

Teacher Interest-Led Inquiry: Unlocking Teacher Passion to Enhance Student Learning Experiences in Primary Mathematics

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ABSTRACT

Building on recent research into the importance of positive teacher emotions for student learning experiences, the current study involved five upper primary teachers at a Victorian government school developing inquiry mathematics units built around topic areas of personal interest or passion. Respective students (n=88) elected to participate in one of five structured inquiries developed by these teachers. Despite being given a mandate to let their own passion drive their topic choice, interviews with teachers indicated that they invariably anticipated the interests of students when selecting their topic. Moreover, although teachers enjoyed the experience of developing and delivering the inquiry units, their emotional responses were inextricably linked to the perceived student learning experience. Student questionnaire data revealed that participation in the inquiry units was associated with increases in students' intrinsic motivation to learn mathematics. Students attributed positive evaluations to the opportunity to learn mathematics in a context in which they were personally engaged. Possible future research directions are discussed.

Keywords: teacher enjoyment, student enjoyment, intrinsic motivation, inquiry-based learning, teaching mathematics thematically, primary mathematics

INTRODUCTION

Recently, there has been burgeoning research interest in understanding both the causes and consequences of positive emotions experienced by teachers, particularly in mathematics classrooms (Jacobs, Frenzel, & Stephens, 2017). One potential cause of positive teacher emotions might be in providing teachers with greater autonomy over the context through which they design learning experiences in core instructional areas, such as mathematics. The Teacher Interest-Led Inquiry (TILI) program is an approach to the teaching of mathematics focused on teachers developing a unit of mathematical inquiry connected to an identified topic of personal interest or passion. The TILI program was implemented by a team of five teachers at an Australian primary school with respective Year 5/6 students (10-12 y/o) each participating in one of the five 'electives'. The TILI program incorporated teacher interests, an element of student choice and an inquiry-based pedagogical approach. The purpose of the current paper is to explore the impact of TILI on the teaching and learning experience.

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BACKGROUND LITERATURE

Structured Inquiry, Student Choice and Student Learning Outcomes

Inquiry-based learning approaches to mathematics are gaining traction in educational settings across the world (Thornton, 2017). For example, the Australian Academy of Science, in association with the Australian Association of Mathematics Teachers, has recently launched an initiative entitled *re(Solve)*, designed to develop a suite of resources to support inquiry-based learning in mathematics classrooms across compulsory schooling (Tripet, Patel, Thornton, & Walker, 2018). Similar projects focused on providing educators with high-quality resources to facilitate inquiry-based instruction have been developed in other jurisdictions, for example, the European Union, with the *IncluSMe* (Ariza, Quesada, & Abril, 2017), and *Fibonacci* (Maaß & Artigue, 2013) projects (to name only two). Although the precise meaning of the term inquiry may vary considerably depending on the context and who is defining it, such approaches have an underlying similarity in that they treat mathematics as a process to experience, rather than a product or end-point (Thornton, 2017). Artigue and Blomhøj (2013) reviewed several interpretations and definitions of inquiry-based mathematics education and put forward a synthesis of the types of student activities likely to be relevant to this pedagogical approach. This list included: “elaborating questions; problem solving; modelling and mathematizing; searching for resources and ideas; exploring; analysing documents and data; experimenting; conjecturing; testing, explaining, reasoning, arguing and proving; defining and structuring; connecting, representing and communicating” (p. 808).

Banchi and Bell (2008) identify four levels of inquiry based learning that can be located on a continuum describing the extent to which students are responsible for directing the inquiry process: confirmation inquiry (least student-directed), structured inquiry, guided inquiry and open inquiry (most student-directed). Structured inquiry, for example, can be viewed as partially student-directed. It typically involves the teacher providing the topic, catalyst questions, and scaffolding the approach students are expected to take. Students are responsible for analyzing and interpreting the data collected, and collating and synthesizing their findings.

A comprehensive meta-analysis into assisted discovery-based learning, incorporating structured inquiry, found that this pedagogical approach had more positive impacts on student learning outcomes when compared with explicit instruction and unassisted discovery-based learning – including within mathematics education (Alfieri, Brooks, & Aldrich, 2011). Moreover, inquiry-based learning more generally has been linked to a range of affective student outcomes, including positive attitudes towards academic subjects, self-efficacy, and intrinsic motivation (Saunders-Stewart, Gyles, & Shore, 2012). One aspect of inquiry-based learning in mathematics that appears to be linked to positive affective outcomes is the notion of allowing students to choose topics of interest. This aspect has been shown to be particularly effective for engaging previously disengaged students in the inquiry process (Calder, 2013).

Carmenzuli and Buhagiar (2014) describe a project involving teaching mathematics through an inquiry-based approach to a group of thirteen students identified as having social, emotional and behavioural difficulties. Drawing on a range of qualitative data sources, including interviews with students and student reflective journals, the authors found that both the novelty of this approach and the active learning involved served to both decrease boredom and increase enjoyment of mathematics classes. Exemplary quotes from students included: “When we’re doing experiments I feel more motivated to learn and to search for the solution.” and “We never had the opportunity to learn in this way. Usually the same four students work everything out. Here everyone has the opportunity. This motivates me.” (p. 76). The program of learning described by Carmenzuli and Buhagiar is notable also because many of the activities outlined seem to fit within the paradigm of a structured inquiry approach, as opposed to more radical open-inquiry where the teacher is far less directive in establishing the learning agenda. The program outlined in the current study, TILI, is an example of a structured inquiry approach. Specifically, teachers determined the mathematical content to be learnt, an authentic context to support this learning, and provided structured investigations for students to explore.

Teacher Enjoyment of Teaching Mathematics and Student Learning Outcomes

Beyond adopting a structured-inquiry approach, the key idea behind TILI is to harness teacher passion for an authentic topic of interest (e.g. dance), described by Kunter, Frenzel, Nagy, Baumert, and Pekrun (2011) as “topic-related affective orientation” (p. 290). Research into the potential value of teaching mathematics thematically is not new (e.g., Handal & Bobis, 2004), and tends to echo the claims made by advocates of inquiry-based learning approaches. For example, it has been asserted that teaching mathematics thematically

can make mathematical learning more purposeful for students, embed the learning in experience, and help connect the known to the unknown (Handal, Bobis, & Grimison, 2001; Seely, 1995). A similar rationale is inherent in several of the principles underpinning the Realistic Mathematics Education (RME) movement out of the Netherlands. According to Van den Heuvel-Panhuizen and Drijvers (2014), the primary thrust of RME is that realistic situations can support “the development of mathematical concepts, tools, and procedures” whilst also serving to provide students with a meaningful context to which they can subsequently apply their burgeoning mathematical knowledge (p. 521).

Despite this prior research outlining the potential power of teaching mathematics through meaningful contexts, and evidence in support of inquiry-based learning approaches more generally, we could not identify any prior research specifically examining the benefits of building thematic units around topics of teacher interest and passion. We argue that the development and delivery of mathematical learning experiences around an area of interest can be expected to promote positive emotional responses for the teacher, in particular, high levels of enjoyment. Research indicates that teacher enjoyment can enhance the student learning experience, motivate teachers to improve instruction, and reduce teacher burnout (Frenzel et al., 2016). Moreover, teachers who are more enthusiastic about teaching mathematics have been shown to demonstrate higher quality instructional practice (Kunter et al., 2008).

With regards to its impact on students, teacher enjoyment of teaching mathematics has been demonstrated to be related to student enjoyment of learning mathematics, with this relationship mediated by the level of enthusiasm displayed by the teacher (Frenzel, Goetz, Ludtke, Pekrun, & Sutton, 2009). In order to explore the reciprocal relationship between teacher and student enjoyment, Frenzel et al. (2018) followed 69 middle and high school teachers and their students across several disciplines, including mathematics, for a six month period. It was revealed that teacher enjoyment at the beginning of the school year was positively associated with student perceptions of teachers’ enthusiasm for teaching, as well as student enjoyment, halfway through the school year.

This body of research might imply that teaching mathematics through a context or activity that a teacher is passionate about could impact student enjoyment of learning mathematics. The suggestion is that allowing teachers to connect the content of their lessons to an area of passion is likely to lead to teachers both enjoying these lessons, and presenting these lessons enthusiastically. Given the conceptual overlap between enjoyment and intrinsic motivation (Amabile, Hill, Hennessey, & Tighe, 1994), it can be postulated that experiencing mathematics taught in this manner might result in higher levels of intrinsic motivation to learn mathematics amongst students. Intrinsic motivation to learn mathematics is an important goal in and of itself, and has also been shown to be positively associated with mathematical performance (Güvendir, 2016; Thomson, De Bortoli, & Buckley, 2014).

In the spirit of a designed-based research approach, this research literature can be synthesized with the professional knowledge and context of the researchers to develop a local instruction theory (Gravemeijer & Cobb, 2006). Local instruction theories are particularly appropriate when researchers are concerned with “creating innovative learning ecologies” and examining the learning supported through fostering such ecologies (Gravemeijer & Cobb, 2006, p. 73). Local instruction theories articulate a theory of change to capture both the learning process and the factors involved in supporting this process. Our own preliminary theory for the TILI project is summarized in **Figure 1**. To reiterate, the key claim is that developing and delivering TILI units will unlock teacher autonomy, interest and passion, in turn leading to teachers experiencing higher levels of enjoyment when teaching mathematics. These higher levels of teacher enjoyment will consequently generate higher levels of student enjoyment, leading to increased intrinsic motivation to learn mathematics and superior student performance.

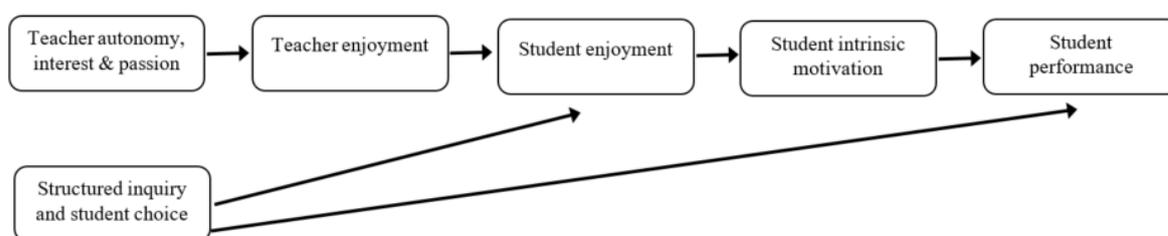


Figure 1. Local instruction theory informing development of the TILI program

It is worth noting a couple of additional aspects of **Figure 1** in particular. First, we are suggesting that pursuing an inquiry-based approach, including providing students some level of choice about their inquiry topic, will improve both student enjoyment and student performance. Although some of the increase in student performance is likely to be mediated through increased student enjoyment, there are several more cognitive components of inquiry-based pedagogies that can be speculated to lead to superior student performance. For example, the active construction of knowledge leading to opportunities to develop deeper understanding, and opportunities to comprehend connections between concepts, in part leading to the application of knowledge beyond the classroom context (Saunders-Stewart et al., 2012). Secondly, improvements in teacher autonomy, interest and passion in the context of curricula design is likely to have additional positive effects for teachers (and thereby, for learners and schools) beyond improved teacher enjoyment of teaching mathematics. For example, job control, which might include autonomy over instructional content and process, has been shown to be negatively correlated with cynicism and exhaustion, the two core dimensions of burnout (Hakanen, Bakker & Schaufeli, 2006). Such additional effects have not been factored into our local instruction theory, in part because mathematics instruction forms only a small aspect of a generalist primary teacher's instructional responsibilities (perhaps 20%-25% of time allocated to instruction). Speculating that participating in TILI might reduce teacher burnout, even if TILI became the main means through which teachers taught mathematics in a primary school, seems like an overreach.

THE CURRENT STUDY

The purpose of the current paper is to explore both the teacher and student experience of participating in TILI. The specific research questions that will be addressed are:

1. How do teachers describe their experience of developing and delivering the TILI program?
2. To what extent did participation in the TILI program improve the study school students' intrinsic motivation to learn mathematics?
3. What factors did study school students identify as being responsible for their positive experience of the TILI program?
4. To what extent is there evidence linking teacher enjoyment of teacher mathematics to student intrinsic motivation to learn mathematics?

METHOD

Participants

Student participants were Year 5 and 6 (10-12y/o) students (n = 88) who attended a medium-size government-run primary school in Victoria, Australia (507 total student enrolments). The school's Index of Community Socio-Educational Advantage (ICSEA) was 1154, with 69% of students' families distributed in the top quartile of the Australian population on this measure. This means that the school is relatively socio-economically advantaged in terms of the parent communities' occupation and education levels.

Teacher participants were the classroom teachers of these students (n = 5). Note that all classes were composite classes, which included both Year 5 and Year 6 students.

Measures

Intrinsic motivation can be defined as the "desire to engage in behaviours for no reason other than sheer enjoyment, challenge, pleasure, or interest" (Lepper, Corpus, & Iyengar, 2005, p. 184). Intrinsic motivation to learn mathematics was operationalized through incorporating the measure included in the Programme for International Student Assessment (PISA) 2012 study (Thomson et al., 2014). Items were measured on 4-point Likert scales, as per the PISA study. Students were asked, "Thinking about your views on maths: to what extent do you agree with the following statements: Strongly Agree (4), Agree (3), Disagree (2), Strongly Disagree (1)?" Items included: *I enjoy reading about maths*; *I look forward to my maths lessons*; *I do maths because I enjoy it*; and *I am interested in the things I learn in maths*. Scores on this instrument range from 4 to 16. Cronbach Alpha on the two administrations was acceptable-to-good ($\alpha=0.76$ and 0.84).

Procedure

The first stage in the development of the TILI program was for the five participating teachers to independently consider areas of personal interest or passion from which they might develop a unit of mathematical learning. Teachers brought their ideas together at a planning day. Led by one of the participating teachers (the second author), they workshopped their ideas and began to connect teaching and learning activities to their chosen themes (within the context of the curriculum). Although there was flexibility and discretion in terms of the exact curriculum content covered to support authentic connections between mathematics and the inquiry topic, all teachers gave some consideration to how they may use their topic to explore percentages, ratios and decimals (identified as an area of student need). Following this planning day, teachers then worked independently to finalize a unit of work around their chosen theme. Themes included: basketball, dance, robotics, space and zoos.

Participating students were then invited to complete a pre-TILI questionnaire. In addition to the intrinsic motivation to learn mathematics measure, this questionnaire described each unit and gave students an opportunity to elect their preferred unit from the options provided by the teachers (86% of students participated in their first choice, 14% their second choice). The primary purpose of presenting TILI units as student electives pooled across five classes was to free-up teachers to choose their theme of interest independently of what they anticipated to be acceptable to students in their own classrooms. For example, a teacher may have been reluctant to choose dance as a topic if they anticipated strong negative reactions from a group of students in their classroom.

Students participated in their TILI group over a five week period: three one-hour sessions per week for a total of 15 sessions. At the completion of the unit, students completed a post-TILI program questionnaire, which revisited their intrinsic motivation to learn mathematics, framed in the context of their learning during the TILI group. The questionnaire also contained some qualitative items. All Year 5/6 students participated in TILI (n=115), with only 88 students completing both the pre and post questionnaires due to a range of practical, school-related issues (e.g., student absenteeism, extra-curricular commitments).

At the conclusion of TILI, the five teacher-participants were interviewed by the first author of this paper. Teachers were informed about the purpose of the interview, including potential publication of research findings, and all consented to share their experiences with TILI. Interviews were semi-structured, and focused on the teacher experience of developing and delivering a unit of mathematical work based around a particular topic of personal interest.

Data was analyzed using a mixed methods approach. Quantitative data was analyzed using SPSS Statistics (v25). Qualitative student questionnaire data, and teacher interview data, was analyzed thematically. The thematic analysis of data approximated the process outlined by Braun and Clarke (2006). Specifically, working collaboratively, both authors worked iteratively through the following six steps: 1) familiarisation with the data, 2) generating initial codes, 3) searching for themes, 4) reviewing themes, 5) defining and naming themes, and, finally, 6) producing the report.

Example of a TILI Unit: Mathematics through Basketball

In order to illustrate the types of mathematical inquiries taking place in classrooms, a brief outline of one of the TILI units is provided. This particular unit was developed around a teacher's passion for basketball, and can be considered to appropriately encapsulate the spirit of the TILI initiative. The teacher began by sharing their passion for basketball with the students and then exploring the students' personal connection with the sport. The 'Mathematics through Basketball' unit consisted of a series of structured-inquiries that used basketball as the context to explore mathematical concepts. **Table 1** outlines the key mathematical inquiry questions that were explored in the unit, a brief description of the related investigation and the related mathematical ideas. The unit covered a range of integrated concepts, with a focus on exploring percentages, decimals and fractions and data representation.

Table 1. Examples of a TILI Unit: Mathematics through Basketball

Inquiry question / focus	Description	Key mathematical ideas
What are different ways to make basketball scores?	Students explored basketball scoring records and the different ways these may have been achieved (i.e. combination of 1, 2 and 3 point shots).	Problem solving; part whole-reasoning; additive and multiplicative thinking.
Can you score faster than All-Star NBA players?	Students explored the scoring rate during the highest scoring NBA All Star game and then investigated whether they could score at an equivalent rate.	Ratios and proportions; percentages, fractions and decimals.
Is the 'granny style' free throw technique more effective than regular free throws?	Students were introduced to 'granny style' free throw technique used by several professional basketballers and investigated the effectiveness of different techniques.	Percentages, fractions and decimals; data collection and representation; experimental probability; estimation
How close are you to dunking?	Students investigated their height, reach and vertical leap, compared with professional basketballers.	Measurement, estimation, ratios
Can you design a basketball tournament?	Students explored the design of a tournament timetable, within particular parameters (related to time, team size and fixtures).	Timetables; problem solving.
How do we interpret a basketball 'box score'?	Students explored 'box scores', with a focus on shots, shooting percentages and total points; they then collected and interpreted their own data set from video footage and their own basketball games.	Percentages, fractions and decimals; applying mathematical operations; data collection and representation.
How do we decide who the most efficient shooters are?	Students explored different ways of solving for effective field goal percentage and compared the effectiveness of shooters.	Percentages, fractions and decimals; multiplication of fractions.

Table 2. Teacher Interest-Led Inquiry Units and Teacher Characteristics

Teacher pseudonym	Inquiry Unit	Years teaching experience	Additional information about teacher
Kim	Basketball	8	The Numeracy Leader at the school, who has previous experience working in international schools.
Helen	Robotics	4	A teacher with expertise in ICT, who has previous experience working in computer science. She has been working at the school for two years. She is interested in fostering ICT as a vehicle for problem solving based learning.
Antonella	Dance	3	A mature-age graduate teacher working at her first school, with previous professional experience in Public Relations. She has a strong interest in communication and literacy.
Erica	Zoos	17	An experienced teacher in her first year at the school, who has particular expertise in literacy. She has worked in various school contexts, mainly in low socio economic schools with high English as an Additional Language (EAL) populations.
Ella	Space	18	An experienced teacher who is the team-leader and leads the school's inquiry team, in her second year at the school. She has worked in a range of schools with varied student profiles, including working as a Science specialist.

RESULTS

Teachers Experience of Developing and Delivering the TILI Program

As part of the TILI project, five teachers developed mathematics inquiry units around areas of personal interest (see **Table 2**). Following implementation of the program, these five teachers were interviewed by the first author. Thematic analysis of the interview data revealed four themes that warrant discussion:

1. Teacher passion for their topic area varied.
2. Student interest in the topic remained a consideration for all teachers.
3. Most teachers perceived the inquiry units effectively engaged students in mathematics and led to meaningful mathematical work.
4. Teachers generally enjoyed teaching the inquiry units.

Each of these themes is elaborated on in turn, with illustrative quotes from teachers to substantiate each theme provided.

Teacher passion for their topic area varied

Despite the thrust of the TILI initiative being for participating teachers to develop a unit of mathematical work around a topic in which they were highly passionate, the actual level of teacher passion for their chosen topic varied somewhat. Three teachers were identified as being highly passionate about their area of focus, while the remaining two teachers were deemed to be less passionate about (but still interested in) their topic.

For example, one of the teachers (Antonella) identified as highly passionate explained her choice: “Because it (dance) is a passion of mine that I’ve had since I was a child. And it is still very much relevant to my life as an adult... It was a bit of a no-brainer for me.” Another highly passionate teacher, Kim, chose basketball as a focus: “I’m personally very interested in basketball, it’s something I’ve been interested in for a long time. I was interested in making the connection between something I enjoy like basketball, and my teaching in maths, which I also enjoy.” Helen, the third teacher highly passionate about her topic, used robotics as a context for mathematical learning: “I like playing The Sims so I was debating something around that. My background is actually in computer science and games development. It’s something I really enjoy... I really enjoy coding.”

In contrast, Erica, the teacher who chose zoos, showed a level of interest in the topic, “I like animals”, but had a greater focus on student engagement and the practical value of the learning: “All the kids are animal crazy (and) I know it is a job people can do”. Similarly, Ella, who chose space, recognized that her true passion was travel, but made this choice for practical reasons. Specifically, Ella considered the prior learning experiences of students earlier in the year, and was again cognizant of the need to choose a topic that would be perceived as appealing: “If I was just being selfish and chose out of my own interest I’d have done travel but I knew these kids had already done a lot of investigation centered around travel so I opted not to do that”. When describing the notion of an inquiry unit around space, this teacher noted: “Kids are generally excited about it when you look into it”. However, she also recognized that it was not an area of particular personal interest: “No, I didn’t have a burning passion for it (space). But not to say that I don’t find it interesting”.

Student interest in the topic remained a consideration for all teachers

It is apparent from the teacher responses noted above that at least two of the teachers, Erica and Ella, appeared to prioritize the interests of students above their own. However, interviews with all teachers revealed that they chose their topics, and developed units of work, with particular students, or types of students, in mind. For example, Antonella chose her topic partly to target girls that she believed were disengaged in mathematics and who she knew already shared an interest with her in dance: “(They) probably don’t love maths. So, if you’re able to hook them into something – like a lot of the girls in my class do dancing and are interested in music”.

Similarly Helen chose robotics over her other area of passion, horses, partly because she perceived that a technologically-oriented topic had more potential to engage students. Helen stated that: “I think (robotics) is a really good way to engage particularly the kids we’ve got because gaming is such a huge thing for them”. However, when contemplating horses, she concluded: “I couldn’t work out a way to do it that was also going to be engaging for the kids... I don’t think (horses) would have been as useful for them somehow. It would have been great for me”.

Kim was highly passionate about basketball, and his own interest appeared to be the primary reason why he chose to develop his inquiry unit around this particular topic. However, in a similar manner to the other teachers, anticipated student interest remained an additional explicit consideration: “I also know that there’s a lot of children in my class who are really into basketball... I chose it (basketball) because of my level of engagement, but I also knew that was complementary to their interests as well”. Kim went on to state that: “I’ve always been interested in sports science and sports statistics... I thought it was something I could explore in a learning context that the kids would enjoy, and that I would enjoy”.

Most teachers perceived the inquiry units effectively engaged students in mathematics and led to meaningful mathematical work

Helen, Erica, Antonella and Kim all discussed how most students remained highly engaged throughout the inquiry units, which helped to support a productive learning environment. Ella was more circumspect about the overall level of engagement in her inquiry, largely because behavior management issues impacted her choice of inquiry activities and the overall running of the unit. These overall findings are consistent with previous research that suggests that inquiry-based learning experiences tend to effectively engage students in mathematics learning (Carmenzuli & Buhagiar, 2014).

Antonella noted that some students who were normally somewhat anxious about mathematics were more comfortable within the context of her inquiry unit: "There was a lot more enjoyment, and I think they were a bit more relaxed". Antonella perceived that this greater comfort, combined with the opportunity to engage in more 'hands-on' learning, supported some students who were typically lower performing to experience greater success with their mathematics. She recalled an anecdote about one particular student who seemed to 'get' angles for the first time whilst engaging in the dance inquiry:

There's one particular student who's very low. And watching her be able to tell me like what a right angle is, and tell me why it's 90 degrees, was so exciting... She got to see success in a lesson where she probably wouldn't usually put her hand up... I think because I did a lot of literally like moving your body, getting outside, dancing. It kind of takes that away from, yes, they're still definitely doing maths, and I'm explaining to them why it is maths. But it's not just saying, okay, well, draw all these triangles and work out the measurement.

Kim emphasized how participating in the basketball unit seemed to transform how a number of students viewed mathematics instruction:

I felt like the kids came to each session really positive... entering a math room in upper primary often you get a sense of negativity that you can feel in the room amongst a number of the children, and there's outward moans and groans amongst a number of them. I had kids throughout the day saying, "I can't wait until maths starts," "I can't wait until it happens," so there was a real positive energy in the classroom at the beginning of the lessons, which is a really good way to start things.

In a similar manner to Antonella, Kim also noted that the fact that the learning was occurring in a more meaningful context enabled students to attend to, and make sense of, concepts that might have previously been highly abstract and perceived as irrelevant:

I think what went well was that I tried to have a combination of practical interactive stuff that the kids were doing outside on the basketball court, as well as things that we were doing inside. We'd introduce the investigation, go outside and do part of the investigation, record the data and come back in and analyze it and discuss it.

However, he noted that, for some students, translating a practical engagement with a particular mathematical idea into tangible written work remained challenging:

Having some children who were very engaged in the interactive activities, and engaged in some of the mathematical ideas - in terms of their capacity to express interest in the mathematical ideas and discuss them - but, it didn't always translate to the (written) work they were doing. (This was) somewhat unsurprising, but it is an ongoing challenge that we have with a number of these kids when they're learning maths.

Similarly, Erica noted that during the teaching of her zoo unit her students were highly engaged throughout, although this was partly a consequence of the particular students who nominated to participate:

I had a really great group of kids. I had all the animal lovers and a lot of them were incredibly keen to do it. At that level, I was very lucky. They're here to do their work. They want to do it and they're learning from it hopefully.

By contrast, Ella noted that although some students were engaged, significant behavior management issues amongst a small group of students impacted her capacity to facilitate the unit as envisioned: "Because of the dynamics of the group we couldn't follow through on some of those (more engaging) things". Ella in part attributed these difficulties to these particular students not wanting to participate in this inquiry, despite it being their first preference: "They didn't want to be in this group... It was their first preference. They're claiming it wasn't."

Despite this, as discussed by other teacher-participants, Ella also noted that the hands-on nature of the learning experiences helped students persist with tasks they found difficult. In fact, it was when reflecting on what some of her students gained through the inquiry experience that Ella became most positive and animated about the unit:

The hands-on stuff was probably their favorite part of it. And it was really lovely to just see them excited about what they were doing. There were some kids that earlier in the year would have given up on some of the challenging tasks but there were a few of them that really persisted through those. So, that was lovely to see.

Interestingly, Helen concurred that having a small group of students in a group who did not perceive that they were given their first preference could impact engagement. She notes:

I'd say most of them were highly engaged with it and enjoyed it. There were a couple who were not very keen, basically because they got their second preference and they wanted their first preference, and they just weren't going to move past that – the fact that they weren't in the group that they wanted to be in... I think for some of them, not getting what they wanted was a big challenge.

However, Helen was also very positive about the power of participating in inquiry to allow students to struggle with important mathematical work. She suggested that the opportunity to engage in what was perceived as purposeful learning helped to build student persistence: “The couple that did start giving up, I soon worked out that if I ignored them for 15 minutes, they'd then actually get back into it. They brought themselves back whereas normally they'd just continue to go “yeah, no”.”

Finally, it is worth noting that, in contrast to the experience of Ella (and to a lesser extent, Helen), Kim noted that behavior management was less of an issue during the TILI unit due to the high level of engagement of students than would typically be the case with this cohort. He attributed this both directly to student interest in the topic of basketball, as well as the fact that basketball provided a meaningful and authentic context through which he could build relationships with students, due to their shared passion for the sport:

I think the students seemed to have a really positive experience, and also seemed to connect somewhat to my relationship building with a number of the kids. Because obviously basketball is an area of real interest at the moment for the kids, and it spilled over to kids watching basketball in some of the recesses with me, or talking about it, then talking about some of the stats with me. So, there seemed to be this impact on the relationship development, which was a positive thing as well. Knowing the kids that were involved, behavior management was less of an issue with these kids than I've experienced with them in other contexts. So, to me, overall I actually thought the behavior of the kids - a number of whom are normally pretty challenging - was actually really positive. Because they saw this as a more positive learning experience.

Teachers generally enjoyed teaching the inquiry units

Overall, teachers were positive about the experience of teaching their inquiry units. This finding is important given that teachers' enjoying teaching their inquiry units is a central working assumption of the local instruction theory underpinning TILI (see **Figure 1**). However, again, this enjoyment of the teaching experience was inextricably tied up with the student learning experience, and the level of engagement and enthusiasm demonstrated by students. This notion that student and teacher affective experiences are interlinked and reciprocal, at least from the teacher perspective, is not surprising given previous research connecting teacher and student enjoyment of teaching and learning mathematics (Frenzel et al., 2009, 2018).

Antonella discussed how she enjoyed teaching her unit because it connected to her interests outside of school: “I looked forward to it, again because it was my interests and passions about what I am as a person out there.” For Erica, it was the opportunity to work together as a team to develop the approach that was a particular highlight: “That was really inspiring. I really liked it from the collaborative aspect of it, when we were planning it together, sort of having to think about what your passion was”. Interestingly, both Antonella and Erica noted that they felt they could have benefited from some additional ongoing professional support when implementing their unit, potentially through making it a professional learning team (PLT) focus. Erica stated:

For me who doesn't see everything numerically, I had to think, what is really possible for my skillset and my abilities? I felt that this could have worked better as a PLT whereby one of our meeting times or one of our planning times was talking about the maths, talking about, “I'm having trouble. I don't know where to go from here.”

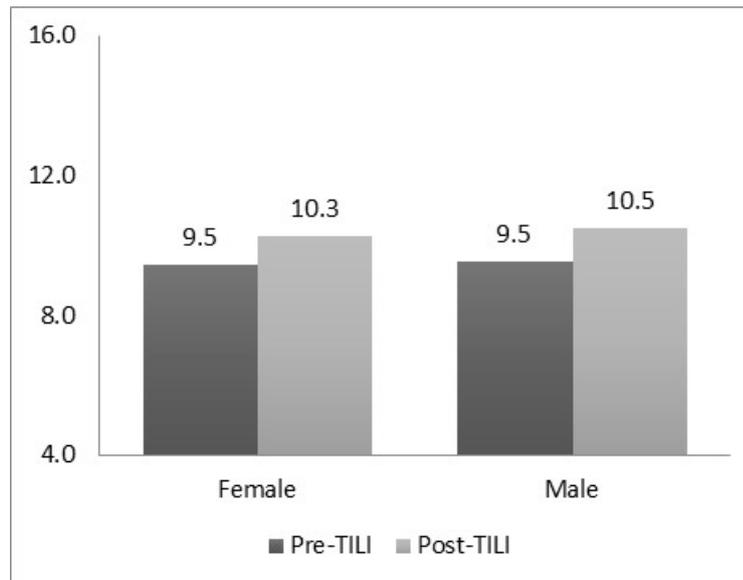


Figure 2. Pre and Post TILI Program intrinsic motivation to learn mathematics by gender

As discussed earlier, Helen noted that the purposeful learning context for students led to greater levels of persistence, which in turn helped her frame her experience of teaching the unit as positive:

I really enjoyed it. It was really good. (Students) coped a lot better when they were struggling with something because there was a bit of intrinsic motivation because they wanted to get those skittles knocked over or whatever it was...

Kim noted that he found it more enjoyable than a typical mathematics class, largely because he did not have to concern himself with student engagement.

I found it more enjoyable than teaching maths ordinarily... The biggest impact on my enjoyment, reflecting on it, was the level of engagement with the kids. It allowed me to truly enjoy the mathematical teaching experience without my kind of concerns around how I can engage the kids, which is often the most challenging thing for me to do as a mathematics teacher.

Finally, although as previous noted, Ella was somewhat ambivalent overall about her specific experience teaching her inquiry unit due to a small group of highly challenging students, she remains supportive of the principles underpinning TILI:

"I do think that if kids see you're passionate about something, that they're going to grab onto the coat tails of what you're selling and come along for the ride. I do think that when anything you do is connected to the real-world, they'll buy into it more."

Overall Impact of TILI on Intrinsic Motivation to Learn Mathematics

In addition to the teacher interview data, pre- and post- program questionnaires were administered to student participants. The remainder of the results section considers the analysis of this questionnaire data. Our first consideration is whether participating in TILI impacted student intrinsic motivation to learn mathematics.

A mixed-design analysis of variance was undertaken, with intrinsic motivation to learn mathematics before and after the TILI program included as the within-subjects factor, and gender included as a between-subject factor. There was a significant difference between pre-TILI ($M=9.50$, $SD=2.66$) and post-TILI ($M=10.39$, $SD=2.43$) student levels of intrinsic motivation to learn mathematics; $F(1, 86) = 11.01$, $p < 0.01$. The effect size for this analysis was medium (partial $\eta^2 = 0.113$). Gender was not associated with changes in intrinsic motivation $F(1, 86) = 0.056$, $p > 0.05$. Participating in TILI positively impacted student intrinsic motivation to learn mathematics equally for males and females (see **Figure 2**).

Table 3. Pre and Post TILI Program intrinsic motivation to learn mathematics by item

	I look forward to my maths lessons	I do maths because I enjoy it	I am interested in the things I learn in maths	I enjoy reading about maths
Pre-TILI				
Strongly agree	10%	11%	10%	3%
Agree	40%	27%	50%	19%
Disagree	40%	44%	32%	56%
Strongly disagree	10%	17%	8%	22%
Post TILI				
Strongly agree	16%	14%	17%	6%
Agree	56%	39%	56%	27%
Disagree	26%	38%	23%	41%
Strongly disagree	2%	10%	5%	26%

A breakdown of student responses to individual items from the intrinsic motivation to learn mathematics scale indicates a positive impact on student attitudes across all items (see **Table 3**). The greatest impact of the TILI program was on whether students look forward to maths lessons; with 72% of post-TILI students providing a positive response to this question (agreed or strongly agreed), up from 50% of the pre-TILI group. Notably only 2 respondents post-TILI 'strongly disagreed' with this question, down from 9 pre-TILI. Framed another way, prior to participating in the TILI program, approximately half of students did not look forward to their mathematics classes. This had fallen to approximately one-quarter of students after the program was completed.

Part of the motivation for developing the TILI program were teacher perceptions of negative student attitudes towards mathematics, with teachers extrapolating from Attitudes to School Survey data as well as anecdotal evidence (e.g., groans and negative comments from students at the beginning of mathematics lessons). Indeed, levels of intrinsic motivation to learn mathematics were similar for the upper primary participants from the current study to that of middle-secondary students in Australia participating in the PISA study. For example, 45% of 15 year old Australian students (Year 9, 10 & 11) agreed or strongly agreed with the statement "I look forward to my mathematics lessons" (Thomson et al., 2014), compared with 50% of students in the current study pre-TILI. By contrast, the equivalent percentage for Year 1 and 2 students from a Victorian school in the Russo (2017) study was 92%. Consequently, it seems that, at least prior to TILI, the current cohort of students held attitudes towards mathematics more similar to students in middle-upper secondary school than early primary school. It is worth noting that this decline in intrinsic motivation to learn mathematics as students progress in their schooling is consistent with prior research (Lepper et al., 2005).

TILI Compared to Other Learning Approaches

In addition to the TILI program, this student cohort had exposure to varied approaches to mathematical learning. The approaches can be broadly described as:

- Fluid groupings, with students organised by readiness-to-learn levels across different number concepts (three hours per week, except during the TILI program).
- TILI Program, which ran for five weeks for approximately three hours per week (replacing fluid groupings in the timetable).
- In class mathematics learning, with students exploring applied mathematical concepts in mixed groups in their own classrooms (two hours per week throughout the year; continued throughout the TILI program).

Following the TILI program, student participants were asked which approach they enjoyed the most as well as which was most effective for their learning. Two thirds of students indicated that they enjoyed the TILI program more than other learning approaches, while almost half (48%) found the TILI program to be most effective for their learning (see **Figure 3**). These findings are particularly notable given there is compelling evidence in the literature that students are able to distinguish between mathematical activities they enjoy, and those activities that most effectively support their learning (Sullivan, Clarke & Clarke, 2012). The fact that TILI was nominated by students as the most enjoyable and the most effective approach suggested that most students endorsed TILI as an approach to mathematics instruction.

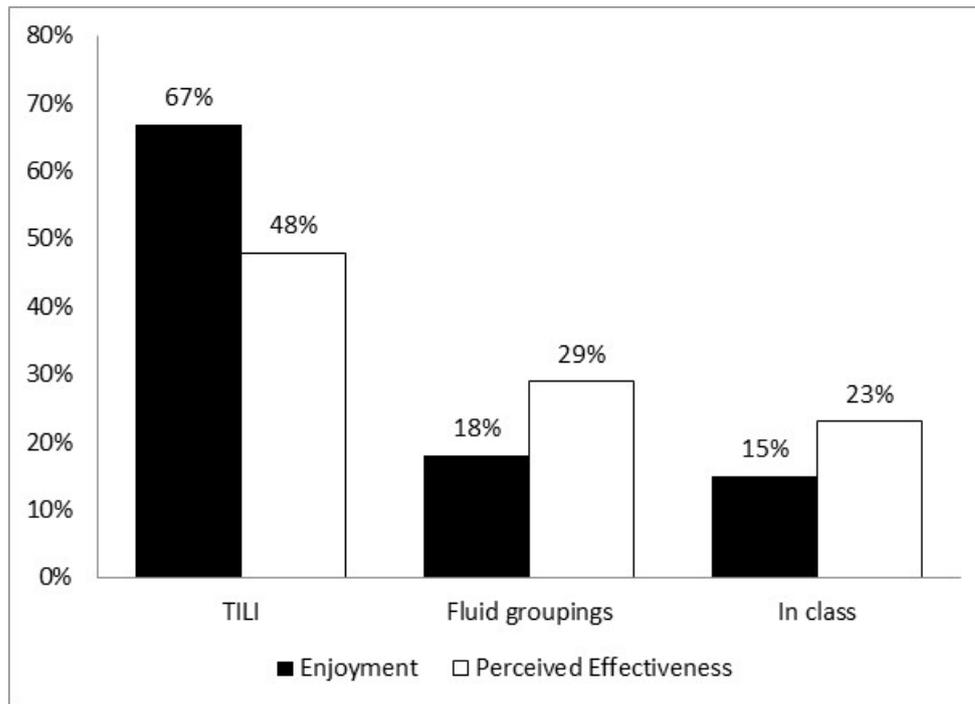


Figure 3. Enjoyment and perceived effectiveness of different learning approaches

Table 4. Summary of the analysis of student responses describing why they enjoyed TILI

Theme	Number of respondents	Percentage of respondents
Learning Context	57	69%
Connecting Mathematics	19	23%
Choice	10	12%
Social	8	10%
Novelty	6	7%
Skills/Knowledge Development	6	7%
Generic Positive	3	4%

Student Reflections on the TILI Program

As part of the post-program questionnaire students were asked what they most enjoyed about their TILI maths unit and why. Six distinct themes emerged from a thematic analysis of student response data: learning context, connecting mathematics, choice, social, novelty, and skill/ knowledge development. **Table 4** collates the number of student responses categorised to each of these themes. The three most frequently occurring themes are elaborated on below, with exemplary student quotes provided.

In response to this question, most students (69%) explicitly mentioned the context in which the learning took place and/or specific learning activities undertaken within the unit of work. For example, one student (Student 1) enjoyed “designing the (zoo) enclosure and finding out how big it had to be and making it unique” while another (S2) enjoyed “making dance routines with different angles”. It is worth noting that responses coded to this category were often brief and highly concrete, for example, “I got to use robots” (S3), or “Playing basketball” (S4).

Approximately one-quarter of students (23%) explained their enjoyment by emphasising the value in connecting mathematical learning to their personal interests. Students highlighted the impact of these connections on both their level of engagement and learning. For example “I enjoyed doing a subject while doing another subject, it made it more fun and (led to) more understanding” (S5) and “You got to have fun and learn about maths and your interest at the same time” (S6). On occasion, students discussed connecting mathematics in the context of making mathematical learning more authentic: “It was more fun because we got to have a chance to use the maths we learn in a real life activity” (S7) and “I liked doing maths problems based on real data and my own interests” (S8). Such comments are consistent with literature emphasising the importance of providing students with meaningful contexts to support their mathematics learning (Handal et

al., 2001; Van den Heuval-Panhuizen & Drijvers, 2014). For other students, negative attitudes towards mathematics were counterbalanced by positive attitudes towards the learning context: “You could have fun doing maths because it was hidden by your passion” (S9), and “I love dance, so incorporating (it) into something I don’t exactly like makes maths fun” (S10). Again, this resonates with previous research demonstrating the power of inquiry-based learning approaches to engage students who might otherwise be typically disengaged during mathematics class (Carmenzuli & Buhagiar, 2014).

As mentioned earlier, students were given an opportunity to choose which TILI group they would like to participate in. This aspect of choice was explicitly mentioned by 12% of students as a factor relating to their enjoyment. An indicative comment by a student was that they enjoyed “the freedom to choose a topic you wanted to learn about” (S11). Another stated “I enjoyed the choice involved because normally you do what you’re told” (S12). This finding is also consistent with literature supporting the power of providing meaningful choice as a pathway for engaging students in mathematics (Calder, 2013).

Teacher Content Passion and Student Intrinsic Motivation

As noted previous, three of the five TILI teacher-participants were identified as being highly passionate about their chosen topic, whilst the other two teachers were interested but not passionate. One of the aspects we were interested in attending to further was whether the level of teacher passion for the topic area impacted on the student learning experience. To address this question, we undertook an additional Mixed Design ANOVA, with student intrinsic motivation to learn mathematics the within-subjects factor, and whether their teacher can be classified as higher passion or lower passion as the between-subject factor. The analysis revealed that being taught by one of the three teachers highly passionate about the unit topic did not significantly impact changes in intrinsic motivation to learn mathematics [$F(1, 86) = 1.545, p > 0.05$]; however the finding was in the hypothesised direction and the issue perhaps warrants further scrutiny.

Figure 4 presents the data for the individual intrinsic motivation to learn mathematics items, displaying the percentage of students who held a positive view of the respective statements (agreed, strongly agreed) pre- and post- TILI cross-tabulated according to whether their teacher was highly passionate, or less passionate, about the topic. Despite the non-significant overall results, it appears that being taught by a teacher highly passionate about the topic resulted in students being more inclined to look forward to their mathematics lessons (pre = 50%, post = 76%) compared with being taught by a teacher less passionate about the topic (pre = 50%, post = 65%). Similar results were noted for the items relating to enjoyment of mathematics (higher passion, pre = 31%, post = 54%; lower passion, versus pre = 50%, post = 50%), and interest in mathematics (higher passion, pre = 57%, post = 76%; lower passion, versus pre = 65%, post = 68%). Although the small number of TILI electives ($n = 5$) means drawing conclusions about a possible relationship between being taught by a teacher highly passionate about the inquiry topic and more positive student views towards mathematics is beyond the scope of the current study, we suggest that this is a potentially fruitful area for future research.

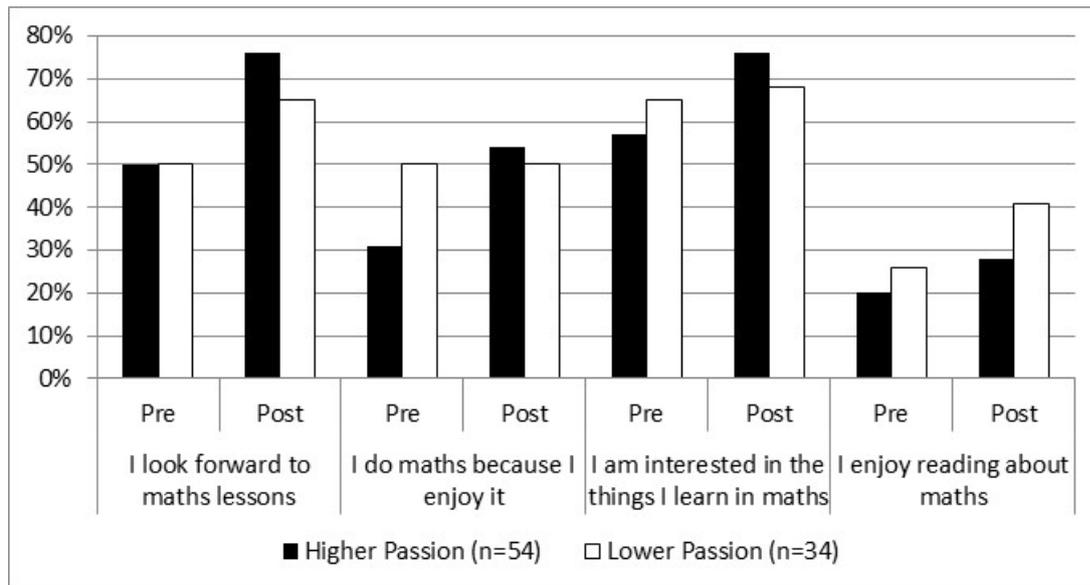


Figure 4. Percentage of students agreeing/ strongly agreeing with intrinsic motivation to learn mathematics items by teacher passion for topic

DISCUSSION AND CONCLUSIONS

The current study examined how participating in an inquiry-based unit of mathematical work developed by a teacher with a strong interest in the context through which the mathematics is being explored impacted the student learning experience. Our local instruction theory assumed that creating and delivering interest-based units of work would allow teachers to experience greater enjoyment when teaching mathematics, by allowing teachers to introduce mathematical content through a topic area in which they were highly passionate.

Our first research question considered the teacher experience of designing and delivering their inquiry units. Despite being given a mandate to develop an inquiry-based unit around an area of personal interest or passion, all five teachers were highly cognizant of how they envisioned students would respond to their chosen topic. In two instances, this resulted in teachers forgoing choosing a topic they were highly passionate about to instead focus on something of personal interest which they anticipated to be more acceptable to students. Moreover, although teachers generally enjoyed teaching their inquiry units, the reasons provided for their enjoyment were framed almost exclusively through the lens of their students responding positively to the learning offer. The positive response of students was in turn attributed by participating teachers to a variety of factors, including the hands-on nature of the learning activities, and the opportunity students had to connect mathematics to a real-world topic often of authentic interest to them. These findings echo the rationale underpinning Realistic Mathematics Education. In particular, they resonate with both the “activity principle” – that mathematics is best learnt by students being highly involved in their lessons – and the “reality principle” – that students learn effectively when engaged in contexts that are meaningful to them and through applying mathematics to solve real problems in such contexts (Van den Heuvel-Panhuizen & Drijvers, 2014, p. 522-523).

One of the implications when reflecting on the interviews with our study teachers is that it might not make sense to conceptualize teacher enjoyment of teaching mathematics independently from the anticipated and actual student learning experience. Teachers enjoy teaching when students are responsive, engaged, and successful with their learning. Consequently, although our local instruction theory suggests that higher levels of teacher enjoyment will lead to higher levels of student enjoyment, it is important to acknowledge that the causal mechanism might also operate in the other direction; that is, heightened student enthusiasm and engagement can drive teacher enjoyment. This finding is consistent with prior research, which suggests an iterative relationship between teacher and student enjoyment (Frenzel et al., 2018).

With regards to the second research question, there was evidence that participating in TILI improved student participants’ intrinsic motivation to learn mathematics. Both male and female students experienced

similar improvements, with a particularly notable increase in the percentage of students who looked forward to their mathematics lessons post-TILI (50% to 72%). In addition, two-thirds of students most enjoyed learning mathematics through the TILI program, when compared with the two other approaches (i.e., fluid groups and in-class mathematics learning). These findings are consistent with prior research suggesting that student enjoyment of learning mathematics is related to teacher enjoyment of teaching mathematics, when this teacher enjoyment manifests as outwardly expressed enthusiasm towards the subject (Frenzel et al., 2009; Frenzel et al., 2018). They are also consistent with evidence that students find inquiry-based learning approaches to mathematics, including structured inquiry, to be a positive, motivating experience (Camenzuli & Buhagiar, 2014).

The third research question examined what in particular students enjoyed about participating in the TILI program. Three notable themes to emerge were: students enjoying the learning context, including specific learning activities; students valuing the opportunity to connect mathematics to an area of personal interest or passion; and the importance of allowing students to choose which TILI unit to participate in.

It is notable that the central themes that emerged explaining why students enjoyed the TILI program reflected our working hypothesis as to why we thought teachers might benefit from involvement in TILI in the first instance. We proposed that providing teachers with the autonomy and freedom to plan a mathematics unit around a topic of interest would enhance their enjoyment of teaching mathematics. Interestingly, rather than noting that they benefited from the teacher displaying more positive emotions, students perceived that participating in TILI directly conferred these benefits to them. This may reflect the fact that there was overlap in teacher and student interest in particular topics (e.g., basketball, dance, robotics). It is likely also a consequence of student choice and inquiry-based learning being additional mechanisms explicitly built into the TILI program, both of which have been associated with improved student intrinsic motivation (Patall, Cooper, & Robinson, 2008; Saunders-Stewart et al., 2012). This is not to say that students did not perceive that they benefitted from having a teacher who was teaching mathematics with greater enthusiasm and passion, as we did not probe this issue directly in the post-TILI questionnaire.

Indeed, turning our attention to our fourth and final research question, the level of teacher passion did not appear to significantly impact overall student intrinsic motivation to learn mathematics. However, when the individual items of the Intrinsic Motivation to Learn Mathematics questionnaire were considered, there was perhaps some preliminary evidence that being taught by a teacher particularly passionate about the content resulted in students holding more positive attitudes towards their mathematics class, and being more interested in mathematics. Future research should consider undertaking TILI with a larger group of teachers, which would allow more systematic and in-depth consideration of how the level of passion the teacher held towards the inquiry topic impacts the student learning experience.

To further tease out other possible mechanisms for TILI's positive impact, future research might also consider two additional aspects. First, it could examine the importance of shared interest in the topic between teacher and students through systematically accounting for how interested students were in the teacher's chosen topic. Secondly, it could account for the role of student choice in the model through examining whether, for example, doing TILI with your classroom teacher generated smaller gains in intrinsic motivation to learn mathematics than choosing a preferred TILI unit from a suite of alternatives.

Finally, we will conclude this paper with an anecdote that further supports the potential of this type of approach to learning mathematics. A Year 6 student was interviewed by their prospective secondary school principal as part of a transition program and relayed his response to the question: "What would you want your learning to look like in Year 7?". The student's response: "I wish we could learn maths like we did in the basketball unit. The teacher made this so fun and interesting; and we learnt a lot!"

Disclosure statement

No potential conflict of interest was reported by the authors.

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