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Appropriation of Engineering Discourse through the Technological Design Process

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ABSTRACT

CONTEXT

As technology and engineering education has evolved in recent years, little emphasis has been explicitly placed in its potential to blend in STEM (Science, Technology, Engineering and Mathematics) subjects naturally with an emphasis on practicable knowledge which develops discipline specific discourse. With this paper, I wish to contribute to the knowledge on engaging students in the design process in technology (school curriculum) to assist in developing technological and engineering discourse.

PURPOSE OR GOAL

One of the goals of STEM education is to help ensure that critical thinking skills (incorporating engineering discourse) come from studying STEM subjects (PCAST, 2010). This can be achieved through a learning environment in which learning strategies and approaches are personalized and adapted to the learner's own learning styles. To achieve such a learning environment, it is crucial to examine the existing environment in secondary schools and to adopt methods which provide rich learning experiences for students through their active engagement in the learning process.

APPROACH OR METHODOLOGY/METHODS

This research proposed to study the classroom practices of a technology teacher and students (age 15-16; Year 11) in a technology classroom which had a focus on the knowledge and skills students used through investigation and experimentation while designing individual projects. The collection and processing of data was made through observation field notes, audio recordings taken during classroom observations, interviews, discussions, photographs of students working and student technology portfolios.

ACTUAL OR ANTICIPATED OUTCOMES

A variety of engineering and structural concepts were noted by the students through observations and in the conclusion's sections of their portfolios, which resonates with interdisciplinary terminologies and scientific explanations. Giving the students an opportunity to engage in the design process is a crucial part of technology in schools to develop discipline specific discourse.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

We can appreciate the position of technology in the school curriculum and its potential to develop discipline specific discourse through the practicality of real-life authentic scenarios. An enriched authentic context in technology naturally enhances knowledge transfer and engineering discourse.

KEYWORDS

Engineering discourse. Integration. Technology Education.

Goals of Science, Technology Engineering and Mathematics (STEM)

Research suggests that STEM learning should be viewed not just as a cognitive process but as a socially constructed practice that fosters STEM literacy. A range of goals for STEM alignment have been proposed, including:

- Increasing interest, competence, and the perceived usefulness of mathematics and science (Gattie & Wicklein, 2007).
- Improving technological literacy, which promotes economic advancement (Rogers, 2005; Douglas et al., 2004).
- Enhancing student learning experiences (Rogers, 2005).
- Preparing students for university engineering courses (Project Lead the Way, 2005).
- Increasing STEM workforce readiness and improving STEM literacy (Barlex, 2008).

There is reasonable evidence to assume that some of these goals may be achievable. The literature indicates little clarity about how STEM education might be constructed in a classroom environment in terms of how the subjects could relate to each other (PCAST, 2010). Effective STEM integration requires a deeper understanding of the practices of both students and teachers, especially when the design process is central. Participating in discipline-specific discourse is crucial for constructing, sharing, and refining knowledge, as it plays an integral role in learning science and mathematics within a context (Lemke, 1990; Norton, 2006; Prediger & Link, 2012).

This paper investigates students' learning experiences and discourse development. The analysis of discourse development within a technology classroom will be presented which could further provide an avenue to understand learning opportunities and strategies to develop interdisciplinary integrated discourse to achieve STEM literacy.

The Role of Discourse in Interdisciplinary STEM Learning

The term *discourse* is a broad concept, and as per Gee (1999) are ways of knowing, doing, talking, reading, and writing. The term discourse refers not only to the stretches of language, but also include both the context (i.e., engineering, mathematics, technology, or science) and the cultural demands, which is key for understanding the interdisciplinary aspects of technology education. Moje et al. (2004) also argues that bringing the multiple perspectives and discourses in a classroom could further scaffold student learning and improve science content literacy. Study conducted by Beers & Sweeney (2019) shows that interdisciplinary approaches in STEM enhance student understanding by bridging content areas, with discourse playing a vital role in helping students connect scientific, mathematical, and technological concepts.

Based on a meta-analysis study, Fidai et al. (2020) demonstrate that the design process significantly improves students' mathematical achievement, while Ortiz (2008) highlights how communication and representation in physical modeling enhance understanding. These findings support the link between hands-on technological design and the development of discourse, reinforcing the role of interdisciplinary learning in STEM education.

Appropriation of Knowledge

It could be argued that literacies are developed through social practices. Adams et al. (2011) and Case & Light (2011) argue that literacies and discourse emerge from social interactions, where students negotiate meaning and develop experiential discourses. These social practices are crucial in shaping students' professional identities, particularly within technology classrooms, as they engage collaboratively and contextually in interdisciplinary learning. Building on the concept that discourse develops through social practices, Levrini et al. (2015) introduce the notion of appropriation as a deeper stage in this process. Appropriation signifies students' ability to internalize and apply interdisciplinary knowledge, transforming their understanding into actionable insights within a context. This dynamic process allows students to engage meaningfully with concepts from science, mathematics, and technology, facilitating a more integrated learning experience. However, the role of appropriation in shaping discourse during technological and engineering design activities remains underexplored in existing literature. Examining this aspect is crucial for advancing our understanding of effective interdisciplinary integrated discourse.

Role of ‘S’ and ‘M’ in Developing STEM Literacy

Engagement with science subject promotes progressive learning in which youth develops content knowledge through discourse and participating in authentic science (NGSS, 2012). The theoretical rationale for engaging in scientific practices is based on the philosophy that students cannot fully understand scientific content and appreciate the nature of science without engaging in authentic practices themselves.

Mathematics is often used to perform essential tasks such as measurement, unit conversion, and solving equations that inform the design and functionality in projects. Studies show that math provides the precision and structure required for technical work, such as calculating forces, dimensions, and material properties (Wang & Sun, 2021). For example, Beers and Sweeney (2019) emphasize that interdisciplinary programs must align with math standards to enhance student understanding and problem-solving capabilities across various STEM fields. It could then be argued that students need to be given opportunities then to engage in interdisciplinary programs and experiences to develop discipline related understanding and discourse.

Role of ‘T’ and E in Developing STEM Literacy

Literature reveals that there is more agreement among technology educators about the activity of technology than the content. The traditional focus of technology education being on activity has represented a narrow interpretation of the procedural knowledge of technology (McCormick, 1997; Williams, 2000). This focus has typically been on the development of manipulative skills of using tools more effectively and safely. The knowledge in technology is divided into procedural knowledge which relates to activity and content knowledge (McCormick, Murphy & Hennessey 1994). A realization has been that there are many significant cognitive skills that are suitable to be developed in the context of technology education, a domain where the theory into practice is narrowed through the design process (Williams, 2000).

Technological knowledge is that which underpins technological activity, such as the use or creation of technological artefacts/products. It is through technological activity that technological knowledge is constructed and defined (Landies, 1980). This study will focus on the ways students and teacher work in a technology classroom to co-construct technological knowledge through application which further assists integrated discourse development. Researchers have argued that procedural knowledge in technology underpins technological problem solving (Levinson, Murphy & McCormick, 1997). Technological knowledge is context dependent and is used in combination with conceptual knowledge (understanding relationships among relevant concepts) and strategic knowledge (planning what to do next) to resolve dilemmas which arise during practice (Levinson, Murphy & McCormick, 1997; McCormick, 1997) could lead to integrated interdisciplinary discourse development.

In contrast, engineering is often regarded as a subset of technology, focusing on structured problems with clearly defined solutions (Dym et al., 2005). Technology deals with ill-defined problems that require creativity, adaptability, and a broader set of skills (Williams, 2000). While both disciplines encourage problem-solving in dynamic, real-world contexts, technology lacks a clearly defined body of knowledge in the curriculum. This absence of rigid boundaries promotes an interdisciplinary approach, as it draws on various domains to address complex, open-ended challenges (McCormick, 1997).

Interdisciplinary Discourse in Technology Education: Challenges and Opportunities

Interdisciplinary discourse refers to the integration and interaction between different academic disciplines, which aligns well with the context of technology education involving multiple domains such as science, mathematics, and engineering (Beers & Sweeney, 2019). Multiple discourses exist in classrooms, as highlighted by Wallace (2004), and earlier studies by Moje et al. (2001) observed various discourses, including disciplinary, instructional, and everyday discourses. Their study found that the existence of multiple discourses within a classroom can inhibit purposeful science learning. This underscores the necessity of implementing proper strategies to promote interdisciplinary discourse, facilitating science and maths learning through engineering and technology design activities. These discourses often coexist in technology classrooms, where students must navigate between highly specialized discipline related language and everyday understanding.

An integrated learning environment where language naturally blends through discussion may foster the appropriation of discipline-specific terminology within design contexts. Practical experimentation encourages integrated discourse development, allowing students to transfer content knowledge within a context and engage proactively with scientific terminology (Honeycutt-Swanson et al., 2014; Kelly, 2007). When students collaborate to construct new contextual meanings, their interactions strengthen disciplinary discourses and enhance their cross-disciplinary content knowledge and language. This literature review highlights the critical role of interdisciplinary discourse in enriching technology education, establishing a foundation for further research in this area. This paper argues that when students collaborate to construct new meaning together, their collaboration strengthens disciplinary discourses and knowledge through the procedural activities of technology, which strengthens their cross-disciplinary content knowledge and language.

Introduction to the research

This research studied the classroom practices of a technology teacher and 19 of his students (age 15-16; Year 11) in a technology classroom. The brief was to construct a street luge, a gravity powered vehicle, which incorporated safe and effective driving position. The brief specification included completion date, maximum wheel size allowed, and the final submission date of the student portfolio. . One of the constructed street luges has been shown in Figure 1 for reference.

Figure 1: A snapshot of a street luge manufactured by a student.

A case study design methodology was implemented to observe a Year 11 (age 15-16) technology classroom. In this case study, evidence was collected through classroom observations, classroom discussions with the participants, interviews with students and teachers and from student’s technology portfolios. How do students develop integrated discourse while participating in investigations and experimentation within a technological design context, and what role does this discourse play in their understanding of interdisciplinary concepts?

This paper will highlight an initial stage in the project implemented during Term 1 called ‘the momentum testing’ design phase, where students were expected to select the right set of wheels for their luge to provide the optimal driving speed and comfort.

Findings

On the day of testing the wheels, the teacher took the class to a 250-260 m racetrack in the school backyard to test the luge with three-wheel sets: 50 mm, 70 mm, and 100 mm diameters. The same pilot was used for all experiments. The 50 mm wheel was fitted to the luge, and two readings were taken with the same pilot. Another student recorded the time for these two test runs. Similar readings were taken for the 70 mm longboard wheels and 100 mm wheels. The teacher initially fitted the 50 mm wheels, while two students fitted the 70 mm and 100 mm wheels.

Not all students physically interacted with the luge, wheels, or tools. Instead, many observed how the pilots drove the luge with the three-wheel sets, taking note of the time taken to cover the distance.

Analysing the data collected from the field initiated a series of discussion in the design room which provided an opportunity to think and reflect about their choice of the wheels. These discussions involved the use of interdisciplinary discourse from technology and indirect references to science and mathematics concepts which was not purposely introduced by the teacher, but naturally developed during the discussion while trying to understand and explain the observed phenomenon, as it is obvious from the excerpt below:

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….?"

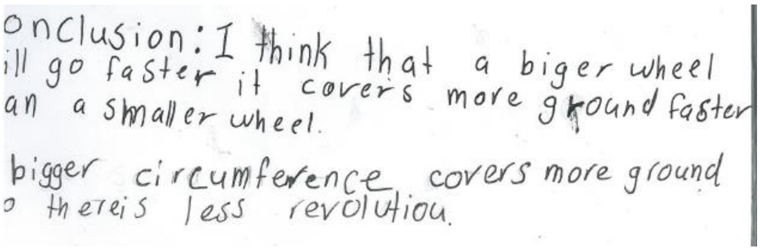
Tr: "While doing a revolution do they cover more distance (referring to bigger wheels)? Is that what it is or they do less revolution and cover more distance? Think about these mountain bikes, why do they have bigger wheels? Does the circumference of the wheel have anything to do with the distance travelled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

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

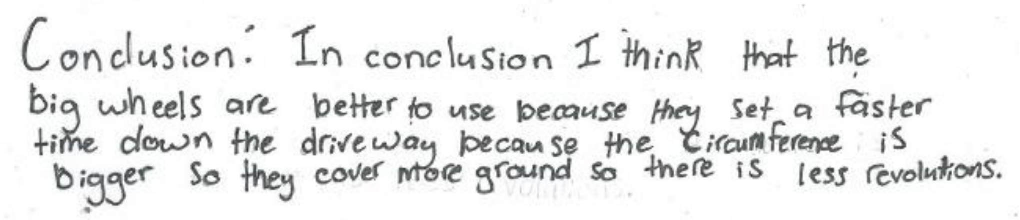
Tr: "So, they can go over terrain they are designed to better work on. You know they don't get caught; they actually go over them, so I kind of believe that the bigger wheels have their effect as well. Now the circumference means something else doesn't it, it means the distance it will cover or travel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

The excerpts indicate how students recalled prior knowledge through contextual discussions, relating it to the current experiment. The concept of why bigger wheels cover more ground than smaller wheels was discussed in class, primarily initiated by the teacher, but students actively contributed the discussions. These contributions, expressed in common language, combined elements of science, math, engineering, and technology. Student EG introduced the term "cover more distance," which was supported by KMC, who mentioned that bigger wheels experience "less resistance." The teacher further explored whether bigger wheels make more revolutions than smaller ones, encouraging students to explore the idea without providing a definitive answer.

Students naturally shifted toward technological and engineering applications of the wheels, discussing why they might choose one wheel size over another. For example, EG mentioned that bigger wheels go over "rocks and stones easily," reflecting his practical riding experience and connecting it with the technology of the product. Testing the wheels in a real-world context allowed the teacher to discuss findings using everyday language that integrated concepts such as "circumference," "revolution," and "resistance." This created a learning environment where students connected these concepts through technological discourse, blending scientific and mathematical ideas. See Figure 2 (a) and (b) for conclusions derived by students HM and KMG respectively.



(a)



(b)

Figure 2: Conclusion derived by student (a) HM and (b) KMC

Students LG, MQ, MY and NP were sitting in close proximity to students EG, HM and KMC in class. There were considerable discussions amongst these students after this episode in subsequent classes while students writing their final conclusions. Another example is during the class discussions, student KMC introduced the term 'less resistance on them', and student MY who was sitting next to KMC ended up utilising the idea and elaborated it in more simple and common language like 'the smaller wheels do not ride over rough ground so easy and slows it down'. After a thorough analysis of the student portfolios, it can be concluded that there are five different knowledge areas where students focused while derving their conculsions, which are presented below:

Prior Knowledge

(a) Addition and Mean

All student portfolios demonstrate students' capability to generate conclusions derived from their observations in the field and calculations, which includes knowledge from middle school mathematics like basic tabulation and calculating the mean(s), and from their basic understanding of circles, diameter, circumference, and revolutions.

(b) Circumference of the wheels

Students had no problem in deciding the size of the wheels initially but their engagement and discussions around the term 'circumference' and 'revolutions' gave meaning to the terms within the relevant context of the experiment. In the technology portfolios, students have indicated this understanding in writing that bigger wheel's cover 'more ground per revolution' than smaller wheels and so concluded they are faster. These terminologies were discussed and introduced by the teacher during the classroom discussions. Terminologies like 'grounds per revolution', 'bigger wheels cover more ground so there is less revolution' are consistently used by six (6) students from this class. A general understanding that the bigger 100 mm wheels can cover more ground with less revolutions which made them faster than the smaller 50 mm wheels was developed amongst these students.

The student portfolios reflect how students adopted and used the terminology introduced by the teacher, as evidenced in their portfolios. Their participation in observing and collecting data likely contributed to their appropriation and understanding of these concepts. The discourse appropriation was supported by creating the right environment to perform the investigation including various choices of wheels, constructed street luge, tools, steel trucks, racetrack, experimental controls, luge driver, data collection techniques, the design room, workshop, the teacher and most importantly the technological and engineering design process.

(c) Wider Wheels and Weight Distribution

There were two students (JS and LG) from this class who discussed in some detail about the merits of the 70 mm diameter longboard wheels in terms of its width and the better weight distribution it offers. LG mentioned that the 70 mm wheels are the best for ‘speed’ with smoother wheels and ‘balance wise’. The term used were ‘wider’ and ‘better dispersed weight’. The student also wrote that the 70 mm wheels are better to navigate over ‘sticks and stones’ and were designed to go downhill. Both student JS and LG had discussions with each other and the teacher in class regarding weight dispersion. Student JC wrote the 100 mm wheels are not smooth and ‘if you go over something like a rock or a bump then you will feel it’. This demonstrated their ability to apply practical reasoning to their analysis.

The teacher indicated that there were many instances in the classroom where students came up with questions which involved knowledge from other subject areas. In one instance, student (JS) brought up the idea of how the width of a wheel would affect the speed of the luge which gave rise to the following discussion between the teacher and the student:

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 (70 mm) 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 only took place between the teacher and the student JS, student LG was sitting near JS during this session and only participated as a listener. It was interesting to analyse the conclusion drawn by student JS who decided to use a wider wheel set over a narrower wheel as shown in Figure 3 below:

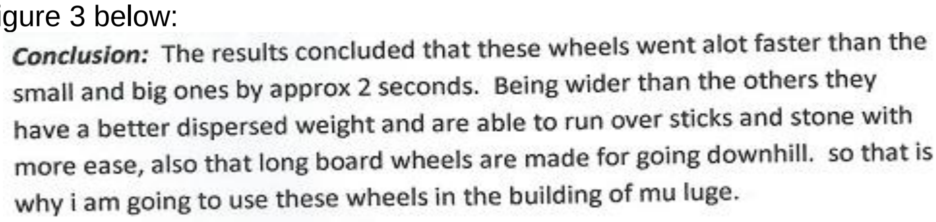

Conclusion: The results concluded that these wheels went alot faster than the small and big ones by approx 2 seconds. Being wider than the others they have a better dispersed weight and are able to run over sticks and stone with more ease, also that long board wheels are made for going downhill. so that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

Figure 3: A snapshot from a student portfolio (JS) which illustrates generated conclusions.

Student LG also commented in his portfolio that the 70 mm wheel are best ‘balance wise’. No other students from this class commented on the weight distribution aspect in their portfolios.

It could be said that both student JS and LG demonstrated an understanding of why wider wheels were better than the narrower ones and referred to the even distribution of weight, width of the wheels and their ability to run over stones as a few factors which provided a better grip and affected the speed of the luge. It can be said that the students in this class explained the device knowledge in simpler terms or common language to express the observed phenomena, and in the process incorporated meanings from science principles and concepts expressed in simple language.

Discussion

In this technology classroom, students were expected to co-construct a classroom culture to impart meaning to their actions. This study observed that the written conclusions commonly related to the classroom-initiated discussions within the context of the experiment. The teacher and students had discussions that included discourse which blended concepts from other subjects (science, maths and technology) to make sense of the collected data. These discussions and accompanying discourses in many instances were naturally initiated while trying to make sense of their observations. The blending of science and mathematics concepts with the technological knowledge happened within the context of the experiment and there was evidence that students were able to respond with integrated discourse, to articulate complex ideas in relatable terms, fostering a deeper understanding of the material. As Lakoff and Johnson (1980, p. 233) stated, understanding is evident through the negotiation of meaning. Niebert et al. (2012) through research studies has showed if students are required to come to terms with how the STEM community uses terminologies, helpful metaphors and analogies must be unpacked carefully in terms of students' direct experiences. The technological design context of designing street luge and associated engineering gave students an opportunity to unpack cross disciplinary concepts.

There is also evidence that peer proximity and interaction facilitated the sharing and development of integrated discourse. KMC's introduction of the term "less resistance" was adopted and simplified by MY, demonstrating collaborative learning and the natural transfer of concepts between students, enhancing their understanding through discourse.

It cannot be definitively concluded if the all students explicitly saw the cross- disciplinary connection, but their portfolios explicitly recognized the interdisciplinary connections which drives the use of knowledge from other domains. This experiment also allowed them to experience the collective nature of experimenting, establishing experimental controls, negotiating meaning, and critiquing knowledge claims, paralleling the processes of authentic science (Adams et al., 2012). Students showed their understanding through statements like "bigger wheels cover more ground per revolution," concluding that larger wheels are faster. The exact scientific terminologies may have not been used in this classroom, which is also reflected in their portfolios; however, it seems like they understood whole purpose of the investigating wheels and appropriated discourse which explained the observed phenomenon in simple plain language. From Rogoff's (1995) work, appropriation of language including words and utterances refer to the social norms of the community within which the students practice and participate. This study has shown that the use of technological knowledge and scientific concepts coexist and could take the form of everyday discourse in student's work.

Conclusion and Recommendations

Technology education in schools provide a curriculum which introduces students to the technological and engineering design process. The purpose of the school curriculum is not to integrate science and mathematics content, but it is clear from this study that integration of science, maths, and engineering content through technology naturally happens when participants seek explicit and deeper details on understanding the observed phenomenon focused on the challenge.

This study proposes that educators use everyday language within the context of design, and get students to build knowledge around devices, components, and their working to initiate prompts for interdisciplinary discussions. In this process students will appropriate everyday vocabulary and language which could be used further to develop formalized scientific language or to apply mathematical concepts.

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