipline, (c) thick (deeply contextualized and reflective) in the sense of involving a metacognitive and epistemological dimension, (d) nonincidental in the sense of being consistently used throughout classroom activities, and (e) a carrier of social relationships in the sense that it positions the student within the classroom community (Levrini et al., 2015). Rogoff (1995) used the term *appropriation* from Bakhtin's (1981) literature and considers the term *appropriation* as words and utterances that refer to the social norms of communities. In this study, the term *appropriation* refers to the socio-cultural learning process where students internalize disciplinary discourse, which involves moving beyond simply recalling technical terms to meaningfully use disciplinary language within the relevant context to advance design reasoning (Rogoff, 1995). By analyzing classroom discussions, student interactions, and teacher facilitation, this research investigates how interdisciplinary discourse development in technology classrooms supports STEM literacy and interdisciplinary learning.

Research Significance

This study contributes to the ongoing dialog on STEM education by providing insights into how students interact with engineering and technology within a secondary school setting. Understanding how students develop interdisciplinary discourses in STEM education can inform curriculum design, teaching strategies, and policy decisions. The findings can help educators construct a learning environment that supports interdisciplinary knowledge integration within a design context, ultimately enhancing students' STEM literacy and problem-solving capabilities.

Theoretical Framework & Literature Review

STEM literacy is a critical component of general K-12 education demonstrating the ability to apply science, technology, engineering, and mathematics concepts to solve complex, real-world problems. The integration of these disciplines within a context fosters not only content knowledge but also critical thinking, problem-solving, and interdisciplinary reasoning. Despite the literature putting greater emphasis on STEM education, existing literature reveals inconsistencies in how these subjects are integrated within secondary education (Thibaut et al., 2018; Margot and Kettler, 2019), particularly in technology classrooms. This study highlights the role of socio-cultural interactions in shaping students' conceptual understanding by examining how engineering and technology-based discourse contributes to the development of STEM literacy.

The socio-cultural framework provides a comprehensive lens for examining STEM literacy. The socio-cultural perspective asserts that learning is inherently social and mediated by cultural tools, language, and interactions with more knowledgeable others (Vygotsky, 1978; Lave & Wenger, 1991; Mercer, 2004). STEM literacy, within this framework, emerges through participation in structured learning environments where discourse, cooperation, collaboration, and problem-solving are central (Kelly, 2011; Hand et al., 2003). Students acquire scientific and technological knowledge by engaging in authentic classroom interactions, negotiating meaning through discussion, and internalizing norms of the discipline through engagement in the design context (Lemke, 2001; Moje, 2007).

Discourse plays a pivotal role in STEM learning as students develop literacy through communicative practices embedded in specific social contexts. Gee's (1999) discourse theory highlights how language constructs knowledge and identity within disciplinary domains. In STEM classrooms, students are not merely expected to acquire technical vocabulary, but learn how to think and communicate like scientists, engineers, and technologists through structured participation within a design context (Lemke, 2001; Moje, 2007; Pearson, Moje, & Greenleaf, 2010). The teacher's role in technology is crucial in scaffolding student interactions and guiding students toward appropriating disciplinary discourse (Van de Pol, Volman, & Beishuizen, 2010). Rogoff's (1995) theory of *appropriation* further reinforces the notion that students learn by participating in socio-cultural activities, gradually internalizing expert ways of thinking and reasoning (Leung, 2020; Wendell & Rogers, 2013; Mercer & Howe, 2012).

Research on STEM integration has consistently emphasized the importance of authentic, interdisciplinary learning environments to foster interdisciplinary learning (English, 2016; Kelley & Knowles, 2016). However, studies suggest that classroom practices often remain fragmented, treating STEM subjects in schools as distinct rather than interrelated domains.

Technology Education

Technology classrooms offer a promising space for STEM integration to happen, as students engage in technological design (Kolodner et al., 2004; Norton, 2008; Wendell & Rogers, 2013). Such environments support students in constructing interdisciplinary knowledge through hands-on experimentation and collaborative problem-solving within a technological design context (Kelley & Knowles, 2016; English, 2016).

The transition from multidisciplinary to interdisciplinary discourse (and transdisciplinary) remains an area of immense interest to practitioners and researchers. While multidisciplinary learning involves parallel exploration of different STEM subjects, interdisciplinary learning integrates STEM concepts to create a cohesive framework of understanding and interdisciplinary learning (Beane, 1995; Vasquez et al., 2013). While transdisciplinary learning goes a step further by moving beyond the boundaries of disciplines altogether, emphasizing the mobilization of knowledge and practices to address real challenges and to achieve shared goals (Nicolescu, 2002; Mansilla & Duraisingh, 2007). The socio-cultural perspective provides us a basis to argue that this transition occurs through guided participation in collaborative activities where students engage in iterative problem-solving, share diverse perspectives, and refine their reasoning through action and dialogue (Lave & Wenger, 1991; Mercer, 2004). Cunningham and Kelly (2017) argue that students develop deeper conceptual understanding when they are encouraged to participate in interdisciplinary discourse, linking scientific and mathematical reasoning with engineering and technological applications in meaningful ways.

Despite growing recognition of the importance of STEM discourse, gaps remain in our understanding of how students' appropriate disciplinary language while working on technological design contexts (Osborne, 2010). Existing research has not sufficiently examined the role of socio-cultural interactions in shaping STEM literacy within technology education. Additionally, studies have yet to explore how classroom discourse mediates students' ability to transition from multidisciplinary engagement to interdisciplinary (or transdisciplinary) reasoning and discourse (Pearson, Moje, & Greenleaf, 2010). While this study emphasizes the move toward interdisciplinary reasoning, it also accommodates some scholars also argue that the ultimate trajectory is toward transdisciplinary reasoning, where disciplinary boundaries become less significant and knowledge is utilized primarily to achieve shared end goals (Malone Back et al., 2016; Takeuchi et al., 2020). Understanding this process is critical for designing curricula that foster STEM literacy and contextual integration.

This study seeks to fill these gaps by analyzing student-teacher interactions and investigating discourse development in a technology classroom. By examining how students appropriate and internalize STEM discourse through participation in Technological Design-Based Learning, a form of design learning distinct from other disciplines because of its focus on technological problem solving and engineering practice. This research contributes to the broader understanding of socio-cultural influences on STEM literacy development. Through empirical analysis, this study will provide insights into how collaborative, discourse-driven, integrative learning environments can enhance students' ability to integrate knowledge and develop discourse across STEM disciplines.

Method

This study employs a qualitative case study method to examine how students develop STEM literacy through socio-cultural interactions in a Year 11 secondary school technology classroom. A case study design was suitable for this research as it enables an in-depth exploration of student discourse appropriation and interdisciplinary learning within an authentic educational context (Yin, 2018). The study is interpretive in nature, focusing on understanding the experiences and interactions of students and teachers as they engage in disciplinary discourse and knowledge construction in a technology classroom.

Participants and Setting

The research was conducted in a Year 11 technology classroom in a secondary school in New Zealand. The participants consisted of 19 students, aged between 15 and 16 years, who were enrolled in a year-long design-based project. The classroom environment was selected due to its emphasis on technology and the design process, which provided a relevant context for examining STEM discourse development. The teacher was an experienced educator with over 20 years of classroom experience in technology. The teacher played the role of a facilitator in guiding students through the various stages of the project.

Data Collection

Data collection involved classroom observations, student questionnaires, semi-structured teacher interviews, informal classroom discussions, focus group interview with students, and student portfolio analysis. Observations were conducted over a ten-month period, during which four classroom sessions were observed per week, each period lasting one hour. Field notes were maintained to document teacher-student interactions, peer discussions, and student engagement in both classroom and workshop. Audio recordings of the classroom supplemented these observations, allowing for a comprehensive analysis of classroom discourse patterns and student participation. In addition to observations, semi-structured focus group interviews were conducted with all students to represent a range of perspectives on discourse appropriation and integration. These interviews explored students' experiences within the design context, their perceptions of integration, and their use of disciplinary language in project discussions. Each interview lasted between 30 to 45 minutes and was audio-recorded for transcription and analysis. The teacher was interviewed twice, once at the beginning (end of Term 1) and once at the end of the study (end of Term 4), to examine integration strategies, scaffolding techniques, and the facilitation of interdisciplinary discourse development in the classroom.

The study also incorporated document analysis to examine students' written work in their technology portfolios. These documents provided valuable insights into how students articulated STEM concepts in written form and how their disciplinary discourse evolved over the course of the study. Analyzing these artifacts enabled a deeper understanding of how students integrated knowledge from multiple STEM disciplines and appropriated domain-specific language within the context of their design.

Data Analysis

Data were analyzed using thematic analysis, as outlined by Braun and Clarke (2006), to identify recurring patterns in students' discourse development and integration of cross-disciplinary information. The analysis followed an iterative process, beginning with the familiarization of data through repeated reading of transcripts, field notes, portfolios and photographs (Nowell et al., 2017; Clarke & Braun, 2017). Open coding was conducted to identify key themes related to socio-cultural interactions, discourse appropriation, and interdisciplinary application of knowledge (Merriam & Tisdell, 2016). These initial codes were then refined into broader themes that aligned with the theoretical framework, focusing on how students constructed and internalized STEM discourse through participation in collaborative activities within the wider context of the design. Interpretation of the findings was guided by socio-cultural theory, emphasizing the role of scaffolding, peer collaboration, and discourse in STEM literacy development.

Ethical considerations and approvals were obtained from the University of Waikato's Human Ethics Committee, and informed consent was secured from all participants and their guardians/parents (BERA, 2018; Creswell & Poth, 2018). Measures were taken to ensure confidentiality of all participants, with pseudonyms assigned to all student and teacher participants. Data storage and handling adhered to ethical research guidelines approved by the University. All participants had the right to withdraw from the study at any stage without consequence, and efforts were made to minimize any potential disruptions to classroom schedule and participant activities during data collection (Tracy, 2010).

To enhance the trustworthiness of the research, the data were revisited to make rich interpretations which proved to be a useful starting point as indicated by Huberman and Miles (1998, p. 185). Triangulation across multiple data sources, including classroom observations, questionnaires, interviews, and document analysis, strengthened the validity of the findings for this study (Huberman & Miles, 1998; Flick, 2018). Thick descriptions of classroom interactions were provided to offer contextual depth and allow for a comprehensive understanding of the classroom (Shenton, 2004). However, despite these measures, certain limitations for the study are acknowledged. The study focused on a single classroom with all male participants, which may limit the generalizability of findings to other STEM learning contexts (Maxwell, 2012). Additionally, the presence of the researcher during classroom observations may have influenced student behavior, though efforts were made to minimize the effect of the observer through prolonged engagement and rapport-building during the initial academic week (Patton, 2015). Future research should examine similar discourse development processes in diverse educational settings to expand upon the findings presented in this study.

Method Summary

By employing a rigorous methodological approach, this study contributes to the understanding of how students appropriate STEM discourse through socio-cultural interactions in a technology classroom. Although framed within a socio-cultural lens, the analytic approach drew from grounded theory principles, iteratively coding classroom data and building interpretations from participants' experiences (Charmaz, 2006). The findings offer valuable insights for educators, researchers, curriculum designers, and policymakers seeking to enhance STEM literacy through discourse-driven, collaborative learning environments supported by a design context.

Findings

Introduction to the Experiment

The street luge project was a pre-defined design challenge presented by the teacher, who provided students with initial attributes and specifications. A prototype of a constructed luge by a previous technology student was displayed and demonstrated to all students initially in the workshop. Students were expected to design and construct individual luge. The intended pedagogical aim of the challenge was to achieve technological outcomes through hands-on experimentation and to promote interdisciplinary discourse linking design, science, and mathematics concepts. On the day of testing, the teacher took the class to the school's backyard where a 250–260-meter track was available for testing the luge with three different set of wheels. The teacher had the same pilot operate the luge for all three-wheel sets to ensure consistency. A 50 mm-diameter wheel was fitted to the existing luge, and two sets of readings were taken with the same pilot. Another student recorded times for both runs with the 50 mm wheel from the bottom of the track. Two sets of recorded time were also taken for the 70 mm-diameter longboard wheels and the 100 mm-diameter wheels. Initially, the teacher installed the 50 mm wheels, while two other students fitted the 70 mm and 100 mm wheels to the luge. Not all students physically interacted with the luge, the wheels, the trucks, or the tools on the day of testing. However, all students observed the pilot driving the luge down the track with the three sets of wheels and noted the time to cover the track distance.

Evidence from the initial questionnaire (implemented in Term 1) suggested that students chose to take Technology in Year 11 because they found its practical aspects to be fun, beneficial, and meaningful for their professional and vocational goals. Most students perceived technology as an interdisciplinary subject that could help them develop generic and engineering skills.

Classroom Discussions and Interdisciplinary Learning

Analyzing the data students collected from the field led to a series of discussions in the design room, providing an opportunity for students to reflect on their wheel choices. These discussions involved interdisciplinary discourse in technology, along with indirect references to science and mathematical concepts, which were not explicitly introduced by the teacher but naturally emerged during the conversation. For example:

Tr: Just try to think about the bigger wheels, think what they do while going down the driveway. Why do you think they go faster (take less time) than the small ones?
HM: Bigger wheels roll faster.
EG: And cover more distance.
KMC: Less resistance on them.
Tr: Are they doing the same amount of revolution as the little one?
HM: No....?

Tr: While doing a revolution, do they cover more distance (referring to bigger wheels)? Is that what it is, or do they do fewer revolutions and cover more distance? Think about these mountain bikes, why do they have bigger wheels? Does the circumference of the wheel have anything to do with the distance travelled then?

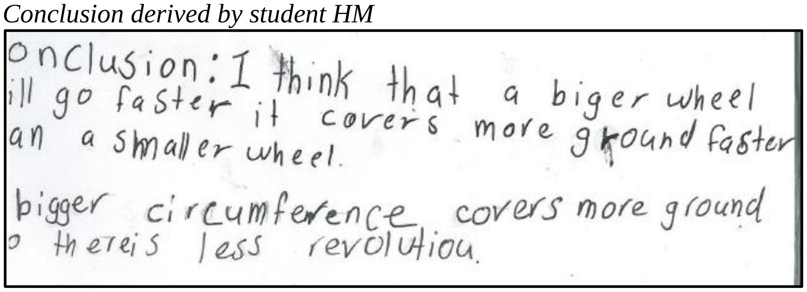
EG: Yes, so they can go through rocks and stones easily.

Tr: So, they can go over terrain they are designed to better work on. You know they don’t get caught; they actually go over them, so I kind of believe that the bigger wheels have their effect as well. Now the circumference means something else, doesn’t it? It means the distance it will cover or travel in one revolution.

The excerpts above demonstrate how students' prior knowledge and experience were recalled through contextual discussions, allowing them to relate these concepts to the current situation. The classroom discussions focused on why bigger wheels cover more ground than smaller wheels. While most of these discussions were teacher-initiated, students were keen to engage and offered their perspectives. These perspectives did not fit into pure science terminology but instead blended scientific concepts with everyday language. For example, student EG introduced the term "cover more distance," which was supported by student KMC, who stated that bigger wheel’s experience "less resistance." The teacher further expanded on the concept by asking if bigger wheels do more *revolutions* compared to smaller wheels. Instead of providing a direct answer, the teacher encouraged students to explore and reason through the concept to reach their own conclusions (Figure 1).

Figure 1

Conclusion derived by student HM



Interestingly, students leaned towards more technological applications of the wheels and provided justifications for their preference in their final conclusions. For instance, student EG noted that bigger wheels can go over "rocks and stones easily," relying on practical experience. The teacher reiterated this reasoning and took the opportunity to briefly define the term *circumference*. The technological context of testing wheels through driving experience allowed the teacher to discuss findings in plain language, while reinforcing concepts such as *circumference*, *revolution*, *resistance*, and their effect on speed. As a result, students incorporated elements of this discourse into their design decisions during reflection.

Experimental Controls and Investigation

Classroom discussions also included explanations of experimental controls implemented during the momentum (wheel testing) investigations. Below is an excerpt from this discussion:

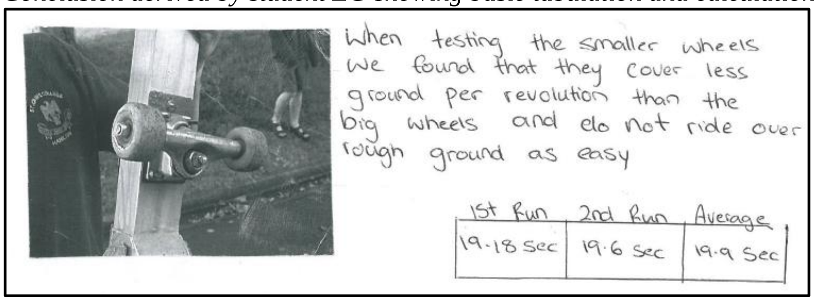
> **Tr:** When you explain what we did, try to explain that we used the same luge, the same weight of pilots... So, what do we call that??... control... so, what does that mean?
>
> **NT:** We use the same pilot with the same luge and the same weight?
>
> **Tr:** So, there is no variation, so that's the thing that did not change. Does that make sense? Because there is no good if we are testing for wheels and then you go for one and then go for another one, we got different pilots to start and suddenly the axis is going to be wrong...... well, it is going to be different, it could be different.

This discussion reinforced the nature of scientific experimentation and investigations as part of the design process.

Students demonstrated their ability to generate conclusions derived on their field observations and calculations, drawing upon middle school mathematics concepts, such as basic tabulation and calculating means. They also utilized their foundational understanding of circles, diameter, circumference, and revolutions. The conclusions formulated by the students did not incorporate mathematical equations or functions but were instead derived from basic tabulation and calculations. For instance, students identified a relationship between wheel size and the time taken to travel a given distance. Prior knowledge of a fundamental math concept, such as addition and calculating the mean, was naturally integrated into the process as students analyzed their results with guidance from the teacher. Figure 2 presents an example of such a calculation derived by student EG. Students collected field data systematically, recorded it in tabular form, and used them to inform their reasoning and to derive conclusions, aligning their design activity with the scientific method.

Figure 2

Conclusion derived by student EG showing basic tabulation and calculation



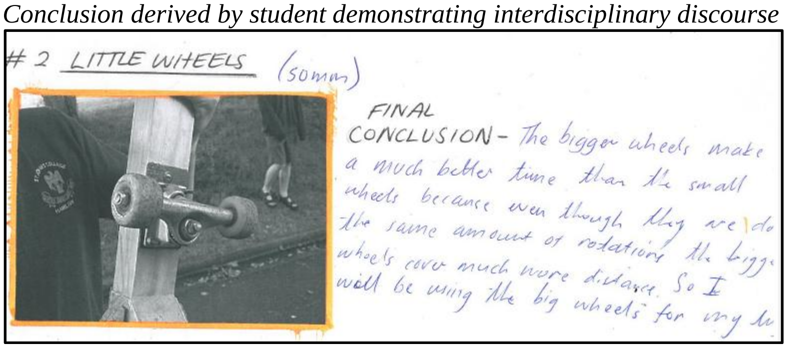
Circumference of the Wheels

Students initially had no difficulty selecting the size of the wheels, but their engagement and discussions around the terms "circumference" and "revolutions" helped them develop a deeper understanding of these concepts within the context of the wheel testing experiment. During an informal discussion with the teacher after class, he noted that students struggled to apply abstract scientific and mathematical concepts during the momentum testing phase.

In their technology portfolios, students demonstrated an understanding that bigger wheels cover *more ground per revolution* than smaller wheels and, as a result, concluded that they are faster (Figure 3). Terminologies like *ground per revolution* and *bigger wheels cover more ground so there is less revolution* were consistently used by six students. Among these students, a general understanding emerged that the larger 100 mm wheels covered more ground with fewer revolutions, making them faster than the smaller 50 mm wheels.

Figure 3

Conclusion derived by student demonstrating interdisciplinary discourse



Wider Wheels and Weight Distribution

Two students, JS and LG, discussed the merits of the 70 mm-diameter longboard wheels in terms of width and improved weight distribution in their portfolios. LG noted that the 70 mm wheels were the best for *speed*, describing them as having smoother wheels and being "better balance-wise." The terms used in their discussions included "wider" and "better dispersed weight." LG also noted that the 70 mm wheels are better suited for navigating over "sticks and stones" and were specifically designed to go downhill.

Student JC on the other hand, wrote that the 100 mm wheels were not smooth, explaining that "if you go over something like a rock or a bump, then you will feel it." JC's conclusion did not initially consider the 70 mm longboard wheels, yet the student's final constructed luge (final product) in Term 4 was fitted with 70 mm longboard wheels.

The teacher observed that students frequently asked questions that required knowledge from multiple subject areas. For example, student JS raised the question of how wheel width might affect the speed of the luge, which led to the following discussion:

Tr: "Yes, that has quite a lot to do with the speed, isn’t it?"

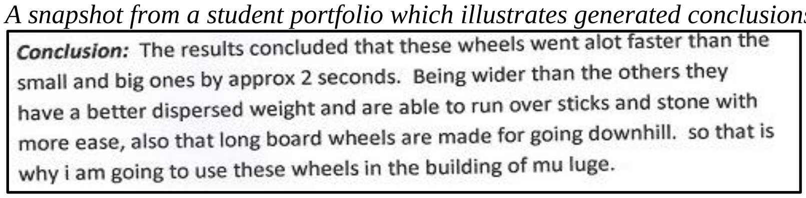
JS: "The others (wheels) were bigger (in diameter), but this one provided a better grip and comfort."

Tr: "Because we got weight spread over a wide distance, the weight is now split, which provides a better grip and balance."

This discussion took place between the teacher and student JS, with student LG sitting near JS during this session being only a passive listener to this discussion. In his portfolio, LG also noted that the 70 mm wheels were the best "balance-wise." No other students commented (Figure 4) on weight distribution in their portfolios.

Figure 4

A snapshot from a student portfolio which illustrates generated conclusions


Conclusion: The results concluded that these wheels went alot faster than the small and big ones by approx 2 seconds. Being wider than the others they have a better dispersed weight and are able to run over sticks and stone with more ease, also that long board wheels are made for going downhill. so that is why i am going to use these wheels in the building of mu luge.

Observations and Practical Experience

Students including JS, JC, LG, and MY, did not ride the luge on the day of testing but focused on observations and practical driving experience to derive their conclusions. For example, JS noted how the 70 mm wheels can run over "sticks and stones’’ more effectively." JC wrote that the 50 mm wheels were not the fastest but were better for "going over small stones and bumps." JC also critiqued the 100 mm wheels, stating that while they were faster, the driver would feel bumps when going over "rocks and sticks." Ultimately, JC decided to use the 100 mm wheels.

LG wrote that while the 100 mm wheels are faster compared to the 50 mm wheels, their "height" (referring to diameter) made steering the luge a practical driving issue. Similarly, MY noted in his portfolio that the 50 mm wheels were too small to "get over rough terrain" and "slowed it down," whereas the 100 mm wheels overcame these issues. Only MY and SS commented that the 70 mm wheel had *better bearing* than the other two-wheel sizes.

Displayed Artifacts

Previous students' work on momentum testing and their derived conclusions, were displayed on the common board in the design room. Additionally, a luge from a past student, fitted with 70 mm wheels, was also displayed in the workshop, influencing students' decisions to select the 70 mm longboard wheels. The teacher instructed students to refer to the format and content of the presentations from previous students on the notice board as reference while students were working on their conclusions. The researcher observed that similar terminology such as *covers more ground*, *circumference*, *revolutions*, and *smooth ride* was used consistently in these previous student conclusions.

Classroom Culture

It was notable that all students ultimately chose to use the 70 mm longboard wheels, a decision supported by the data collected from the field. Classroom discussions centered on why the 70 mm longboard wheel achieved high speed in less time. For example, student NP initially concluded in their portfolio that they would use larger wheels (100 mm wheels) but later selected the 70 mm wheel instead during construction. Similarly, student ST chose the 70 mm wheel size. These two students were seated close to each other in the design room, which may explain their shared decision making.

There was also a noticeable bias towards selecting the 70 mm longboard wheel as the preferred option for the luge, primarily due to its speed and ease of riding. This preference was discussed before the experiments were conducted, but the collected data supported this hypothesis. The 70 mm longboard wheels have also been used in previous years constructed luges, which may have contributed to their selection. It could be argued that, through hands-on investigations using existing technologies (such as street luge and different wheel sizes), students developed an understanding that the 70 mm longboard wheels were the most suitable choice for achieving a smoother ride.

Teacher's Perspective

The teacher did not deliberately incorporate scientific discourse into an engineering or technological design context. In a formal interview conducted at the end of Term 1, he stated:

> They started coming to me after wheel testing with questions, you know, like if we drop two weights, which one will hit the ground first? There is science thinking coming into it, but they were thinking about it in relationship to a project, so introducing things like momentum, weight, component testing, the knowledge of materials, and even the knowledge of processes here, we are going through at the moment, all have knowledge we have to find from some other subjects. (Teacher Interview, Term 1)

Interestingly, some students preferred to use only technological language, with 10 out of 19 students formulating conclusions that were devoid of any science and math concepts. This was evident in their focus group interviews conducted at the end of Term 4.

Focus Group Insights

During these interviews, students NP and JS stated, "We just did it without any science or math." When explicitly asked about the use of scientific and mathematical concepts during the testing phase, the group (MC, TG, and JC) responded as follows:

JC: "Not really, you just watched."
R: "So, you didn't consider anything in terms of distance and speed?"
TG: "No."
JC: "It was nothing like I said..."
TG: "It was more like testing, like where to get the speed bump, to like weight."
JC: "Basically, the momentum testing was just to see which wheels were best for the luge and how fast it could go."
MC: "Some calculations..."
JC: "Yes, taking a look at all the different times you got and saying, oh, this one has got a lower time, so faster."

This discussion highlights the activity-driven nature of technology. Interestingly, TG and MC had indicated in their initial questionnaire (in Term 1) that they did expect to use science or mathematics in the project. Only JC mentioned that he could "possibly" use knowledge from physics, but there was no evidence of cross-disciplinary concept application in his portfolio.

Researcher Reflections

In the observed technology classroom, the teacher and students co-constructed knowledge and developed a unique classroom culture that facilitated discourse development by blending concepts from science, mathematics, and engineering within a technological design context. The interaction between participants, including students working with the tools, devices, and in groups, and engaging with the teacher in the workshop environment, shaped the shared and contextual learning culture. This aligns with socio-cultural learning theories, which emphasize that knowledge is co-constructed through social interaction and engagement with cultural tools (Vygotsky, 1978; Rogoff, 1995).

The importance of discourse in STEM education has been widely recognized (Kelly, 2011; Hsu & Roth, 2014). The present study documents how students negotiated meaning through classroom discussions, and their written conclusions in the portfolios frequently reflected shared classroom-initiated conversations and discussions that emerged while trying to understand observed phenomenon and collected data. The teacher played a key role in encouraging discussions that combined scientific and technological discourse, allowing students to develop an integrated understanding of the observed phenomena. Research has shown that integration requires active teacher input and facilitation, which includes guiding students to make cross-disciplinary connections to facilitate integration (Berland & Busch, 2012). However, in this study, while the teacher facilitated discussions involving scientific and mathematical concepts naturally within the context of the experimentation, some students chose not to engage deeply with these concepts and instead relied on their practical experience and technological reasoning when deriving conclusions. More structured scaffolding may have supported students in appreciating and applying disciplinary knowledge more systematically within this context.

Student Discourse and Integration of Science and Mathematics

A central finding in this study was that students used everyday language to express scientific and mathematical ideas within the context of the experiment, often without explicitly referencing disciplinary terminology. This aligns with research by Lakoff and Johnson (1980) and Niebert et al. (2012), who argued that understanding scientific concepts often relies on conceptual metaphors grounded in everyday experience. The technological design context provided students with an opportunity to engage in cross-disciplinary thinking, which was evident in how they described the relationship between wheel size, revolutions, and speed. However, as observed in the findings, not all students appropriated scientific discourse in their final conclusions and explanations, a phenomenon also noted by Brown and Ryoo (2008), who emphasized that students often revert to common language when scientific terms feel unfamiliar or unnecessary. The data from this study strongly suggests students found the terms mostly unnecessary to be used within the context.

The findings indicate that students who actively participated in investigations within the design process were more likely to develop cross-disciplinary discourse, blending science, mathematics, engineering with technological concepts. This aligns with studies demonstrating that learning is enhanced when students are given an opportunity to engage in hands-on experimentation and problem-solving (Hmelo et al., 2000; Adams et al., 2012). However, the study also revealed that some students maintained a purely technological perspective and approach in deriving the conclusions and choose to describe observations in practical, technology and engineering terms rather than integrating scientific terms and concepts. This suggests that while the technological design and context supported interdisciplinary discourse, not all students perceived it as necessary for deriving their decisions.

The Role of the Teacher in Facilitating Disciplinary Integration

The findings also suggest that the teacher's role was instrumental in this classroom to bridge STEM disciplines by introducing scientific and mathematical concepts within the context of the investigation. There are studies which support the idea that teachers mediate discourse and scaffold student understanding, and guiding students towards deeper conceptual engagement (Kelly, 2011; Cunningham & Kelly, 2017; Mercer & Howe, 2012; Van de Pol, Volman, & Beishuizen, 2010; Reiser & Tabak, 2014). In this study, the technology teacher used metaphors and analogies within the context of the experiment to explain complex ideas, a technique that has been shown to be effective in science education (Wellington & Osborne, 2001). For example, discussions about wheel circumference, revolutions, and resistance helped students understand the underlying science of their experiment supported by basic mathematical calculations.

However, despite the teacher's efforts, the findings highlight a gap in how students appropriated scientific knowledge within this phase of the investigation. Studies by Lemke (1990) and Moje et al. (2001) indicate that students often lacked sufficient background knowledge to integrate scientific discourse unless explicitly required to do so. This would suggest a gap in preparedness rather than reluctance, raising the question of whether prior instruction in key scientific concepts would have enabled richer integration. The teacher in this study did not compel the use of formal scientific language in deriving their conclusions, allowing students to express in ways they found most comfortable. This resulted in some students engaging with interdisciplinary discourse, while others remained within the familiar boundaries of technological language. In both cases, the students derived final conclusions based on the data they had in hand; however, some students went deeper in explaining the meaning behind the data, others choose not to.

Students' approaches towards deriving conclusions frequently reflected trial-and-error reasoning, an attribute of exploratory learning in design and technology education (Van de Pol et al., 2010). Such approaches highlight the critical role of teachers in explicitly identifying underlying mathematical and scientific principles, by guiding them to apply and optimize design performance (Hmelo et al., 2000).

Student Decision-Making and the Preference for Technological Language

A key observation was that students prioritized functionality over theoretical understanding or simply relied on device knowledge. In Technology Education literature, device knowledge (Gott, 1988) refers to understanding how devices or systems function, and it is considered important because it focuses on the material world rather than the natural world. The findings show that many students focused on optimizing the performance of the luge rather than exploring or justifying the scientific and mathematical reasoning behind their results. This is consistent with research by Barnett (2005) and Berland & Busch (2012), who found that students engaged in design-based learning often focused on solving practical problems as they emerged rather than underlying scientific principles.

Additionally, the preference students had for the 70mm longboard wheels suggests that they relied on heuristics and prior knowledge rather than purely experimental findings. Studies have shown that students often make design decisions based on familiarity and perceived success rather than systematically testing alternatives (Jonassen, 2014). This observation aligns with research on engineering decision-making, which indicates that students rely on their past experiences and observed success of past decisions when making design decisions (Cross, 2001).

Multidisciplinary vs. Interdisciplinary vs Transdisciplinary Discourse

The study provides evidence of multidisciplinary, interdisciplinary, and potential transdisciplinary discourse among students. Multidisciplinary learning involves working with multiple disciplines in parallel without contextual integration, whereas interdisciplinary learning synthesizes concepts or methodologies across disciplines into a cohesive framework to be applied within the context (Post, Keestra, & Rutting, 2016). In contrast, transdisciplinary discourse occurs when students engage in problem-solving without consciously recognizing the application of disciplines and overcoming disciplinary boundaries, they instead use knowledge and practices from different domains in achieving shared design goals (Nicolescu, 2002; Klein, 2004.

There was evidence of multidisciplinary discourse involving students discussing concepts from different disciplines without fully integrating them within the context of the experiment, while interdisciplinary discourse requires a synthesis of ideas across domains (Beane, 1995). The data also highlights at times, that students' reasoning suggested transdisciplinary engagement, as they did not explicitly distinguish between disciplinary knowledge but applied concepts pragmatically within the context of the design. The findings suggest that while some students engaged in interdisciplinary discourse, integrating scientific, mathematical, and technological language, others only discussed engineering and technological concepts without explicit reference to science or math, suggesting transdisciplinary reasoning.

This aligns with research showing that STEM integration is complex and dependent on student engagement levels (Cunningham & Kelly, 2017). While some students demonstrated conceptual integration, others treated each discipline separately, reinforcing the need for intentional strategies to support STEM integration, with potential progression toward transdisciplinary reasoning.

Challenges in STEM Integration and the Role of Prior Knowledge

One challenge observed in the findings was that some students struggled to integrate scientific knowledge despite engaging in hands-on experimentation. Research suggests that students often view science, mathematics, and engineering as separate disciplines rather than interconnected fields (Lederman & Niess, 2000). The findings from this study supports the argument that students need explicit scaffolding to recognize interdisciplinary connections (Hmelo et al., 2000).

Additionally, students' prior knowledge played a significant role in shaping student reasoning. Students were influenced by previous classroom artifact (displayed luge) and past student derived conclusions, which contributed to the bias toward selecting the 70mm wheels. Students often rely on solutions which are familiar to them rather than systematically evaluating alternatives (Jonassen, 2014). This indicates that while hands-on learning is valuable, explicit reflection of design choices and comparison of alternatives may be needed to promote deeper cross-disciplinary reasoning to achieve an integrative learning environment.

Implications for STEM Education

The findings from this study suggest several implications for STEM educators:

Scaffolding Integrated Discourse. While there was evidence that students engaged in multidisciplinary discourse, not all students displayed interdisciplinary integration within the context of the design. In this classroom, the focus was on developing technological knowledge and practices to solve the problem in hand. While students used science and mathematics concepts during experimentation, these links were not always explicit to students. There is an opportunity for teachers to explicitly model and reinforce interdisciplinary language use through Technology design based learning to help students connect scientific principles with technological applications through technology as a school subject.

Encouraging Conceptual Engagement. Some students prioritized engineering functionality over scientific reasoning, and this could be expected in any technology class. Future instructional strategies in technology could include structured reflection exercises in portfolios where students articulate the scientific and mathematical basis for their design decisions. This could assist students to think critically across disciplines assisting discourse development.

Addressing Heuristic Biases in Engineering Decisions. The preference for previously successful designs suggests that students often relied on heuristics rather than systematic experimentation. In Technology DBL, students are confronted with disciplinary heuristics, such as the scientific method, hermeneutic reasoning, or designerly ways of thinking, which guide their problem-solving processes. STEM Educators should encourage students to compare and justify design choices using empirical data gathered through systematic investigations where possible, rather than defaulting to familiar solutions.

Conclusion

This study provides further evidence that technological open-ended design challenges offer extended opportunities for STEM integration, but students' engagement with scientific and mathematical concepts varies significantly in technology. While some students merged interdisciplinary discourse, others remained comfortable with keeping their explanations within a technological framework, reinforcing prior research that STEM integration requires explicit instructional support (Berland & Busch, 2012). These variations in class suggest that without intentional instructional strategies supporting integration, students may struggle to connect STEM disciplines in meaningful ways, limiting their ability to develop interdisciplinary discourse. The findings highlight the importance of teacher scaffolding, implementing structured reflection, and intentional integration strategies in fostering deeper interdisciplinary learning through technology. By ensuring structured support, educators can help students transition from fragmented STEM knowledge to a more interconnected understanding of STEM concepts.

Statement on Artificial Intelligence

No AI tools were used in performing or communicating the work represented in this manuscript, except for Grammarly, which was used solely for grammar and punctuation checks. All aspects of data generation, analysis, manuscript development, and revision were conducted by the author without AI assistance.

Competing Interests

The author has no competing interests to declare.

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About the Author

Mathew Thomas (Mathew.thomas@openpoltechnic.ac.nz) is a Principal Academic Staff Member (Principal Lecturer) at the Open Polytechnic Of New Zealand teaching within the Engineering Degree Program. https://orcid.org/0009-0005-4483-1441