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Research article

Introducing the ProInterest model: Designing tasks for sustainable positive mathematics experiences

Laura Tuohilampi[1] and Huifei Jiang[2]

[1] The University of New South Wales, Sydney, Australia
[2] The University of Hong Kong, Hong Kong, China

Abstract: This study introduces the ProInterest model, a novel framework designed to foster long-term student engagement in mathematics. ProInterest model identifies features that trigger initial interest and subsequently sustain student interest towards mathematics activities. We explore the interplay between these features based on a focused narrative review and demonstrate their application through a case analysis of two mathematics tasks that look different on the surface, yet can be identified to share common features fostering interest when looked through the lense of the ProInterest model. We also apply the model to tasks generated by experts and AI. We show that applying the model to identify features that can trigger and maintain student interest towards a task, one can reveal shortcomings in typical mathematics tasks: humour and creativity are typically missing, and even tasks aimed to be tailored to appeal to students may utilise unimaginative layout and structure. This research bridges a critical gap in the knowledge of interest promoting mathematics tasks by providing a practical tool for educators and instructional designers to create engaging mathematics experiences.

Keywords: engagement in mathematics, interest development, mathematics tasks, ProInterest model, task design

Correspondence: l.tuohilampi@unsw.edu.au

1 Introduction

Mathematics educators' collective effort of motivating, engaging, attracting and entertaining students to study mathematics is a paramount endeavour that has been ongoing for decades. Interestingly, the issue of student dis/interest in mathematics continues to challenge educators globally despite all those efforts. Longitudinal studies can reveal students developing maths aversion during their schooling, as well as gradually worsened development over the years (Attard, 2013; Beswick et al., 2021; Martin et al., 2012; Nyman, 2020). In Tuohilampi et al. (2016) study the data of students' drawings of their mathematics classrooms showed that by the end of 5th year, as many as 70% of the students in the cohort had ended up seeing their mathematics classes as an entirely negative learning environment. These findings concerned Finnish students, who by the

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time were excelling in large scale studies, such as Programme for International Student Assessment (PISA; OECD, 2010). Indeed, even the highest achievers can feel unconfident about their skills or struggle findings mathematics enjoyable (Metsämuuronen & Tuohilampi, 2014). Finally, disinterest towards mathematics can perpetuate the gender gap, as qirls and women in particular have widely reported to suffer from low self-efficacy and anxiety worldwide (Morán-Soto & González-Peña, 2022; OECD, 2013). These issues likely have an impact on long term engagement: it has been noted in multiple studies internationally that students 'opt out' or 'switch off' mathematics when it is not obligatory anymore (Martin et al., 2012; Nyman, 2020). The motive of this study comes from the realisation of mathematics education being in vain if students end up actively discarding what they have studied.

The presented predicament is against the explicit aims of mathematics education. In most curricula engagement, enjoyment, and interest in mathematics is called for explicitly. For example, in Australia, where the first author currently works, the recently updated local syllabus (NSW Education Standards Authority, 2023) states that 'When students enjoy learning mathematics, they develop a positive self-concept and become self-motivated learners through active participation in appropriately challenging tasks. This can enhance their resilience in solving mathematical problems relevant to further education and their everyday lives.'. Similar statements are made in earlier Australian syllabi, so it is interesting to notice that this goal has not been met for the last decades in Australia (Watson et al., 2006; Beswick et al., 2021). In the syllabi, what is meant by interest, enjoyment and confidence, or how to achieve such outcomes, is left for the reader to interpret. In this study, the discussion of interest development will shed light to why such obscurity might be the very reason for the poor engagement in mathematics.

1.1 The present study

The literature suggests students' engagement connecting with better learning quality; it can make teachers work easier; it plays a role in students choosing STEM-related careers and is a preferred learning outcome per se (Berger et al., 2020; McPhan, et al., 2008; Nakakojia & Wilsona, 2014; Wang et al., 2015). This means that the concept of engagement is of interest to students, teachers, researchers and stakeholders. The term itself can be defined through several key concepts, such as the type of behaviour, the depth and the duration of commitment, a certain kind of cognition or emotion, and student agency (Fredricks et al., 2004; Helme & Clarke, 2001; Reeve, & Tseng, 2011; Stipek, 1996).

As evidenced in Middleton et al. (2016), student engagement in mathematics can be reinforced through interest, namely, by using activities that trigger and maintain student interest both momentarily and in the long run. Acknowledging the different stages of interest development (Figure 1), as well as understanding how to foster them, may assist in promoting productive long-term engagement. In the study of Tuohilampi et al., (2024) it was also evidenced that when mathematics is truly fun, it promotes all aspects of engagement and leads to deep understanding and valuing mathematics. In the studies of Tuohilampi & Attard (2024) and Dong (2024) it was demonstrated that many mathematics activities either lack having interest triggering features, or features to maintain interest. This can lead to tasks contributing to poor student experiences, and also result in teachers' using tasks that do not deliver what they promise.

In sum, studies to date have shown the importance of engagement, interest being one of the key components in deep, long-term engagement, and mathematics tasks having a role in fostering interest. What is unclear is what exactly makes a mathematics activity interest fostering. Considering the forgoing discussion, the present study aims to respond to two research questions 1) Which features have been identified to trigger and maintain students' interest in mathematics tasks in relevant studies? 2) Which interest triggering and maintaining features can be found in mathematics tasks that have shown, or are designed to promote student engagement?

2 Narrative literature review (RQ1)

Our purpose is to provide an understanding of features promoting interest development, identify the main findings, trends and controversies in the research, and point out the direction for future research (Baumeister & Leary, 1997). To achieve this, we use a focused narrative literature review to 1) elaborate on the interest-development framework by Hidi and Renninger (2006) and how it connects with long term engagement and 2) identify interest triggering and maintaining features of mathematics tasks in relevant studies.

According to Baumeister and Leary (1997), a narrative literature review is a method of integrating and synthesising existing research on a particular topic in a narrative way. This approach provides a flexible way to select and analyse literature. Although this flexibility provides a comprehensive way to synthesize materials, it also introduces subjectivity and bias. This may be attributed to the lack of standardized protocols, which could reflect researchers' perspectives. To mitigate these limitations, we have focused on transparency (Baumeister & Leary, 1997). For example, we used specified keywords, research methods, and target populations when searching for related literature. Furthermore, we acknowledge that a focused narrative review lacks an explicit intent to maximize scope that could result in only select literature that supports our world view (Grant & Booth, 2009). This was mitigated by not intentionally excluding any study that we initially identified as relevant. Moreover, our focus is not on mapping the field entirely, but to identify any features that promote interest to provide a starting point for building a framework for interest-promoting features.

Using a focused narrative review, we can focus on a specific aspect (features of interest development) of a broader topic (interplay between interest and engagement). This involves selecting a limited number of key publications and providing a detailed analysis of their findings. We have a narrow focus, aiming for in-depth analysis. We provide an examination of selected publications, synthesising their findings and drawing conclusions of interest fostering features. Using a focused narrative review, it is possible to notice that the most important contributions might come from fields outside mathematics education.

For our review, 27 studies were included (Table 1). We searcher articles using keywords “interest-development”, “Hidi&Renninegr”, “Interest AND math* AND tasks” and also identified relevant studies form the reference lists of relevant articles. We used multiple databases, including Google Scholar, ScienceDirect, Scopus and also our own libraries of relevant articles, being inclusive in terms of the publication time and domain. Most importantly, we did not aim for systematic review of the many studies discussing mathematics engagement or interest, value or intrinsic motivation towards mathematics. We wanted to identify studies elaborating on the mechanisms behind triggering and maintaining interest, and what exactly can contribute to those mechanisms.

Table 1. The 27 studies included in the focused narrative review

What could be identified	References of the studies
Mechanisms of interest-development (13 studies)	Deci et al. (1985) Mitchell (1993) Csikszentmihalyi (2002) Eccles and Wigfield (2002) Fredricks et al. (2004) Hidi and Renninger (2006) Renninger et al. (2014) Durik et al. (2015) Renninger and Hidi (2015) Harackiewicz et al. (2016) Middleton et al. (2016) Rotgans and Schmidt (2017), Renninger et al. (2019) Kaur and Chin (2022)
Features promoting interest in mathematics tasks (5 studies)	Ryan and Grolnick (1986) Sullivan et al. (2003) Guberman and Leikin (2013) Maiorca and Stohlmann (2016) Parhizgar and Liljedahl (2019)
Student perspective of what makes an interest-promoting experience (9 studies)	Betts and Knapp (1981) Cuddeford-Jones (2012) Linnenbrink-Garcia et al. (2013) Kohar et al. (2014) Linnenbrink-Garcia et al. (2016) Nyman (2016) Pinheiro et al. (2017) Nyman (2020) Attard (2021)

2.1 The interplay of interest development and long-term engagement

Interest development involves multiple aspects, such as psychological and situational factors, as supported by both classic and recent literature. Hidi and Renninger (2006) developed the Four-Phase Model of Interest Development, emphasizing the important transition from situational triggers to sustained interest. Other researchers have indicated that autonomy is one of the key factors in fostering long-term interest (Deci et al., 1985). Additionally, Eccles and Wigfield (2002) proposed that goal setting and motivational beliefs are associated with interest development. More recently, Durik et al. (2015) emphasise tailored instructional strategies to promote student interest, particularly in the context of mathematics and science learning. They argue that a 'one-size-fits-all' approach is insufficient for fostering interest, and instead advocate for more personalized and context-sensitive methods (Durik et al., 2015). Renninger and Hidi (2015) emphasised that the value of a task is critical for maintaining interest, while Harackiewicz et a. (2016) suggest that targeted educational interventions that emphasize autonomy, utility value effectively, and creating engaging environment can sustain student interest. In general, these studies provide a comprehensive understanding of interest development, emphasizing the importance of both psychological and contextual influences.

Interest development is thus one of the key components to tackle in the journey towards long term engagement. As Middleton et al. (2016, p.19) state:

> *In the here and now, we can see students developing interest, and engaging with gusto, while over the long term, they may try to avoid further mathematics coursework. Or, students may be bored with a particular algebra task, but tend to enjoy and seek out algebraic puzzles in their free time. What we see is the cycle of self-regulation that serves to manage engagement behaviours, but may or may not result in long-term valuing of mathematics, positive affect, and improved mathematics performance.*

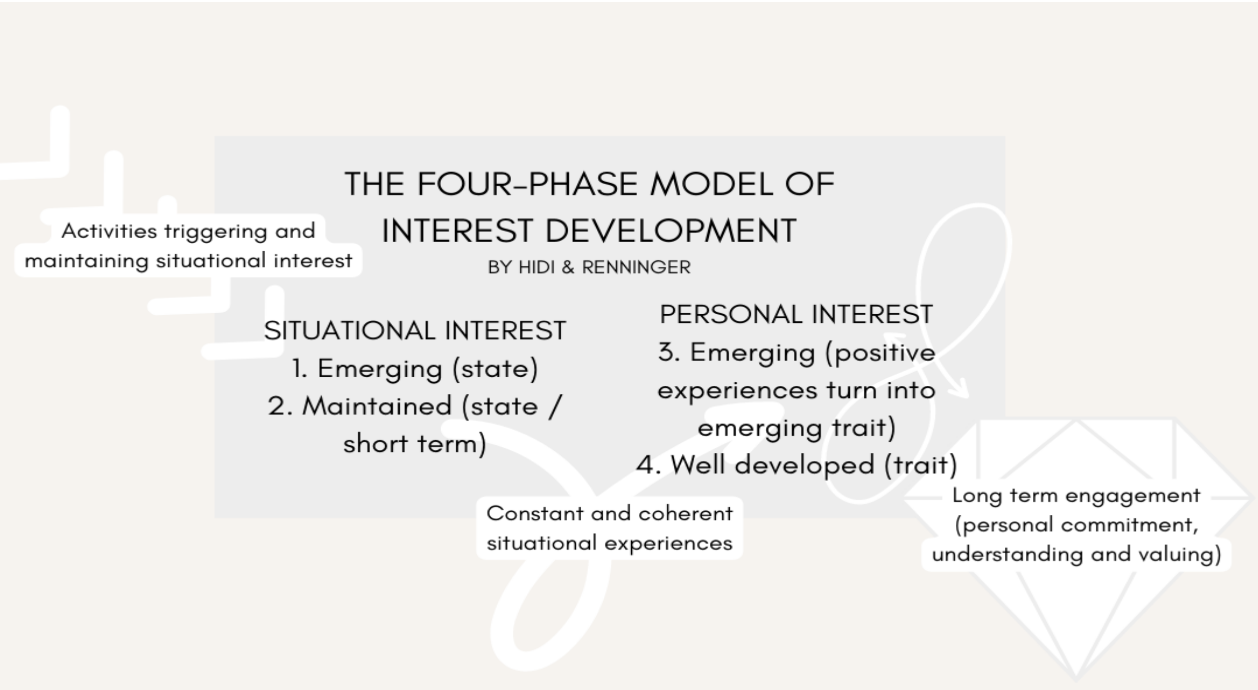
The statement underlines the importance of all aspects of engagement to develop. It is not enough to see students participating, if deep understanding and emotional fulfilment are not accompanied.

Middleton et al. (ibid. p.19) shed more light to the issue by arguing that 'When experiences tend to be consistent and coherent over time with regard to motivational affordances, it becomes more probable that the person will develop a (positive or negative) long-term disposition and identity toward mathematics.'. With motivational affordances, we understand the researchers referring to the affective aspect of engagement as described in the seminal research by Fredricks et al. (2004) where engagement is defined as a multidimensional construct including behavioural, affective and cognitive components. The three components are also manifested in the concept of interest: the psychological state of attention and affect toward a particular object or topic, and a motivation to engage and re-engage (Harackiewicz et al., 2016). The process described by Middleton et al. (2016) was confirmed empirically by Rotgans and Schmidt (2017), who noticed that individual interest can be increased by a repeated arousal of situational interest. It has also been empirically shown that what triggers that arousal is subjective (Renninger et al., 2019).

To land on this positive long-term engagement through consistent motivational experiences, interest triggering activities are an important factor. This consequential function is one of the two perspectives of interest, focusing on 'What would create interest that would result in…?' (Renninger et al., 2014) and could range from what is asked from students to what the process looks like; what resources are given and what is the significance of the work (Kaur & Chin, 2022). Another way to define the concept is seeing interest as a reaction to something that has been present. This perspective leads to examining the emergence of interest, circling back to interest triggering activities. Both approaches see the concept as something that happens between an individual and an object, environment or situation and can be seen as representing the trait/state aspects of interest. A dual function of interest promoting activities appears: fuelling interest to emerge and interest sustaining to contribute to a motivational experience short and long term.

The two functions are woven into a four-phase model of interest development by Hidi and Renninger (2006). Frequent and successful situational interest leading in long term personal interest proposes a flow chart displayed in Figure 1 below.

Figure 1. The four-phase model of interest development integrated to long term engagement by the authors



Situational interest was elaborated by Mitchell (1993) a few decades ago, however, there is still more to investigate. Rotgans and Schmidt (2017) called for studies uncovering the 'underlying mechanisms' for the growth trajectory for individual interest modelled by Hidi and Renninger (Figure 1). Our contribution is to examine what features in mathematics tasks can promote the first two stages of interest development, triggering interest and then have it maintained, according to the relevant literature?

Researchers have often suggested specific means, such as modelling (Maiorca & Stohlmann, 2016, Parhizgar & Liljedahl, 2019), to promote interest towards mathematics. Also, Guberman and Leikin (2013) state that mathematical problem solving is 'at the heart of mathematics teaching and learning' (p. 33), seeing a challenge as 'an interesting difficulty' (p. 36). Another commonly suggested approach is to contextualise problems (Sullivan et al., 2003). In their study, Sullivan et al. (2003) discuss the use of real-life contexts, but they end up challenging the consensus of using real-life contexts as a straightforward solution that serves all students. Sullivan et al. (2003) remind about some contexts being alienating to some students, also that adult's real-life contexts differ from those of students. Sullivan et al (2003) summarise literature showing that imaginary contexts (fantasies) can have stronger responses than real life contexts. Ineffective use of context or forced modelling challenges may explain why in a study by Kohar et al. (2014) only 34% of surveyed students found themselves interested in tasks they had themselves co-designed to enable reasoning, communicating, cognitive challenge and real-life feel.

Harackiewicz et al. (2016) point out that interest is essential to academic success. Unfortunately, practical interest interventions addressing situational interest, problem-based learning, and utility value continue to be fully explored (Harackiewicz et al., 2016). In Nyman's (2016) study, students' interest was said to be prompted by 1) having mathematics in the foreground, 2) giving challenge, 3) allowing student influence and 4) allowing students to present their results. Nyman's (2020) list aligns with the suggestions discussed above, as well as with a list by Attard (2021), where the four aspects are supplemented by 5) relevance 6) positivity and 7) a mixed format, such as providing technological affordances.

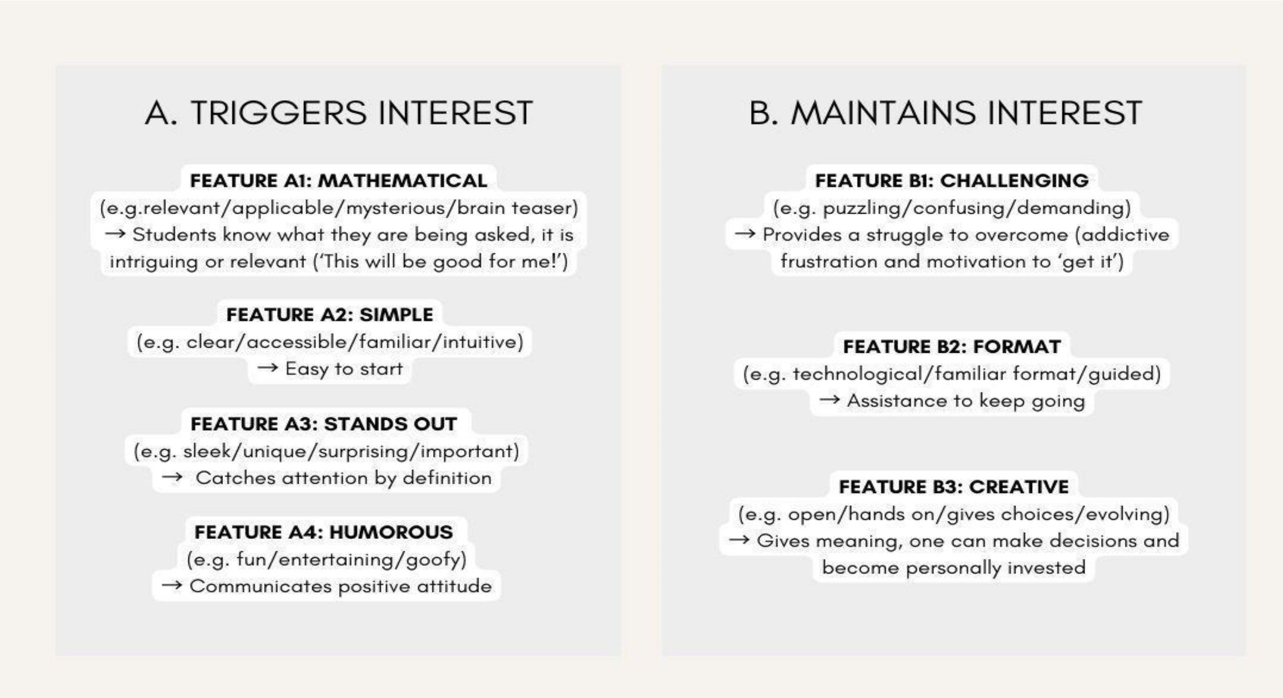
Educational research (Linnenbrink-Garcia et al., 2016) suggested a variety of ways for increasing student interest and engagement in class. One effective strategy involves providing competence support, which can increase students' attention by designing tasks with challenging work, well-explained examples and encouraging feedback (Linnenbrink-Garcia et al., 2016). Furthermore, tasks should be designed to support students' autonomy by providing opportunities to participate in decision-making and acknowledging their perspectives. It can be supported by Betts and Knapp's (1981) Autonomous Learner Model (ALM), which encourages students to set goals, select and design activities, get involved with seminars and conduct research based on their own interests and learning needs. Moreover, education researchers (Ryan & Grolnick, 1986; Linnenbrink-Garcia et al., 2013) also highlight the importance of meaningful interaction between students and teachers in enhancing students' situational interest.

To make things more practical, we will bring into the discussion what appeals to young people in general, introducing features that are used for entertainment, or to sell products to school aged children. According to market research (Cuddeford-Jones, 2012), the triggers for students from Year 2 to Year 9 are: Sleek, neat designs; Stands out; Uniqueness; Humour; Does new stuff all the time; Creative; Gives choices; Positive attitude.

Finally, we'll add psychology research that knows a lot about how to arouse attention. If, for example, a cue is given with laughter, the human brain's attention is better caught than when given in a neutral tone (Pinheiro et al., 2017). Whenever something unusual or unexpected occurs, the human brain easily pays attention. Thus, instead of triggering interest, maintaining the situational interest may be the tricky part: as soon as the initial surprise has passed students' attention can begin to dissipate. On the other hand, maintaining interest might happen through very traditional means. For example, including aspects of drilling (repeated exercises) into activities may be one way to keep students engaged, and can promote further creativity, as noted by Csikszentmihalyi (2002, p. 123), who suggests that 'It is a mistake to assume that creativity and rote learning are incompatible.'.

Combining what is suggested above by education research, market research and psychology research, we listed the suggested features. Based on our theoretical knowledge and pedagogical experience thus far, we categorised the different suggestions into features that likely trigger or maintain interest (Figure 2). This way we can suggest a ProInterest model introducing features that have potential to contribute to the two stages of interest-development. It is important to note that we are only theorising how each feature might contribute to triggering or maintaining interest: the empirical testing will follow in the future.

Figure 2. ProInterest model categorising features that have potential to trigger and maintain students' situational interest in mathematics



Based on our tentative trialling of designing tasks using the model, it seems like two of the features triggering interest, A3 and A4 are largely subjective. What stands out (A3) depends on the receiver's previous experiences, perhaps also expectations. Humour, on the other hand, has lots of cultural sensitivity and cannot be served as one-size-fits all. The features that maintain interest are more universal and ensure curiosity and resilience when faced with a cognitive challenge. Triggering features are needed to get students working on the challenge that supports learning and understanding. We anticipate, in line with what was said about a different discipline, Yoga, by world renowned practitioner Kino MacGregor (2024), that one can "start practicing for all kinds of weird reasons and it does not really matter why you start" (as long as one starts), … "But it does matter why you stay". Thus, we assert that the maintaining features a needed to ensure the challenge worth enduring in terms of a deep learning process.

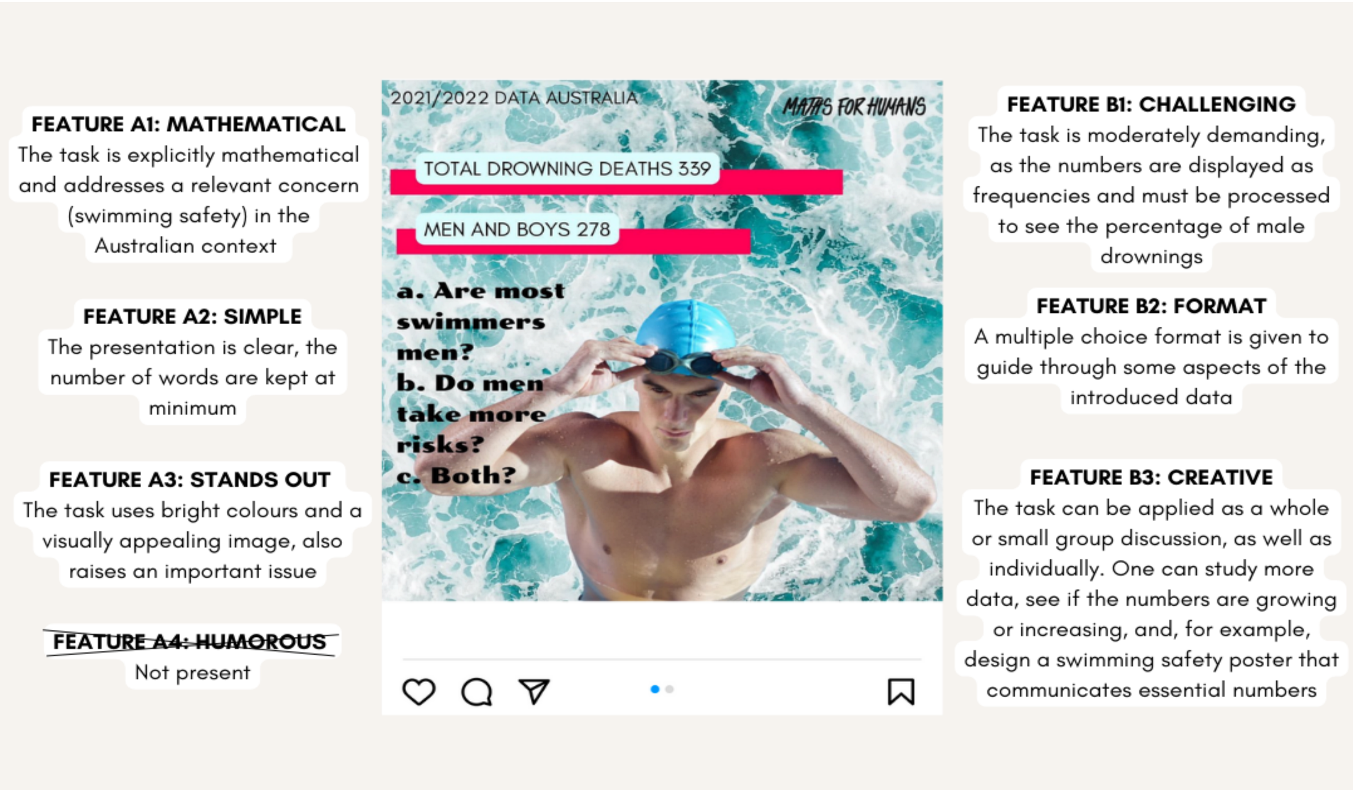
3 Case analysis (RQ2)

To answer the second research question, this study employs a case analysis to identify interest-promoting features that can be found to promote interest through analysing different mathematics tasks. Case analysis is a research approach that involves an in-depth examination of a single or multiple cases within real-life context (Heale & Twycross, 2018). This method provides detailed insights into different cases, which, in the present study, refers to various types of mathematics tasks.

3.1 Applying the ProInterest model on two mathematics tasks

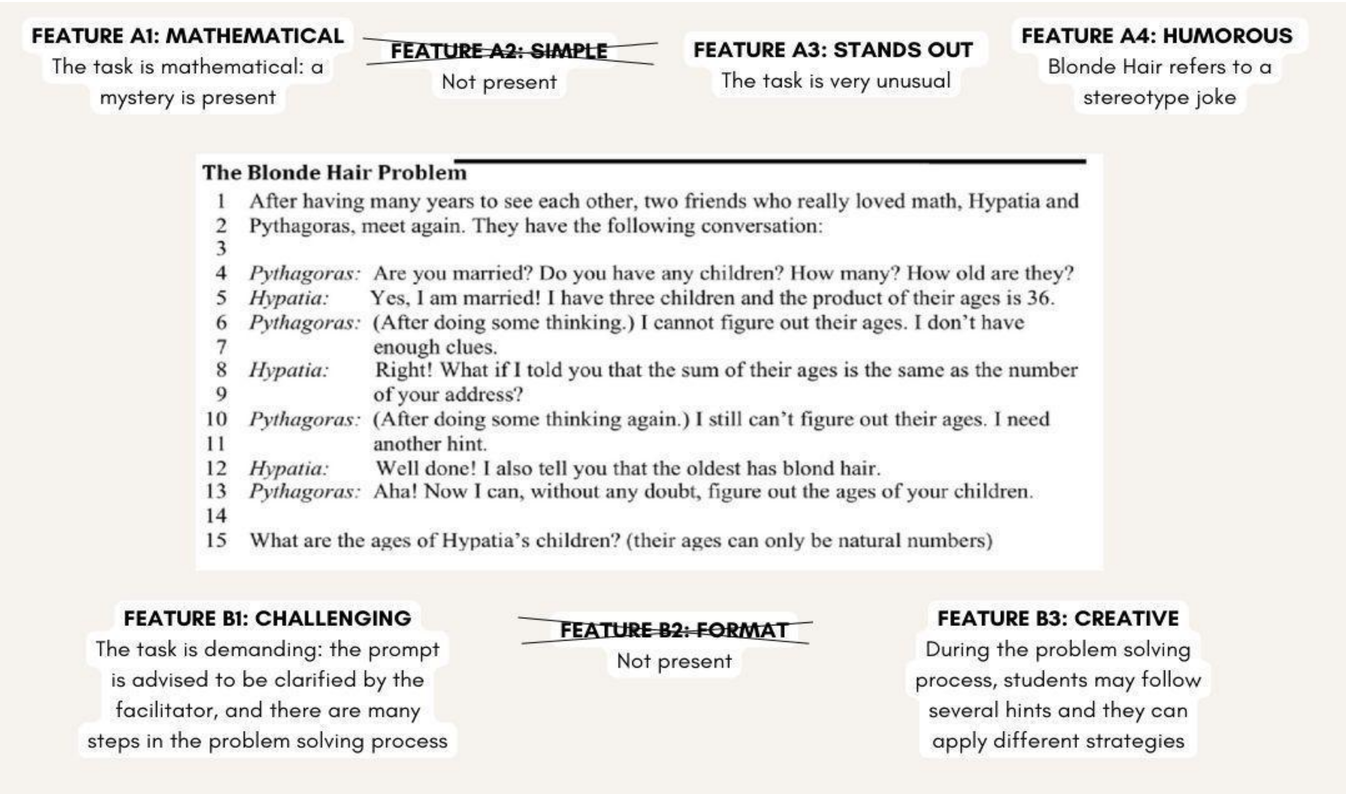
Next, we will introduce two tasks that manifest most or of the listed features. We have chosen these tasks, as they both have promoted interest whe trialled with students, yet they seem very different at the first glance. As the reader will learn, they have many similarities when it comes to their potential to trigger and maintain situational interest. The first one is done by the first author's team and shared in social media as part of her many experiments. In Figure 3, we present how the task meets the features triggering and maintaining situational interest.

Figure 3. How the ProInterest Features are met in a task shared in social media



The second task comes from a study of Stylianides and Stylianides (2011). The first author initially encountered this task (see Figure 4) in a conference and was much influenced by the ideas the researchers introduced in their presentation. The task is confusing and intriguing, and in our experience surprisingly easy to get off to a good start if the facilitator directs the problem solver to start finding potential combinations of the three factors of 36. Most importantly, the problem solvers do not need any special skills, it is enough to do some basic calculations and realise the logic behind what prompts Pythagoras to ask for one more hint. Stylianides and Stylianides (2011) findings show important positive changes in student's beliefs about mathematical problem solving after having experienced just this one task. The first author has since applied the task on multiple occasions, and her experiences have confirmed the findings. The students have, albeit puzzled, eagerly taken on the challenge, persevered, and expressed immense content after having solved the problem. Every one of them has solved the problem, and many of them have expressed being pleased to experience mathematics as fascinating, some of them for the first time in their lives as communicated to the first author. Similar account was described in the findings of Stylianides and Stylianides (2011). It is interesting to see that the task meets most ProInterest Features (Figure 4).

Figure 4. How ProInterest Features are met in a task discussed in Stylianides & Stylianides (2011)



Four out of seven features are common to both tasks (Figures 3 and 4) despite their seemingly differing appearances. This suggests a variety of mathematical activities to meet the interest promoting features.

Based on our anecdotal knowledge, we argue that many mathematical resources are yet to manifest these features. The learning of mathematics likely tolerates a few indifferent experiences, however when promoting interest and long-term engagement is explicitly aimed (for example, in the national curricula), occasional application of interest promotion might be critical. For example, in a study of Schukajlow et al. (2012), the researchers were not able to find differences in how students assessed their interest between three different task types. The finding may be explainable with the ProInterest model: in the next section we'll show that there were no essential differences between the task types when it comes to either triggering or maintaining student interest. Let us take a closer look at the tasks used in Schukajlow et al. (2012) study to see how they meet the interest promoting features (Figure 2).

3.2 Tasks that hardly differ when it comes to the interest triggering features

Schukajlow et al. (2012) call for references to reality to attain more student interest, increased motivation and positive emotions. In their empirical study (Schukajlow et al., 2012), three different task types were introduced, asking students to assess their interest towards the tasks. No differences were found. We found this result interesting and wanted to test if we could explain it using the ProInterest model: perharps the tasks do not differ when it comes to the features triggering interest, making it hard to identify any difference at the first glance? The three types described by Schukajlow et al. (2012) were 1) 'intra-mathematical problems' (mathematics tasks without context), 2) 'dressed up mathematical word problems' (for example, asking students to apply a mathematical operation in a fabricated situation) and 3) 'modelling problems' (for example, using a real-life context where mathematical operation needed to be applied). As discussed earlier, modelling and real-life relevance have often been suggested to promote interest, which may explain the assumption of the degree of real-life context accounting for interest. Since this was not the case, it is worth remembering that real-life contexts were problematised by Sullivan et al. (2003), and not included as one of the features suggested by Nyman (2016) or Cuddeford-Jones (2012) to promote interest (see Figure 2). Attard (2021) calls for relevance and explicit links to students' lives but is not suggesting manufactured contexts.

In Figures 5, 6 and 7, we will show to what degree the three sample tasks representing the three task types in the study of Schukajlow et al. (2012) meet the ProInterest Features. The justifications are given after the images.

Figure 5. How ProInterest Features are met in the intra-mathematical task (Schukajlow et al, 2012)

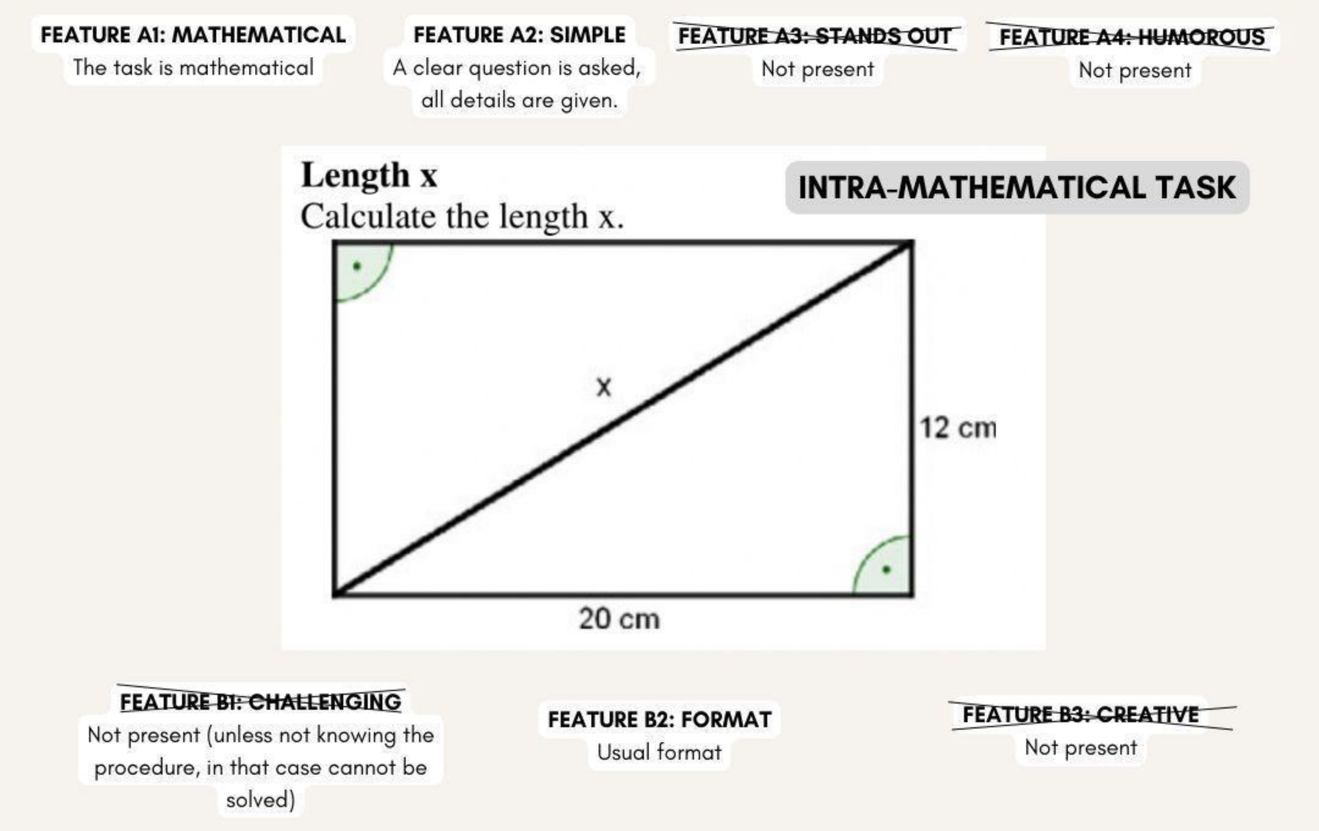
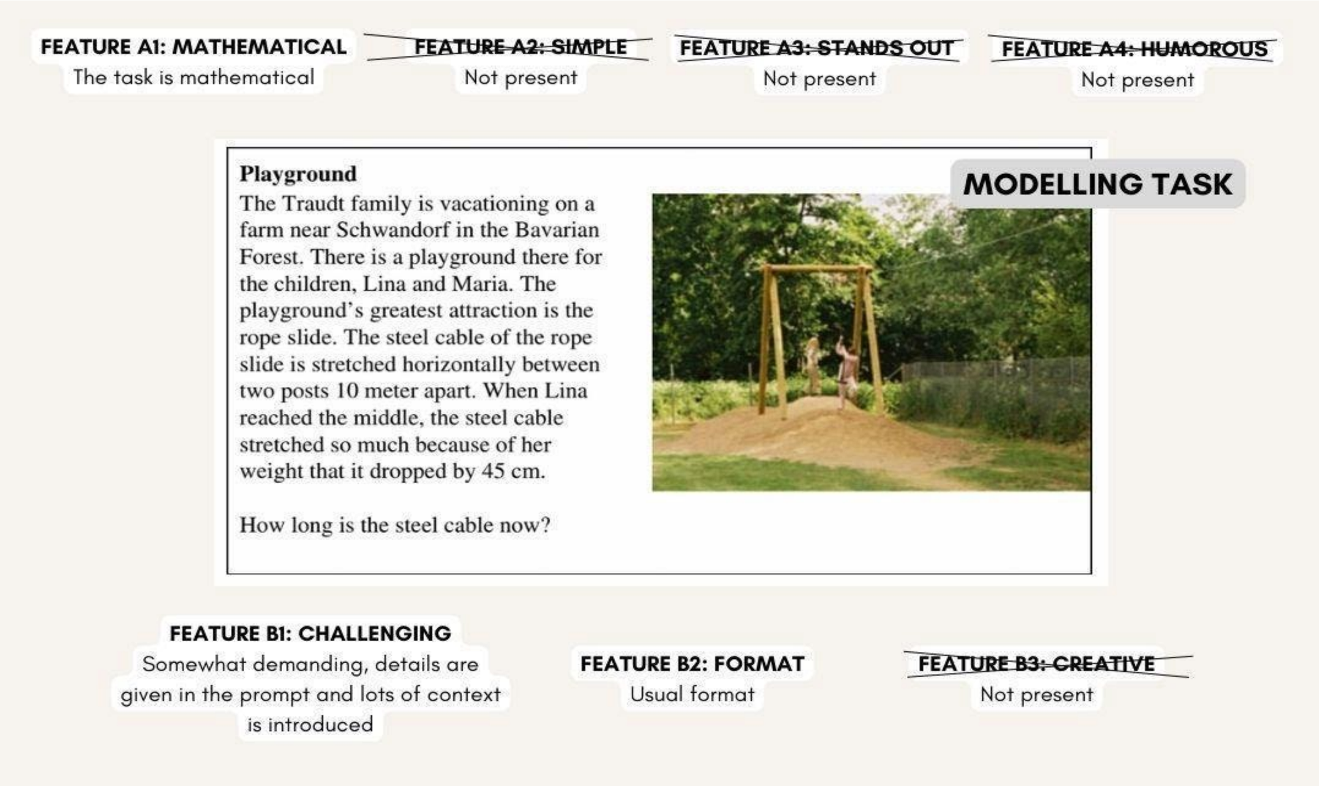


Figure 6. How ProInterest Features are met in the dressed up task (Schukajlow et al, 2012)

Figure 7. How ProInterest Features are met in the modelling task (Schukajlow et al, 2012)

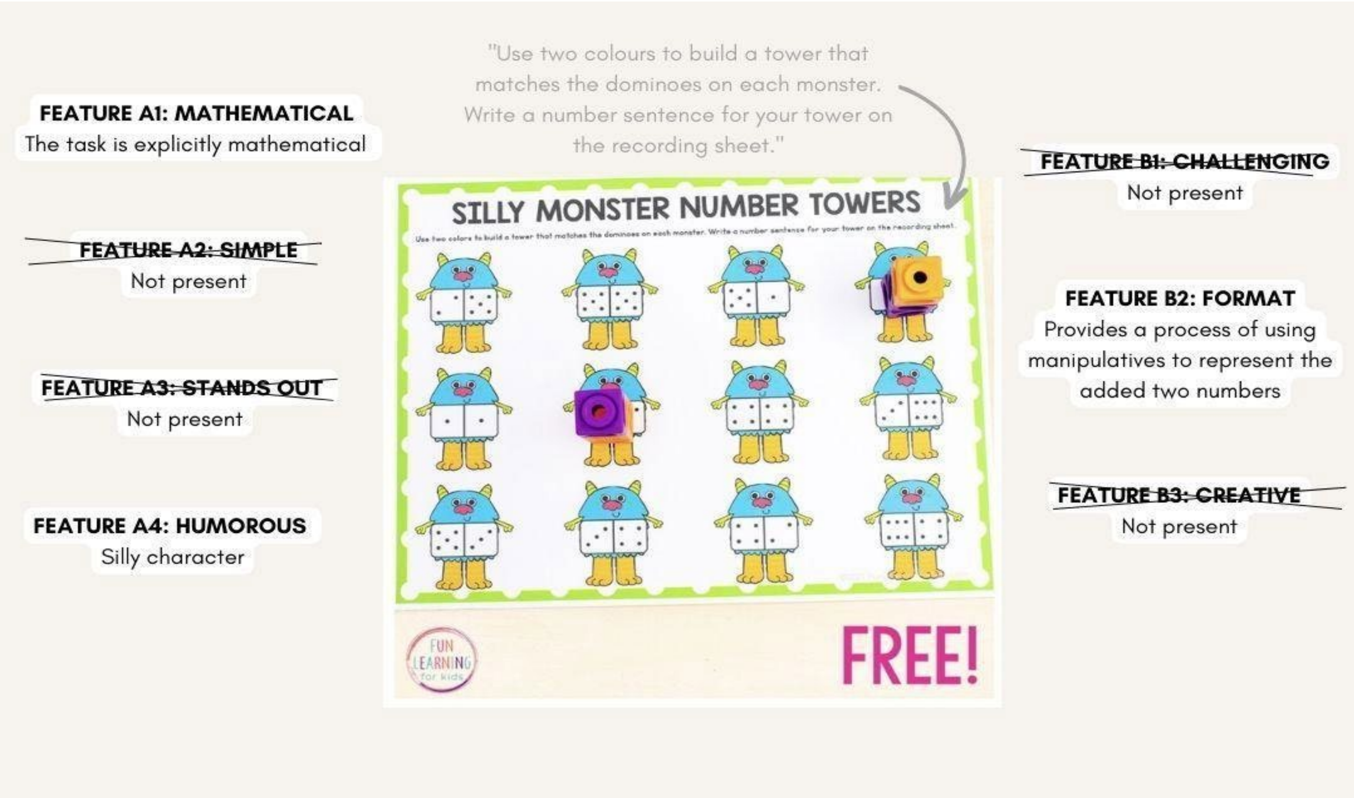


All three tasks are clearly mathematical. The first one is very straightforward, making it simple. None of the tasks stand out: in mathematics textbooks the use of images or pseudo context with characters (such as Trainer Mansfred) is very common and do not make a task to stand out. On the contrary, the way images and context stories are used in the tasks provides a usual format that assists in completing the task (once details are collected, one can apply the appropriate formula and forget about the characters). None of the tasks communicate humour, and they do not allow creativity.

The essential difference lies in the challenge, in how much details are given to the students versus how much they need to figure out (i.e. model) themselves. Challenge is a feature to maintain interest, which becomes more apparent after having started with the task, but in the study of Schukajlow et al. (2012), the examinees were instructed not to solve the tasks. They were instructed to determine whether they would be interested in working on the problem based on just reading the prompts. At one glance, one would likely pay attention to features that trigger interest, in which there were no essential differences. This might explain why the researchers did not find any statistically significant differences in students' perceptions of these tasks: similar findings were introduced by Parhizgar and Liljedahl (2019), who also noticed that students could not differentiate between three types of mathematical problems. However, in Parhizgar and Liljedahl's study (2019), after having solved the given tasks, the students reported more flow while solving word problems. The tasks were mathematical and simple to trigger some interest, and challenging and in a usual format to maintain some interest.

For final example, we wanted to apply the model for tasks that may be advertised as fun or engaging, yet potentially lack what is needed (Tuohilampi et al., 2024). First, we have selected a representative fun maths online task 'Silly Monster Number Towers' (Figure 8). The task is advertised to be fun and is offered by a platform entitled "Fun Learning for Kids" (Fun Learning for Kids, 2021). The prompt is to use two colours of blocks to build a tower that matches the numbers in dominoes the bright coloured monsters have on their bellies. In addition, students are asked to write a number sentence for each tower. For example, if there is a monster with dominoes 2 and 5, students can choose 2 yellow blocks and 5 red blocks, pile them to represent a 'monster tower' and write 2+5=7 in a designated recording sheet.

Figure 8. How the ProInterest Features are met in the Silly Monster Number Towers task

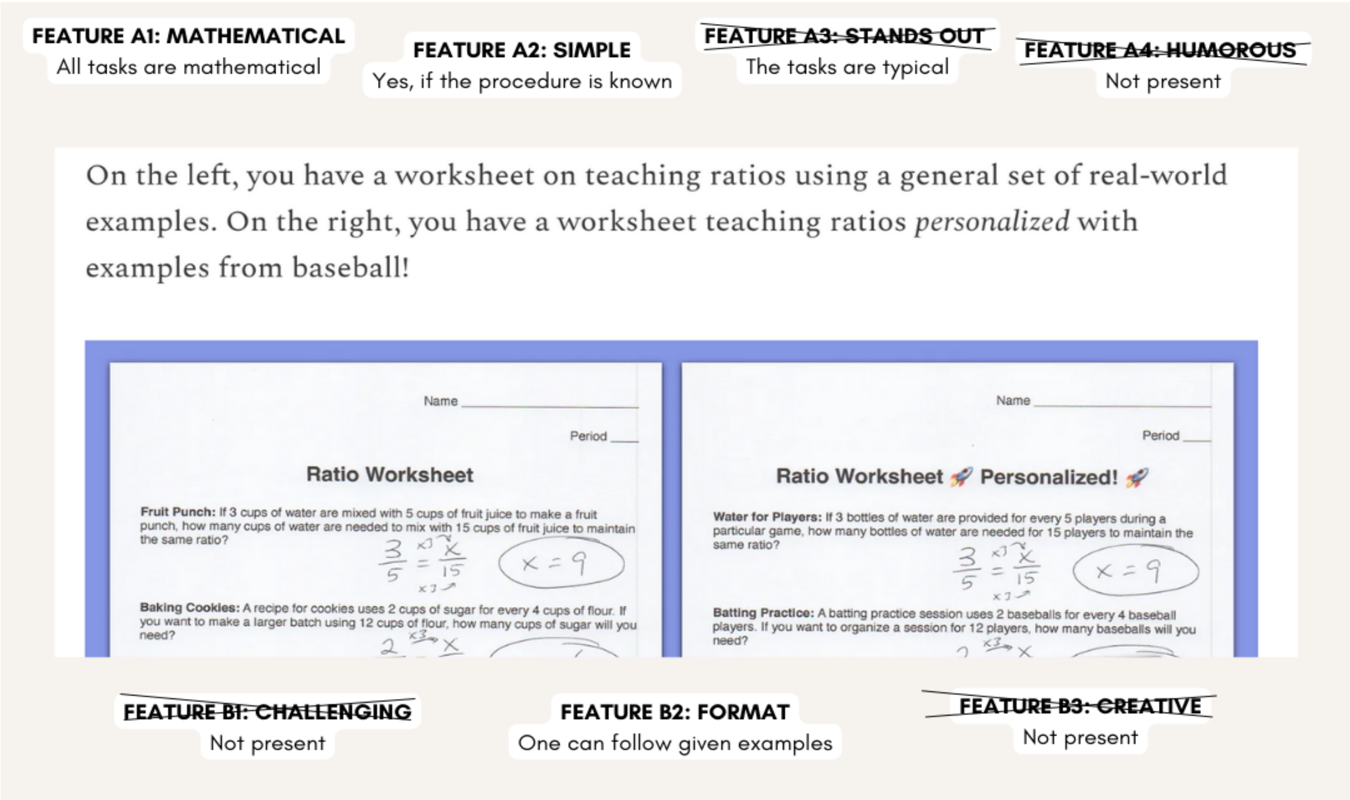


Let us see what triggering features are demonstrated in 'Silly Monster Number Towers'. It has mathematics in the foreground (has feature A1), and there is humour in the title of the task, the characters are indeed labelled as silly (has feature A4). The format is typical to a mathematics task; the use of blocks assists a student with the manipulation of the quantities, and the designated recording sheet gives a clear structure for documentation (has feature B3). However, there are several missing features when it comes to both triggering and maintaining interest. The task is not simple: it requires reading of a prompt written in a small font, plus grasping the different steps of what is asked of a student, not in terms of making mathematical discoveries, but following orders (does not have feature A2). The use of colours, characters and fonts likely aims for a neat look; however, many textbooks and online resources nowadays use similar designs (does not have feature A3). The intellectual challenge is minor: it is a closed addition task where two integers are visually displayed and manipulated (does not have feature B1). The student influence is tokenistic at best, you only get to choose the colours; the task is not evolving or creative (does not have feature B3).

When we first encountered the ‘Silly Monster Number Towers’, our first impression was that the task would likely promote student interest. This was albeit having read literature on the topic and having engaged us in the design of interest developing activities. The analysis here suggests otherwise: not many interest promoting features are available. If we are prone to being mistaken, we doubt the average teacher would be critical with a task’s potential to promote interest. It is not to say that the task would not be very applicable in mathematics learning: our speculation is that procedural fluency can be developed through it. Interest could also be triggered if the task was used in a very surprising way as an alternative to very traditional, dull mathematics exercises, simply by offering something different. In regular use, however, one can argue that over time tasks with accessibility issues (not being simple), unimaginative design (not being particularly exciting), and omitted features to maintain interest (no challenge, minimally interactive, not creative) make a repetitive, meaningless experience. Such tasks should not be advertised as engaging or interest-promoting.

As an alternative to the tasks mentioned above, which are essentially showing minimal potential to fostering interest, generative AI has been touted to improve students’ interest in mathematics. Practitioners, however, have questioned AI’s creativity in truly modifying the tasks for deeper engagement (quite rightfully). Let us consider the example of "teaching ratios personalized with baseball" (Figure 9; Meyer, 2024). The goal here is to use personalised tasks to spark student interest. However, upon closer examination, we see minimal changes in the interest-promoting features. Generative AI simply substitutes general real-world examples with baseball-related ones, failing to truly personalise the student's work.

Figure 9. How ProInterest Features are met in a Ratio Worksheet revisions (revisions introduced by Meyer, 2024)



Let us analyse these tasks through the ProInterest model. On the left, there are real-life contextualised tasks. On the right, AI has revised the tasks aiming to better meet students' interests. Unfortunately, the revisions do not result in any changes when it comes to the interest-promoting features. Both versions are explicitly mathematical (Feature A1). Both set of questions are clearly presented and easily accessible for those who know the procedures (Feature A 2). Generative AI simply changes the words in the content assuming what students might be interested in, which is also a common approach utilised in math textbooks and online resources, failing to present uniqueness (both versions lack Feature A3). The tasks do not include any humorous language or scenarios but are limited to a list of questions (both versions lack Feature A4). There are no rich cognitive challenges (both versions lack Feature B1) or creativity (both versions lack Feature B3), however, the typical nature of the tasks gives a format in both cases (Feature B2) as students can simply follow the procedures given to this type of tasks.

Although the tasks are improved by generative AI attempting to utilise students' assumed preference for the Yankees, there is no room for them to personalise their work through problem solving. The main function of the majority of the educational technologies primarily focuses on generating and modifying content (Cao et al., 2023), which fails to meet students' learning needs and does not effectively support the enhancement of their long-term interest in learning (Meyer, 2024). In our experience, practitioners can identify the poorness of the typical modifications, and the ProInterest model is helpful in pinpointing where the modifications fail exactly.

4 Discussion

The findings of this study give some answers to why students are ‘switching off’ maths, as worded by Collie et al. (2019) and Martin et al. (2012). If situational interest constantly fails to be triggered, maintained or both, learning experiences can become poor enough to feed disengagement over time. To respond to the research question 1) Which features have been identified to trigger and maintain students’ interest in mathematics tasks in relevant studies?, this study reviewed 27 studies relevant to the interest-development framework by Hidi and Renninger (2006) to identify that frequent and successful situational interest leads into long-term personal interest. Based on features discussed in the studies that can potentially contribute to interest-development, we have provided four features to trigger interest (Mathematical, Simple, Stands out, Humorous) and three features to maintain interest (Challenging, Format, Creative) in the ProInterest model. To respond to the research question 2) Which interest triggering and maintaining features can be found in mathematics tasks that have shown, or are designed to promote student engagement?, we have pointed out that typical mathematics tasks can lack many essential features. Even tasks improved by generative AI can fail to meet these features, and supposedly would fail to foster students’ long-term interest development in mathematics. Mathematics tasks may thus play a crucial factor in students losing opportunities for interest development and long-term engagement. Teachers’ may compensate what is missing in the tasks, but they may also be misguided by tasks that are easily accessible with keywords to engage students, such as ‘fun maths’, potentially lacking interest promoting features and doing a disservice to the aim to engage students.

Next, having the ProInterest model, it is now possible to empirically test students experience. It will be important to see if how much depends on teachers’ skills to use tasks as affordances as opposed to a tokenistic manner and to analyse a large set of tasks to make generalisations over all tasks that are aimed to promote interest. These examinations will be our focus in the future. In Figure 10, we propose steps that ensure that the features to trigger and maintain interest are present in mathematics tasks. The steps are introduced through a version of the mathematical problem using Pythagoras Theorem. This content was common in the three tasks contrasted by Schukajlow et al. (2012). We will provide a blueprint for task design that acknowledges all interest promoting features.

Figure 10. Seven steps to apply ProInterest model in a sample task

In the sample task (Figure 10), the problem solver must find out the length of the triangle’s sides, compare their added length to the shortcut, and use the length difference to estimate the number of their individual step lengths to cover this additional stretch. They need to remember the return trip, and multiply by the number of school days. In each step, similar mathematics is used even if the number of school days is not totally accurate, or the estimation of the step length does not hold. When getting to the end of the problem, one cannot check the answer key for the right answer, instead one must rely on their own reasoning and assess how realistic their answer is. The task can evolve to make connections outside the mathematics classroom (why having green areas?). Such debates can turn meaningful for students: for example, when the first author has facilitated The Blonde Hair Problem (Figure 4), students have sometimes had opinionated conversations about gender differences while on the task, Pythagoras being known by everybody and female mathematician Hypatia by hardly anyone.

In the sample task in Figure 10, all features that trigger and maintain interest are present. In step 2, it is advised to introduce a recognizable situation. This can happen in multiple ways: it could be through a real-life context that really matters to students, but it could also be something abstract, as long as it creates a clear entrance to the task. Adding a background story, such as Trainer Manfred and their team (Figure 6) does not necessarily make the situation more familiar, as pointed out by Sullivan et al (2003). We still do not know who Trainer Manfred is, the mere mention of them does not make us interested in them. If instead of Trainer Manfred it was somebody the student would recognise as someone who would ask their team to engage in silly training habits, the situation would make more sense; the context would truly contribute to the feel of the task instead of seeming tokenistic. For step 4, the sample task uses a meme. This results in copyright considerations; our suggested blueprint for interest-developing task design does not take into account further challenges, it simply serves as a starting point to know what to look for. On the other hand, obstacles such as copyright issues do not need to be solved by sticking to what can be printed in a workbook, as a part of the task design could be a provision of original media to be shown and discussed. In steps six and seven, interactivity and assistance could be added by doing just that: using social media, or technological tools, such as GeoGebra, to dynamically operate with variables like step length. These considerations point to multimedia format tasks, consisting of what is shown to students to ensure simplicity, and what additional resources are available. Such application of greater digital affordances suggests new approaches for task design, such as using a documentational approach (Gueudet & Trouche, 2009).

4.1 Theoretical implications

We have clarified the role of interest development in long term engagement, consisting of behavioural, cognitive and affective aspects (Fredricks et al., 2004). Tasks standing out and communicating humour speak to the affective side of engagement, simpleness and formatted to the behavioural, and the rest of the features, mathematical, challenging and creative to the cognitive side. In future studies comparing different task types, the different functions of triggering and maintaining interest should be acknowledged. Further, the importance of interest development as its own learning process should be better addressed. Warshauer (2015) reminds how sometimes studying mathematics can feel momentarily difficult, exhausting and tedious, yet the student might experience this as productive struggle and learn effectively, discovering the joy of knowing mathematics in the long run. Research shows some activities positively impacting students' agency and examination skills and yet being detrimental to explicit learning outcomes (inquiry-based approach was shown less effective than teacher-led approach in PISA 2015 data in Oliver et al. (2021). The latter example shows that sometimes affective processes develop independently from the learning process, requiring explicit focus.

4.2 Practical implications

The role of interest development as part of the learning process, but also as an independent process, must be acknowledged in policy documents. Neither teaching nor curriculum design should see interest-development as something that just happens when stated as a goal, as a side effect of content teaching. So far, this approach has ended up in content knowledge unused by its learners. In task design, we must include features that trigger interest, as well as features that maintain students' interest. In teachers' professional development, there is a need to elaborate on interest development, and the subtle differences in teacher-student interaction that can either promote long-term engagement or result in a slow regression in student engagement. What interest-development stimulates aligns in many ways with other recent enriching strategies, such as rich tasks (Foster, 2013, see also NRICH, 2023), mathematical discourse (Ryve, 2006), number talks (Parrish, 2011) and mathematical modelling (Boaler, 2001). Features promoting a comprehensive learning process may overlap with features promoting interest development, making long-term engagement a comprehensive phenomenon. The role of a teacher in selecting and applying tasks is of utter importance. In the future, we will collect data on students' views and application of interest developing tasks. We are looking forward to continuing the discussion with those data.

4.3 Limitations and future directions

The primary limitation of this study involves the lack rigor of systematic reviews, which can lead to selective bias in the literature included. The findings from a narrative review and case analysis may be difficult to generalize to broader contexts, as it mainly focuses on a narrow range of studies and specific instances. We suggest that future research should continue to examine the ProInterest model and students' mathematics learning-related outcomes, such as motivation, self-efficacy and academic achievement by employing this model in different contexts. This study is a starting point: we challenge the mathematics education community working towards a well-established framework for mathematics designed for engagement. The ProInterest model proposed here must be extensively tested and the features better defined. There is also a need to further examine the different manifestations of interest promoting activities, as well as students' responses to them.

5 Conclusions

In summarising the exploration of features that trigger initial interest and features that can subsequently sustain student engagement, it becomes evident that four key features—Mathematical, Simple, Stands out and Humorous—are essential for triggering initial interest, while three features—Challenging, Format, and Creative—are crucial for maintaining it. However, whether there are more features, and what these features mean to different students are yet to be examined. One of our critical findings highlights that many standard mathematics tasks often lack these critical components, even the ones that are specifically designed and advertised to engage students. Furthermore, tasks enhanced by generative AI can also fail to sufficiently incorporate these features. Additionally, some proportion of mathematics activities must appeal to the emotional aspect. Middleton et al. (2016) suggest that the in-the-moment engagement serves as a combination of intrinsic, extrinsic, social, and individual factors that are interrelating, drawn from personal, social, cultural and macro cultural constraints, and are contributing to the development of a longer-term disposition towards the subject. We should not accept bringing students to the culture that mathematics is boring, hard or not relevant. Sullivan et al. (2003) proposed fantasies: we want to finish this study by mentioning what the first author once heard from her mathematics teacher student: people are interested in superheroes, or antiheroes like Donald Duck and other irrelevant stuff. In the student's opinion, we just need more space for imagination: fantasies, curiosity, stories, humour. One can argue that mathematics inherently embodies features that appeal to the human mind. People are fascinated by imaginary realities, logical ponderings, and the infinite potential for developing mathematical structures, available for anyone to explore. It is time we bring that fascination to where new mathematics users are generated: mathematics classrooms.

Research ethics

Author contributions

Laura Tuohilampi: conceptualisation, investigation, methodology, project administration, validation, visualisation, writing—original draft preparation, finalising of the manuscript Huifei Jiang: AI analysis, methodology, review and editing

Artificial intelligence

Artificial intelligence has not been used in the research or writing the article, but the grammar in some parts of the text has been checked with it.

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Informed consent statement

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Data availability statement

The task annotations generated during the current study are available from the corresponding author on reasonable request.

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Conflicts of Interest

No competing interests to disclose

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