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Science and Mathematics through a Technological Design Context: The Potential

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Abstract

As technology and engineering education evolves, its potential to naturally integrate STEM (Science, Technology, Engineering, and Mathematics) subjects through practical, hands-on learning remains underexplored. This study examines how students engage with scientific and mathematical concepts within a technology-based design project. The findings suggest that while students actively apply cross-disciplinary knowledge in design and experimentation, their conceptual understanding of STEM principles often remains implicit rather than explicit. The role of teacher facilitation emerges as a critical factor, with evidence indicating that strategic interventions could enhance interdisciplinary connections. This study contributes to the understanding of cross-disciplinary integration in technology education, offering insights into how a balanced approach, combining student autonomy with scaffolding, can deepen conceptual learning.

Keywords

Technology, STEM (science, technology, engineering, and mathematics), Integration, Interaction, Technological Design Context

Introduction

STEM Education is a response to the need to change the current practices of teaching in schools and to adopt methods which provide rich learning experiences for all students through their active engagement in the learning process (AAAS, 1989, 1993, Deslauriers et al., 2019; Herschbach, 2011; ITEA; 2000/2002; National Science Teaching Association, 2020; NCTM, 2000). One of the primary objectives of STEM education is to equip students with essential knowledge, conceptual understandings, and critical thinking skills necessary for success in the modern world. The "Framework for 21st Century Learning" developed by the Partnership for 21st Century Learning (P21) emphasises integrating traditional academic content with 21st-century skills- such as problem-solving, critical thinking, innovation, creativity, communication, and collaboration—to prepare students effectively for future challenges. This can be achieved through a learning environment in which learning strategies and approaches are personalised and adapted to the learner's own learning styles. A learning environment has been defined as a "system that accommodates the unique learning needs of every learner and supports the positive human relationships needed for effective learning" (The Partnership for 21st Century Skills, 2007, p. 3). To achieve such a learning environment, it is crucial to understand the current practices of teaching in schools and to adopt methods which provide rich learning experiences for students through their active engagement in the learning process. A brief review of the literature about 21st century skills suggests that the past teaching methodologies are not sufficient for today as the education and skills of the workforce are the single most critical element for successful innovation (Kim et al., 2019; NCREL, 2003; NRC, 2012). There has been evidence gathered from various science-based design programs (K-12) which suggest that children tend to generate low-level factual questions rather than questions that could extend their understanding in problem solving (Chin & Brown, 2002; Scardamalia & Bereiter, 1992). Students do not tend to consider evidence systematically in formulating critical arguments (Linn, 1992) and are proficient at carrying out procedures with guidance but have difficulty focusing their attention on the reasons for these procedures (Krajcik et al., 1998). Many students lose interest in science and mathematics at an early age and thus make an early exit from the so-called 'STEM pipeline' which is one factor in a workforce having low science and/or mathematics ability. Students often find it difficult to apply and integrate knowledge they have acquired in a classroom into real-world problems. Traditional subject disciplines, according to Beane (1995), are "territorial spaces carved out by academic scholars for their own purposes" (p. 9), and their boundaries limit student access to broader meanings. These findings support the need for an integrated learning environment to develop interdisciplinary thinkers who can consciously apply methodology and language from more than one discipline to make connections in content that cuts across subjects.

An understanding of the learning theories and strategies to teach STEM subjects in an integrative fashion in schools could be a promising approach to make science, mathematical, engineering and technological education more interesting and realistic for the students. There is a view held by Lai (2011) that we need to find ways of working in schools and to develop activities to allow students to acquire STEM literacy through the transformation of knowledge from various disciplines for practical application in 'authentic' settings. Literature indicates Design-based science learning offers a structured approach to integrating STEM subjects by embedding scientific inquiry within technological design activities (Fortus et al., 2004; Kolodner et al., 2003). In this model, students engage in iterative problem-solving while using scientific principles to refine technological solutions. This study focuses on studying student-led integration within a technology classroom, which has been an area with little clarity in the literature. In this study, 'integration' refers to the active application of concepts from science and mathematics within a technology-based project. Students demonstrate integration when they use mathematical calculations, applied scientific reasoning, or reference knowledge from other disciplines in making technological design decisions (Beane, 1997; Berlin & White, 1992; Honey et al., 2014). This aligns with the broader definition of STEM 'integration', which emphasises interdisciplinary connections and the application of knowledge to real-world contexts (Wang et al., 2011). The present study highlights how technological design contexts naturally foster science, mathematics, and engineering connections.

STEM as integrated learning

Students often find it difficult to apply and integrate knowledge they have acquired from the classroom to real-world problems. This may be attributed to the fact that teachers often move from topic to topic without any logical connections among topics (Carnegie Mellon University, n.d; Wineburg & Grossman, 2000). Beane (1995) argues that classroom instruction should be constructed in a way that fosters cross-disciplinary connections, supporting the core subject area with a potential to incorporate cross-disciplinary knowledge and skills which encourage students to participate effectively. Beane advocated that addressing real-life questions of interest to students through an integrated curriculum will help promote cohesion rather than fragmentation, making learning more relevant and engaging (Jacobs, 1989; Rothman, 2018) so learning becomes focused, connected and relevant to learners (Drake & Reid, 2020; Vatterott, 2007). Also, teaching a subject in multiple contexts can lead to useful abstraction of the main concepts, allowing students to transfer knowledge more flexibly (Gick & Holyoak, 1983). This aligns with findings from this study, where students engaged in practical problem-solving through the technological design context often lacked explicit articulation of underlying theoretical principles. Isolated science or maths concepts can be more meaningful when real-life applications are explicitly discussed and demonstrated, reinforcing the importance of structured teacher facilitation in interdisciplinary learning environments.

From a practical perspective, the world does not work within disciplinary frameworks, and knowledge from various disciplines is applied to a context as the need arises. This interdisciplinary approach reflects the way professionals in the 21st century integrate knowledge from multiple fields (Rogers, 1997). In STEM, Engineering is often defined as the application of scientific and mathematical knowledge (ITEA, 2000/2002; ITEEA, 2020). Engineering can be regarded as a subset of technology, focusing on solving structured problems with clearly defined solutions (Dym et al., 2005), and a defined body of knowledge (Williams, 2000). Technology deals with ill-defined problems that require creativity, adaptability, and a broad 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. However, within a STEM framework, technology education can serve as a key enabler of cross-disciplinary learning, as it provides authentic contexts in which science and mathematics can be applied. In this study, students engaged in a technological design process that included problem identification, research, idea generation, prototyping, testing, and refinement. This cyclical process reflects models of technology and engineering design (Fortus et al., 2004; Gattie & Wicklein, 2007; Kolodner et al., 2003;) and aligns with core practices outlined in the Standards for Technological and Engineering Literacy framework (ITEEA, 2020). STEM promotion often emphasises improving student achievements in mathematics and science, and technology educators have a unique opportunity to demonstrate the usefulness of these subjects through applied problem-solving (Gattie & Wicklein, 2007). Findings from this study reinforce this potential, as students engaged naturally with science and mathematics concepts through the design task, though their conceptual understanding was often implicit rather than explicitly articulated. It is widely agreed that learning is more effective when students are actively engaged, and this active engagement, through design and problem solving, is an integral element of technology education. However, research suggests that while hands-on inquiry enhances motivation, additional scaffolding is needed to ensure students make explicit interdisciplinary connections (Beane, 1995; Berlin & White, 1992). This study highlights that while students intuitively applied scientific and mathematical concepts, they did not consistently formalise these connections, indicating a need for structured reflection prompts and guided discussions to reinforce STEM integration.

The demand for STEM degrees is evidence of a competitive economy according to many scholars (Caprile et al., 2015; Eurostat, 2014; Sanders, 2009;). However, despite the increasing emphasis on STEM, enrolment of students in STEM programs have been low, requiring educators to explore strategies that not only introduce students to STEM but also sustain the pipeline. A report published by Peter Gluckman in 2011, *Looking Ahead: Science Education for the Twenty-First Century*, and Organisation for Economic Co-operation and Development's (OECD) 2018 paper on *Integrity of Education Systems: A Methodology for Sector Assessment*, have recognised the need to reconsider the traditional mode of discipline-based teaching in the secondary years and whether it should become more sophisticated in its approach to ensure its relevance. Therefore, to increase the number of STEM graduates, it is necessary to develop strategies to promote interest and motivation in STEM programs so students are willing to take on the subjects in the tertiary sector.

Many proposals for a STEM agenda in schools have overlooked the potential of technology education as a significant component which can integrate cross-disciplinary learning. While previous literature has emphasised improving student achievement in science and mathematics, this study highlights how technology education can act as a bridge between these disciplines, providing real-world, hands-on applications that foster deeper engagement (Gattie & Wicklein, 2007). Technology provides the opportunity for authentic integration of science, mathematics and technology to happen through cooperation and collaboration within meaningful design contexts. The increased motivation that can arise through students working on a technological task that they see as interesting, meaningful and relevant has benefits for related work in science and mathematics. Deep understanding is likely to be developed because students are solving authentic problems (Brown et al., 1982). Such understanding is said to be anchored to a personally meaningful context which can be recalled more easily than isolated bits of factual knowledge (Brown et al., 1989). Lai (2011) argues that schools should develop activities which allow students to acquire STEM literacy through knowledge transformation from various disciplines for practical application in 'authentic' settings.

A deeper understanding of classroom practices and the role of teacher facilitation is necessary to refine strategies for designing and delivering effective integrated instruction in secondary education. The findings from this study suggest that while student-driven inquiry promotes engagement, strategic teacher guidance, such as reflective questioning and explicit connections between disciplines, could enhance the depth of interdisciplinary learning and ensure lasting conceptual understanding.

Research, Methodology and Educational Context

This research proposed to study the classroom practices of a technology teacher and 19 male 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 (street luge: a gravity powered vehicle). The project ran over a full academic year, divided into four terms and the luge project was the only major design challenge students had to undertake during this period. 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.

The research study provided an insight into students' perceptions about integration and the knowledge (science, mathematics and technology) they bring to a technology classroom during early design stages. The four school terms (approx 10 weeks each from February until December) of the school year provided the time periods for the aspects of the project: design in Term 1, construction in Term 2 and Term 3 and testing and evaluation in Term 4. This paper will present data from the initial stages of the project (Term 1 design stages) where investigation and experimentation was carried out in the classroom to develop an understanding of the specifications and attributes which need to be fulfilled as a part of the construction of the luge. Data was collected through classroom observations, student questionnaires, audio recorded teacher interview, and focus group interviews with the students. The collected data were used to answer the research question: In what ways do students apply and connect science, mathematics, and technology concepts during experimentation in a technology-based project, and how can this integration be assessed?. This study adopts a case study approach (Yin, 2014) to explore how STEM integration occurs within a single technology classroom. While the sample size is limited to one teacher and 19 students, the depth of qualitative data collected allows for an in-depth examination of student engagement, teacher facilitation, and integration strategies. This study adopted a case study methodology. Case studies are valuable in uncovering rich, context-dependent insights that can inform broader educational practice (Creswell, 2007; Merriam, 1998; Miles & Huberman, 1994;).

The analysis of the data for this research took place within a social constructivist and socio-cultural framework that seeks to explain the integration of science, mathematics and technology in a technology classroom. For this study, the researcher adopted a thematic analysis approach by analysis of data collected in the classroom, questionnaires, individual interview (teacher), discussions (students and teacher), focus group interviews (students) and portfolio analysis to detect patterns and regularities, to formulate some tentative hypotheses that the researcher can explore, and finally end up developing some conclusions from the available data regarding integration.

The collected data were analysed in parallel with their collection with the main aim of understanding the initial interpretations of the raw data and to inform the next step of data collection technique. A rudimentary coding scheme to process the data was then developed to help understand integration in a classroom, and to facilitate later interpretations. This coding scheme was influenced by the initial interpretations of the data that evolved into a story which will be presented in the following sections. The analysis resulted in key themes emerging from the data analysis: students' perception of integration, teacher facilitation of scientific principles, and practical problem-solving through experimentation. These themes were derived through an iterative coding process, aligning with the thematic analysis methodology (Braun & Clarke, 2006). The researcher recorded and stored all available data, revisited the retrieved data to make initial rich interpretations which proved to be a useful starting point as indicated by Huberman and Miles (1998). Thematic patterns were refined by consistently cross-referencing emerging themes with raw data, ensuring alignment between findings and student/teacher responses (Braun & Clarke, 2006). Additionally, researcher reflexivity was employed, with repeated reviews of coded data to minimise bias and ensure consistency in theme identification (Nowell et al., 2017). Integration was measured through thematic analysis of student portfolios, classroom observations, and interviews, focusing on moments where students explicitly connected STEM concepts during the design process (Creswell, 2009).

Findings

Responses from the initial questionnaires suggested that students choose to take technology in Year 11 as they found, from their previous experiences, the practical aspect of technology to be fun, beneficial and meaningful for their professional and vocational goals. In the initial student questionnaire, there is evidence that students anticipated that they may need knowledge from other subjects, especially science (aerodynamics, forces), mathematics (measurement and counting), arts (design) and English (communication) to complete the luge design project as part of their technology curriculum.

The design challenge required students to design and construct a functional gravity-powered street luge. The project required students to optimise performance and safety of the luge while adhering to design attributes following a structured design process. The initial aspect of the project implemented during Term 1 was 'the momentum testing' phase, where all students conducted the experiment using a single luge, ensuring consistent test conditions across all trials. The experiment was performed with the appropriate 'controls' looking to study the relationship among variables such as wheel sizes (50mm, 70mm and 100mm diameter) and pilots' weight (45kg and 110kg) to determine the best combination to provide the optimal speed for the luge over a set trial distance (a track at the school backyard). Two sets of readings were taken for each pilot, using each wheel size and the time taken to cover a specific down-hill distance by the two drivers.

This data was discussed by the students in the design room the following day, which provided the opportunity to think and reflect about their field data. Experimentation was carried out which included data collection, calculation of average time, analysis and drawing conclusions based upon the available statistics as shown in Figure 2:

Figure 2.
A Conclusion Drawn by a Student in Their Technology Portfolio

Results:

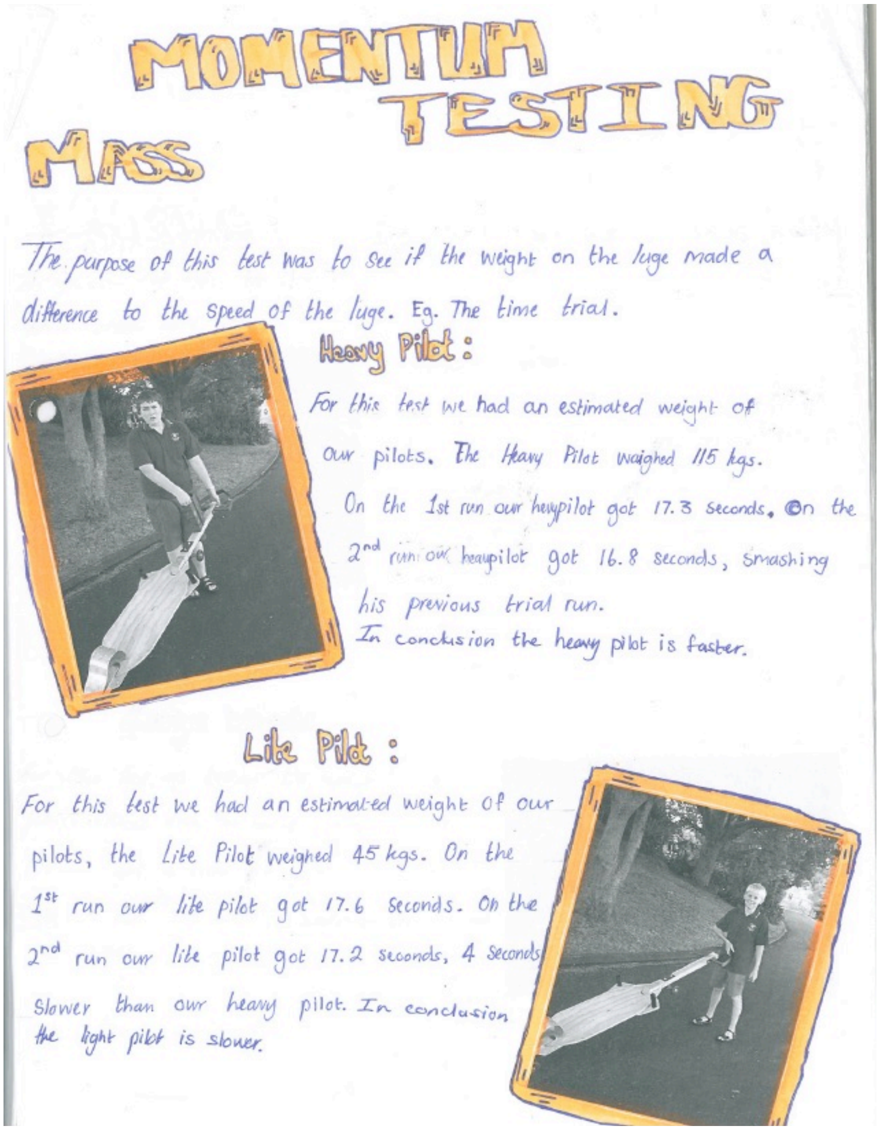
Light Pilot (45kg) #1: 17.6s #2: 17.2s Average: 17.4s

Heavy Pilot (110kg) #1: 17.3s #2: 16.8s Average: 17.05

Conclusion: **In conclusion the heavy pilot at 110kg was faster at an average of 17.05s and the light pilot at 45kg had a slower average of 17.4 s so overall heavier is faster**

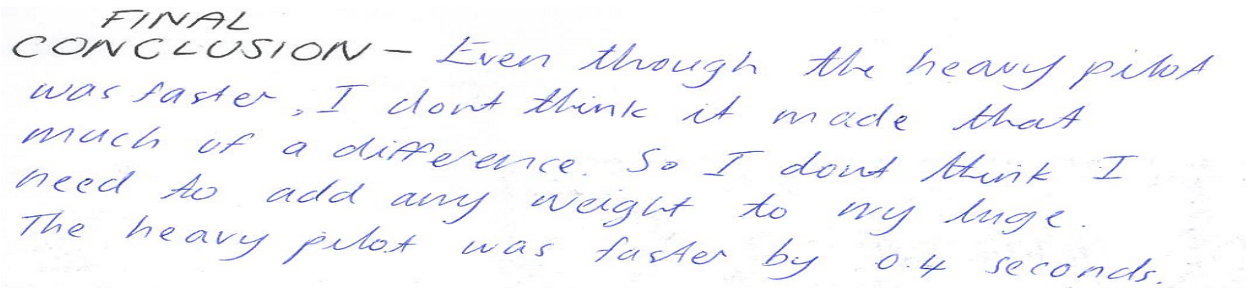
The teacher-initiated discussions focused around achieving an understanding of the collected set of data by the students. The technology classroom discussion has the potential of embedding scientific investigative skills through experimentation. The teacher asked the students to think about the collected data along with technological concepts to justify their observation. However, the teacher did not consider it significant at this point to initiate discussions where science principles could have been used to justify the technological outcome. The conclusions derived by students in their portfolios (see Figure 3 & 4) highlight the experimentation performed to formulate conclusions based on some basic mathematical calculations. The students systematically presented their observation from the collected data for both the 45 kg and 115kg pilots and derived conclusions based on the trial tests performed in the field. It is interesting to observe that the teacher and students did not consider it significant at this stage to explain their observation using principles and concepts from science like force, friction or energy principles. The conclusion was based purely on the collected data from the field. Was this pursued with the teacher – why did he do this?

Figure 3.
A Page from a Student Portfolio



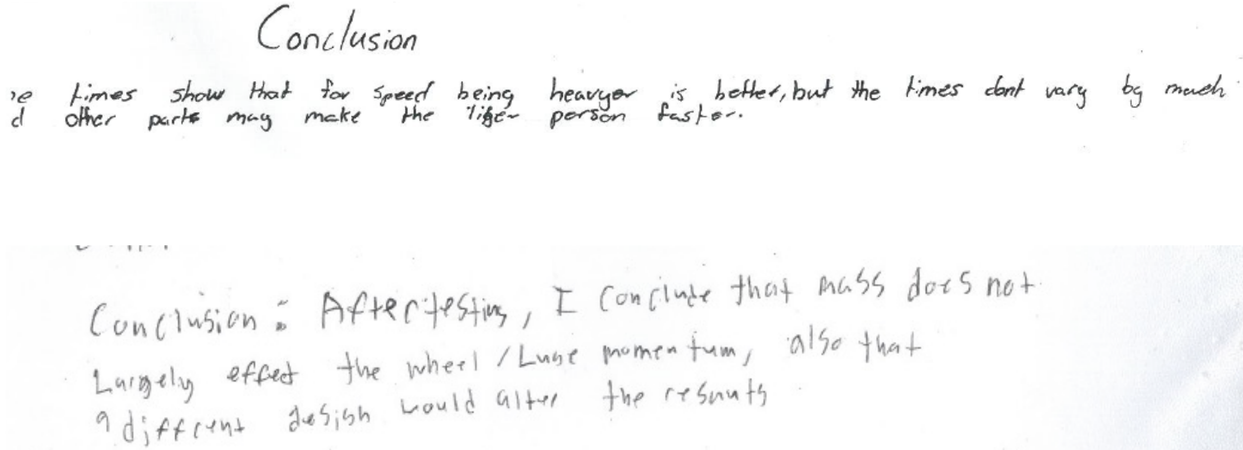
It is interesting to observe that a few students from this class argued that the difference between the observed readings were not significant enough to conclude that the heavier pilot is faster. Scientifically, in an ideal frictionless system, acceleration down an incline depends only on gravity and is independent of mass, as shown through Newton's laws and conservation of energy principles. However, in real-world conditions, friction and air resistance introduce considerable variations. A possible explanation for the heavier pilot reaching the bottom faster could be that frictional forces do not always scale proportionally with mass. A lighter pilot may experience relatively greater deceleration due to friction and air resistance, which could explain the students' observations. While some students concluded that mass played a role, their reasoning lacked a formal scientific explanation. These findings highlight the importance of structured discussions to bridge students' observations and scientific principles.

Figure 4.
Conclusion Derived by a Student in Their Portfolio.


FINAL CONCLUSION – Even though the heavy pilot was faster, I dont think it made that much of a difference. So I dont think I need to add any weight to my luge. The heavy pilot was faster by 0.4 seconds.

The students developed an understanding from the results of this experiment that a heavier person may have a slight advantage over a lighter person in terms of speed. The test pilots (heavy and light) initiated their luge motion with self-generated velocity. Students concluded that heavier pilot is faster. This contradicting data could be attributed to the greater kick-off velocity produced by the heavier pilot compared to the lighter pilot. Students might not have fully understood the underlying principles or might not have considered it necessary at this stage to explain their findings scientifically by referencing abstract concepts such as forces and frictional resistance. However, an analysis of some student portfolios indicates that a general understanding that 'mass does not largely affect speed' was developed from their practical experience and recorded values (see Figures 3 and 4). The students observed that the heavier pilot took less time to cover the same distance compared to the lighter pilot, and a few students noted in their portfolios that this difference was insignificant (Figures 4 and 5), indirectly supporting the scientific concept that mass does not significantly impact speed. However, it is unclear whether students considered factors such as frictional resistance and experimental errors (mechanical and human) in their conclusions, as no explicit references to these factors were found in the portfolios. A key finding from the data is that most students derived conclusions based on their observations and experiences in the technology classroom, which largely align with scientific principles. The recurring theme in the data suggests that many students perceived the heavier pilot as faster, but some also acknowledged that the difference was negligible.

Figure 5.
The Conclusions Derived by Two Students in Their Technology Portfolios Regarding Their Field Data.


Conclusion

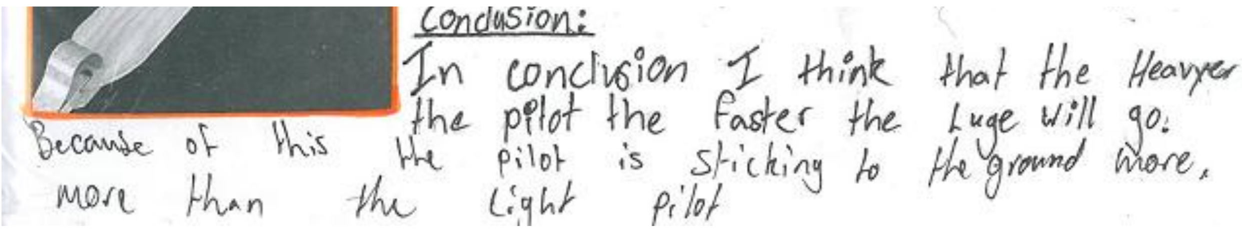
ie times show that for speed being heavyer is better, but the times dont vary by much
d other parts may make the lifer person faster.

Conclusion: After testing, I conclude that mass does not Largely effect the wheel / Luge momentum, also that a different design would alter the resuuts

One student also indicated that a heavier pilot is more 'sticking to the ground' implying a better 'centre of mass' distribution which provides a safe riding and less toppling (instability) than a lighter pilot (see Figure 6). It can be concluded that this student was developing an understanding of the centre of gravity while investigating the evidence gathered, which seems to be consistent with the principles of science.

This natural integration of science and mathematics in technology indicates students developing a practical understanding from the observed phenomenon which can be supported by scientific principles. It is worth noting that the procedural aspect of technology provides a stage for recalling and warranting established science ideas and content.

Figure 6.
Conclusion Derived Using the 'Centre Of Gravity/ Principle.



This research indicates the potential of technology in the school curriculum to serve as a vehicle which could be used to illustrate concepts from science to assist students to explain their field observations. While previous research on design-based learning (Fortus et al., 2004; Kolodner et al., 2003) has explored structured integration of STEM in educational settings, this study contributes a unique perspective by examining natural, student-led integration in a technology classroom. Instead of following a prescribed design-based learning framework, students naturally integrated science and mathematics as they encountered the design challenge, making this study valuable for understanding how implicit integration occurs in authentic learning environments. However, it could be a challenge for the technology teacher to integrate science and mathematics in a technology classroom, since it involves careful accumulation of information from science and mathematics and to logically integrate the information. Such an integrative approach also requires a wider expertise in the areas of science and mathematics by a technology teacher. However, this episode clearly highlights the role a technological design context can play to establish an integrative learning environment which could be achieved through collaboration with science and maths teachers.

The next section will highlight the role of the teacher in this technology classroom.

Teacher and Students' Expectations in Technology

Throughout the project, the role of the teacher shifted from teacher-centric to that of a facilitator who offered suggestions and guidance when students struggled with appropriate design decisions and resolving problems.

The teacher noted during the Term 1 interview:

> *They started coming to me after momentum testing with questions about if we drop two different weights, then which one will hit the ground first. This is where the science thinking is coming in, but they were thinking about in relationship to the project so introducing things like the momentum, speed, mass/weight initiates them to recall and understand the knowledge from other subject areas* (Teacher Interview, Term 1).

The teacher mentioned that even though students can benefit by just doing technology, the subject also offers a certain degree of freedom and independence to work on individualised projects where students can brainstorm and test their ideas, and also realise the integrative nature of technology (Teacher Interview, Term 1). However, it could not be deduced at this stage whether the link to science was obvious to the students during and after the experimentation.

The teacher also noted during a discussion after the field testing:

> *What we are trying to do at the moment is to just get them thinking, thinking that drives them to engage… because there is no right or wrong answer in technology and they don't know that…. It is a matter of getting them to think. Technology is about ways of making decisions when they test it and learn when they evaluate it. I won't let them fall over, I will keep an eye on them to make sure that they are going in the right direction but at least they are starting to take the ownership of their decision (*Teacher Interview, Classroom Discussion, Term 1).

The role of the teacher was crucial during the design stages. Consistent with prior research (Kolodner et al., 2003; Van Breukelen et al., 2016), the teacher played a crucial role in guiding students through design-based problem-solving; however, this study further highlights how such facilitation emerged in response to experimentation rather than through predetermined instructional sequences. The students identified the significance of the momentum testing phase during the classroom discussions (Term 1) and during the final focus group interviews where they were explicitly asked to identify any science and maths ideas they used while designing the luge. The data from the student focus group interviews are presented in the next section.

Student Focus Group Interviews

The interview data provides a wide range of students' perceptions of integration of science and mathematics. A few excerpts from the final focus group interviews (student LG, TJ and ET) are presented here:

> R: Was the momentum testing phase useful?
>
> LG: I talked to my science teacher actually because she teaches technology as well so I wanted to see if she can explain a little bit on basics like a lot more weight and less friction makes greater momentum.
>
> R: So she taught you about the principle? Did she teach you how to use it in technology?
>
> LG: Not quite no, but I think if she did explain it may have helped something about how momentum actually has an effect on it (speed). Because we have learned heavy things go faster but we have not learned how to make a heavier thing lighter.
>
> R: What specific science and mathematics did you use during the momentum testing?
>
> LG: I don't think there was lot to do with maths in the momentum testing phase because we already had our luge and there was this distance and just go for it.
>
> TJ: I think there was this tiny bit maybe the speed, like working out the average speed with distance over time.
>
> LG: If we had more time for testing it would have worked out a lot better. I reckon if more people would have gone for the long board or scooter wheels.

TJ: But in saying that if we did not have the testing then it would have been complete shambles and we would not do what to do.

ET: Yes it would have been hard without momentum testing.

The students (LG, TJ and ET) were interested in understanding the principles of science as they engaged in technological design. The scientific knowledge and technological design skills could be positively fostered in the context of designing artefacts as particular instances open up opportunities to integrate science and mathematics.

The following excerpts are from the second and third focus group interviews (Term 4) with students BC, HM, TJ, JS and JP.

R: What specific science and mathematics did you use during the momentum testing?

BC: Well maths to find out the average speed.

HM: Also calculated the average speed for heavy pilot and light pilot.

R: What specific science and mathematics did you use while momentum testing?

JS: We just did it

R: Any maths?

JS: Yeah, calculating.

JP: Averaging and stuff.

These students (BC, HM, TJ, JS and JP) did not identify the application or the use of science during the momentum testing phase, but some independently made connections to physics principles. The use of mathematics was basic tabulation and averaging at this stage. The students did not provide any evidence of calculating speed in their portfolios. The students might have been referring to the possibility of calculating average speed using the available information to compare the faster and optimal speed.

The following excerpt is from the fourth focus group interview with students MQ, JC and TG.

R: Was the momentum testing phase useful?

MQ: The weight of the pilot was not helpful because I think I can't make myself fat for one race to go faster.

R: What specific science and mathematics did you use while momentum testing?

JC: Not really, you just watched.

R: So you didn't consider anything in terms of distance and speed?

TG: No.

J: 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 was best for the luge and how fast it can go.

R: OK what about maths? calculations?

MQ: Calculations....

JC: Yes, taking a look at all the different times you got and say, oh, this one has got a lower time, so faster.

The above excerpt demonstrates that students did not recognise the application of science and mathematics to their project. The students just followed the instructions provided by the teacher and made sensible conclusions based on the available data collected during the momentum testing phase. It could be said that students ended up constructing a luge towards the end of the year with varying opinions regarding integration of information from science and mathematics.

The following excerpt is from the final focus group interview (Term 4) with students ST and JP. ST and JP did not complete their luge on time towards the end Term 4 but they showed considerable interest in the project during the initial stages of the study.

R: What specific science and mathematics did you use while momentum testing?

ST: Yeah of course things like gravitational potential energy [GPE) when it slides, aerodynamics of the luge.

R: Can you explain a bit more on GPE?

ST: The bigger the slope obviously the faster it would go and things that will affect it is the components such as wheels.

R: Smart.

ST: Yes, we might not have passed this (technology) but we definitely know the science. I think the weight of the pilot also plays some role.

JP: Yes.

ST: This is also a major part of the speed.

JP: You get more momentum if you are heavier and faster as momentum is mass times velocity.

ST: And we are learning this at the moment in physics.

R: Maths?

ST: The timing and the measurement of the wheels.

JP: Averages and tabulation.

It is interesting to note the response provided by the students JP and ST. The students clearly identified the science (from their Year 11 science class) and basic mathematics. The students could relate basic mechanics which they learned in science to the technological design context which opens up possibilities for science and maths teachers to collaborate in technology to justify the application of science concepts and the form it takes during practice. The prior information from science and basic mathematical skills could be effectively utilised and reconstructed through technological modelling, combined with other forms of knowledge adjusted to the context at hand to form technological knowledge. Giving the students an opportunity to investigate the operational principles and mechanisms which form the technological system is a crucial part of technology as this approach opens possible ways to integrate information from science and mathematics.

Discussion

This study highlights the potential of technological design contexts to foster natural integration of science, mathematics, and technology, providing students with opportunities to apply scientific and mathematical knowledge. The findings reveal that students were actively engaged in problem-solving, iterative design, and experimentation, demonstrating practical application of interdisciplinary knowledge rather than explicit articulation of theoretical concepts. This aligns with previous research by Kolodner et al., (2003) and Van Breukelen et al (2016), which suggests that students often engage with scientific and mathematical principles intuitively but may require structured guidance to formalise their understanding. Technology education should be a key partner in experiential education through the integration of science, mathematics and technology because such an approach will help bridge the gap between classroom teaching and authentic learning contexts (Berlin & White, 1992; Furner & Kumar, 2007; National Science Teaching Association, 2020). Students can be provided a chance to appreciate how variables in practical setting can influence design decisions.

One key insight from this study is the role of teacher facilitation in shaping student engagement with STEM concepts. While the teacher provided guidance during the design process, there was minimal emphasis on explicitly prompting students to articulate the science and mathematics underpinning their decisions. Research suggests that when teachers actively encourage students to reflect on scientific and mathematical reasoning, they are more likely to integrate these concepts into their technological work (Gattie & Wicklein, 2007; Van Breukelen et al., 2016). This indicates that while student-driven inquiry is effective for engagement, a combination of hands-on experiences and strategic teacher interventions—such as reflective questioning or guided discussions—could enhance students' ability to make interdisciplinary connections (Honey et al., 2014). While prior research (Kolodner et al., 2003; Van Breukelen et al., 2016) has emphasised the role of teacher facilitation in guiding students through design-based learning, this study contributes new insights into how teacher support underpins a naturally integrated STEM learning environment within a technology classroom. Unlike structured design-based approaches, where scaffolding is explicitly planned, this study highlights how teachers can adaptively provide guidance in response to student-driven experimentation. The findings suggest that teacher facilitation in such contexts is more fluid, occurring as students meet challenges rather than through predetermined instructional sequences. This distinction offers a new perspective on the responsive nature of teacher intervention in open-ended, student-led technology projects.

The working of many product components and their assembly can be explained by concepts from science and technology. The teacher in this study did not rely on concepts from science to assist students to justify their data collected from the field, consistent with findings from Kolodner et al. (2003), and Van Breukelen et al. (2016), who observed that students often do not apply scientific reasoning unless explicitly guided by teachers. The momentum testing phase conducted to study the effect of different pilot weights on the speed of the luge is an example of investigating variables using the available technology and deriving technological knowledge to make appropriate design decisions. A detailed analysis of the student claims in their portfolios shows that most students concluded that the heavier pilot is faster than the lighter pilot, without a scientific reasoning behind their claim, but the investigative outcome was considered technologically appropriate by the teacher and students at this stage.

Another important consideration is the extent to which students' learning experiences translated into deeper conceptual understanding. Although students effectively integrated STEM elements to optimise their luge designs, many did not explicitly reference scientific concepts or mathematical principles when justifying their design choices. This is consistent with research by Beane (1995), which suggests that students may struggle to recognise the relevance of disciplinary knowledge unless explicitly prompted. The study by Berlin and White (1992) also indicates that interdisciplinary learning requires careful scaffolding to ensure students make meaningful connections across subjects. This observation suggests that while technological design tasks provide a strong foundation for interdisciplinary learning, added scaffolding, such as structured reflection prompts or collaboration with science and math teachers or educators, could strengthen students' conceptual transfer (Creswell & Poth, 2018).

Students also analysed experimental data and compared numerical results with their predictions to inform judgements about the likelihood of a particular outcome. For example, while analysing the results from momentum testing, some students identified that the difference in the readings was not significant and inferred that the readings should not make much difference on the dependent variable (speed). Almost all students had evidence in the form of field recordings from the trail runs to perform a basic analysis to conclude similar results. It could be concluded that students develop understandings based on their practical observations in technology.

The findings of this study reinforce that real, purposeful, and useful technological design contexts naturally encourage students to apply science and mathematics concepts. Students engaged in experimentation, made design decisions, and, in some cases, independently recognised connections between disciplines. While prior research (Ethington, 1992; Khoon & Ainley, 2005; Hmelo-Silver, 2004; Murphy & Gibbs, 1996; Thomson & Fleming, 2004; Wigfield & Eccles, 2000) suggests that early student perceptions influence participation, this study provides direct evidence that hands-on technological design tasks enhance interdisciplinary engagement. These insights support technology educators in structuring learning environments where science and mathematics integration occur naturally.

Conclusion

This study reinforces the value of technological design context as a natural vehicle for integration of science, mathematics, and technology. Students demonstrated engagement, problem-solving, and iterative decision-making, highlighting the practical application of interdisciplinary learning. However, the findings indicate that while students actively applied science and mathematical-related skills, their conceptual articulation of underlying principles remained implicit.

These insights suggest that combining hands-on experiences with structured teacher facilitation and scaffolding—such as reflective questioning, explicit science-math connections, and cross-disciplinary collaboration—may enhance the depth of interdisciplinary understanding and integration. Rather than replacing student-driven inquiry, targeted interventions could serve as a bridge between practical experimentation and conceptual learning, ensuring that students not only engage with cross-disciplinary content but also develop a deeper understanding of its application.

Future research could examine how instructional strategies impact students' ability to transfer STEM concepts across educational and professional settings. Longitudinal studies tracking student learning beyond the immediate classroom context could provide valuable insights into the lasting effects of technology-integrated STEM education.

Overall, this study contributes to the understanding of integration of science, mathematics and technology within technology education, emphasising the need for a balanced approach that nurtures both student autonomy and structured guidance. These findings offer practical implications for educators seeking to design engaging, interdisciplinary learning experiences that not only capture student interest but also deepen their conceptual understanding.

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