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Factors that influence student engagement with technology-enhanced resources for formative assessments in first-year undergraduate mathematics

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Even prior to COVID-19, there had been an increase in the use of technology in undergraduate mathematics education to support the development of mathematical understanding and skill, and to enhance the student learning environment. Technology-enhanced resources can be used to provide formative assessment which can help students identify gaps in their knowledge and point towards appropriate action. In this paper, we report on the evaluations of a number of technology-enhanced resources that used formative assessment techniques and were provided for students attending non-specialist first-year undergraduate mathematics modules in Ireland. Analysis of the evaluations and consultation with literature identified twelve decisive factors that encourage students' successful engagement with the resources, covering aspects such as the educational context, affordances and types of technology, technological communication and formative assessment. These factors constitute important knowledge for practitioners as they can use them in the planning, design, and development of technology-enhanced resources for use in their modules. The measures observed during the evaluations indicated both positive and negative engagement providing a link between observations and resultant student engagement, which was found lacking in previous studies on student engagement.

Keywords: Technology-enhanced, mathematics, student engagement, factors, higher education

1. Introduction

The use of digital technologies has become ubiquitous in our societies, accentuated since the start of the pandemic in March 2020. In Higher Education Institutes (HEIs), students are constantly connected via smart phones, laptops and the internet. Consequently, it may be expected that students would effectively engage with technology-enhanced resources provided by lecturers to supplement their learning. However, is this actually the case? How effective are these resources? Are some more effective than others? Currently, debate is ongoing in the international educational community about how best to use digital technology to support student engagement (and, as a consequence, learning) in higher education (Bayne, 2014; Selwyn, 2010). While evidence exists that technology enhances student learning (Henderson et al., 2015), alongside considerable research on students' experiences of using technology (Conole & Alevizou, 2010), it is unclear what implementations of technology achieve maximum benefit (Conole et al., 2008; Henderson et al., 2015). In addition, it is unclear how student engagement with technology impacts on the success or otherwise of these implementations (Bond & Bedenlier, 2019; Henrie, Halverson et al., 2015). In mathematics education, researchers have pointed to the need to establish which technology implementations work best and why, so that they can be used effectively (Drijvers, 2016; Oates, 2010).

In order to investigate this, a research project was established in 2015 that examined how first-year undergraduate students, attending non-specialist mathematics modules in Ireland, engaged with technology-enhanced resources provided by their lecturers. Many of these students take a mathematics module only in their first year, as they are studying programmes such as Business, Computer Science, or Science, and as such this is their only formal engagement with mathematics in higher education. In this paper, the outcomes of the project are used to address the following question:

What factors of technology implementations impact on these students' engagement with such resources?

The paper is presented in six sections. In the first, we examine the literature on student engagement with technology-enhanced resources, with a focus on mathematics education. The second section contains a description of the research project. The methodology used to gather and analyse the research data is contained in the third section. The results of the data analysis are presented in the fourth section. The fifth section contains a discussion and conclusion of the results along with recommended further research. Finally, the significance of the outcomes is highlighted in the sixth section.

2. Background

Technology use in education, and in mathematics education, had been steadily increasing over the last few decades prior to COVID-19. The use of technology in mathematics education has been identified as a solution to some of the problems associated with students' levels of mathematical understanding (Bray & Tangney, 2017). The computational power, multiple visual representations and diverse ways for students to engage with mathematics have been cited as reasons for an increase in technology use (Bray & Tangney, 2017, p. 256).

Within mathematics education, a number of factors that impact on successful technology integration have been identified. Pedagogical changes (such as the design of digital tasks, or communication between teacher and students supported by a digital tool) were found to positively impact on students' mathematical understanding by Thomas et al. (2017). The term "teacher privileging" is used to describe the teacher's use and promotion of the tool within a class setting in order to guide and develop students' successful use of the tool, and this has also been recognised as being important for successful technology integration (Drijvers 2015; Thomas et al., 2017). Other factors of success were focused on the technology affordances. For example, technologies like Computer Algebra Systems can aid in the visualisation of mathematics, and other technological tools, such as online quizzes, have the ability to give immediate feedback (Takači et al., 2015; Thomas et al., 2017). On the other hand, technical challenges and usability issues were identified as barriers (Oates, 2010; Thomas et al., 2017).

Still, the use of technology at scale in first-year undergraduate mathematics remains problematic, in part due to the lack of studies that have demonstrated the benefits technology can bring to this particular student cohort (Thomas et al., 2017). In his lecture on digital technology in post-primary mathematics education, Drijvers (2015) referred to "decisive factors" that beneficially influence the use of technology-enhanced resources, and the need to determine "what works and why". Following an analysis of six cases of technology integration in secondary mathematics, Drijvers (2015, p. 147) concluded that the three areas of (a) design, (b) role of the teacher, and (c) the educational context are 'decisive and crucial'. It is important to identify the decisive factors, as student engagement is pliable and by judiciously using technologies, lecturers can exercise some control over their students' engagement (Fredricks et al., 2016, p. 5; Steen-Utheim & Foldnes, 2018). Student engagement is important as it is known to be a predictor of successful retention and programme completion (Fredricks et al., 2016; Kahu & Nelson, 2018), and there are certain attributes of technology that influence a user's engagement with that system (Henrie, Halverson et al., 2015; Schindler et al., 2017; O'Brien & Toms, 2010). However, due to the complex nature of student engagement, there are difficulties in determining how measures observed during evaluations of technology integration can be used to judge successful student engagement (Bond & Bedenlier, 2019; Henrie, Halverson et al., 2015).

3. Project

The research outlined in this paper stemmed from a project funded by the National Forum for the Enhancement of Teaching and Learning in Higher Education (NF) in 2014, entitled 'Assessment for Learning Resources for First-Year Undergraduate Mathematics Modules' (https://www.teachingandlearning.ie/project/assessment-for-learning-resources-for-first-year-undergraduate-mathematics-modules/). The project had members from four HEIs: Maynooth University (MU), Dublin City University (DCU), Dundalk Institute of Technology (DkIT) and Athlone Institute of Technology (AIT). The resources developed were aimed at addressing a widely-reported problem: that first-year undergraduate students in Ireland are under-prepared for the non-specialist mathematics modules they encounter (Faulkner et al., 2014; Gill & O'Donoghue, 2007). In this project, technology-enhanced formative assessment resources, were used to enhance, or better, the mathematical understanding, learning experience and/or learning environment of students engaged in mathematics learning, to enable assessment for learning. In April 2015, a number of surveys were conducted across HEIs in Ireland to inform the development of these resources. Students and lecturers reported problems in both conceptual and procedural understanding in topics such as calculus and algebra (Ní Shé et al., 2017a). The types of resources developed were aligned with the aims of the NF-funded project and the preferences stated by staff and students in the surveys (Ní Shé et al., 2017b). The following three resources were selected and developed by the lecturers involved in the project:

1. An audience response system called UniDoodle, designed for use in mathematics lectures
    - Student application allows freeform input and multiple choice
    - Lecturer application allows easy viewing of multiple responses
    - Google App Engine cloud-based service for coordination
2. Khan Academy (KA) playlists and mastery challenges implemented via Moodle
    - Freely-available learning resource which provides practice exercises, instructional videos, and a personalized learning dashboard (https://www.khanacademy.org/)
3. A suite of interactive tasks using GeoGebra and Numbas

- GeoGebra is a freely-available dynamic mathematics software that enables the development of interactive mathematics resources (https://www.geogebra.org)
- Numbas is a web-based e-assessment system for producing exam quiz packages in mathematics (https://www.numbas.org.uk/)
- These two applications were used to develop interactive GeoGebra tasks and interactive Numbas assessments that were made available to students via the student Virtual Learning Environment (VLE).

These resources were trialled at a number of HEIs across Ireland during the academic years 2015/2016 and 2016/2017. This prompted the research question which is addressed in this paper, regarding student engagement with such resources.

4. Methods

A mixed methods approach to research design was taken in order to make use of the strengths of both quantitative and qualitative methods (Creswell & Plano Clark, 2018). According to Creswell and Plano Clarke (2018), there are many advantages to using mixed methods in research. First of all, numerical data can be used as a starting point for gathering narrative data, confirming and adding meaning to the numerical data. This in turn leads to an enriched understanding of the problem, which increases the generalisability of the findings. Finally, by using mixed methods, data triangulation is enabled, which enhances the validity and reliability of the study.

Details of the resource implementations and data gathered from students during the trials is shown in Table 1. Note that the UniDoodle resource was only used in in-person lectures or tutorials (UD1 and UD2), the GeoGebra tasks were only used by students in their own time, as were the Khan Academy playlists for KA1 and KA3 trials, and the KA masteries and class/coach functionality was used in class and available to students for use in their own time in KA3.

Table 1. Trial implementation and evaluation details of the NF-resources

	UniDoodle		Khan Academy			GeoGebra	
	UD1	UD2	KA1	KA2	KA3	GG1	GG2
Dates	2015/16	Spring 2016	Autumn 2015	Spring 2016	Autumn 2015	Autumn 2015	Autumn 2016
Course	2nd yr. Eng (Uni1)	1st yr. Eng (Uni2)	1st yr. Comp (Uni3)	1st yr. Comp (Uni3)	1st yr. Business (Uni2)	1st yr. Science (Uni1)	1st yr. Science (Uni1)
Module	Circuit Analysis	Eng. Maths; Problem-solving	Diagnostic testing	Linear Algebra	Business Maths	Diff. Calculus	Diff. Calculus
# Students	12	165	175	80	335	476	396
# Surveys completed (# items in survey)	12 (100%) (42 items)	98 (59.4%) (42 items)	115 (65.7%) (48 items)	37 (46.3%) (27 items)	108 (32.2%) (13 items) 37 (further 13 items)	46 (9.6.%) (14 items)	221 (55.8%) (14 items)
# Students who used the resources	12 (100%)	137 (83%)	175	80	335	467	396
#Focus Groups	---	---	---	---	---	---	2 (n=6)
Used in class with lecturer	Yes	Yes	No	Yes	No	No	No
Use contributes directly to grade	No	No	No	Yes	No	Yes*	Yes*

* In the case of the GeoGebra trials, where students were presented with a number of tasks, only those tasks with an associated Numba's quiz were graded, use of the remaining tasks was voluntary.

4.1 Quantitative Data

4.1.1 Survey

Quantitative data was gathered using a specially designed survey and recorded usage of the resources. The face and content validity of the survey was ensured by engaging the project team in the development of the survey dimensions and items as well as consulting with the relevant literature (MacGeorge et al., 2008; Pierce et al., 2007). In addition, the clarity of the questions was checked using a pilot survey. The project team agreed that items on the dimensions of background, usability, engagement, learning and confidence should be included in a Likert scale survey that students completed after the trial of a resource. During the evaluations, the project members adjusted the number and exact wording of the items according to their specific needs. Thus, the final question items in each trial varied – see Table 1. In addition, in the KA3 trial only those students who had selected that they had actually used the KA resource were asked to complete the second part of the survey. Hence 37 of the 108 students completed the second part of the survey. Full details on which items were asked in which trials are available in Ní Shé (2021).

The responses to the surveys were used to determine factors that students perceived to affect their engagement with the NF-funded project resources. As this was an exploratory phase of the study, no inferential statistics were required. Instead, descriptive statistics were used, such as percentage of students who responded positively or negatively to the items in the questionnaire. The questionnaire responses were initially transcribed into Excel sheets and then imported into SPSS for statistical analysis. The survey items reported on in this paper are items that were commonly asked across the trials of the three resources, and those that were commonly asked in different trials of the same resource. The open questions in the surveys were analysed using inductive analysis based on Thomas' (2006) grounded inductive analysis techniques.

4.1.2. Usage

Recorded usage of resources is used by many researchers when investigating the use of technology in education (Henrie, Bodily et al., 2015; Inglis et al., 2011; Loch et al., 2014). Usage data generally relies on the VLE to record students' access of resources (Henrie, Bodily et al., 2015; Howard et al., 2018), and while this data in itself is reliable, the researcher needs to be careful about inferences taken from the recorded usage (Howard et al., 2018; Inglis et al., 2011). It is possible that, although students access a particular link, they do not engage any further with the resource (Howard et al., 2018; Inglis et al., 2011). The GeoGebra and KA resources were made available via the students' institutional VLE (Moodle), which retains a log of all user activity with respect to access to course materials. Usage of these resources was voluntary, and uptake was generally low; therefore, a decision was taken to gather the students' clicks (or hits) on the URLs to the KA playlists or GeoGebra tasks. The log files were then downloaded to Excel for analysis. As UniDoodle was used in class, usage data was gathered from student surveys and lecturer observations during class.

4.2 Qualitative Data

Qualitative data was gathered using (a) focus group interviews with students and (b) consultations with the lecturers involved in the project trials. There were two focus group interviews carried out after the GG2 trials. Each focus group had three participants from first-year undergraduate science (see Table 1). A semi-structured approach was taken to the interviews. Specific questions required answers, such as the students' reasons for using or not using the GeoGebra tasks that were made available on a voluntary use basis. In addition, a more general conversation about the use of technology resources was pursued. Prior to analysis, the interviews were transcribed and uploaded into NVivo. As the focus of this research was on exploring the factors that influence students' engagement with technology, a phenomenon that has not been widely examined or conceptualised, inductive analysis was considered to be the best approach. A general inductive approach to data analysis was taken (Thomas, 2006). In order to ensure validity and reliability, the five steps outlined by Thomas (2006, pp. 241–242) were rigorously adhered to. For example, step 3 outlines the process for the creation of categories where the research aims are often used to define upper-level categories, and lower-level categories are derived from multiple readings of the text (Thomas, 2006, pp. 241 - 242).

Within the context of the analysis of the focus group data, an upper-level theme of 'Why GeoGebra was Used' (see Figure 4 below) emerged and is relevant in identifying factors that influence student engagement with such resources, the aim of this study. A sub-category of 'Assignments' (see Table 4 below) emerged under this theme; students commonly referred to the fact that they would use a resource when it was part of an assignment. In order to ensure reliability in the coding process, samples of the data were coded by two or more of the authors and an inter-rater reliability measure calculated within Nvivo (Cohen's Kappa coefficient) which was found to be greater than 0.85, indicating excellent agreement.

A form of narrative analysis was used when analysing the transcripts from the lecturer consultations. Narrative analysis is generally used to interpret stories told about everyday life in order to analyse their structure, function and/or substance (Parcell & Baker, 2018). In this case, it was used to analyse lecturer comments regarding their opinions of the success or otherwise of the trial of their resources.

Once the data was analysed, and factors that impact student engagement with resources found, a focussed analysis of the literature was conducted. This was used to determine if other features of technology integration were identified that are known to impact student engagement and success in mathematics education. Focussed literature reviews are used to examine one particular aspect of a body of literature (Randolph, 2009). The literature search focussed on articles relating to technology in education and in mathematics in higher education: what works and what does not. A body of literature relating to both secondary and higher education, mainly peer reviewed, along with seminal articles on technology use in higher education, was consulted. This resulted in the review of 49 articles.

5. Results

The results in this section are presented in five subsections: usage data; survey data; focus group interviews; lecturer narrative analysis; and factors from the literature. In each subsection, we highlight the factors identified by this form of analysis, building up to our final list of 12 factors at the end.

5.1 Usage Data

Firstly, we report the students' usage of the various NF-funded project resources, as summarised in Table 2. This table also includes indicators of whether the resources were used in class and/or whether there was a grade associated with their use, as indicated in Table 1.

Table 2. Percentage of student who accessed the NF-resources

Trial	% students who engaged in any way with resource	Used in Class	Grade associated with use
UD1 (n=12)	100%	Yes	No
UD2 (n=165)	83%	Yes	No
KA1 (n=175)	17%	No	No
KA2 (n=80)	99%	Yes	Yes
KA3 (n=335)	10%	No	No
GG1 (n=467) Graded	92%	No	Yes
GG1 (n=467) Non-Graded	50%	No	No
GG2 (n=396) Graded	87%	No	Yes
GG2 (n=396) Non-Graded	60%	No	No

It is clear that there are differences in the usage of the various resources, with figures ranging from 17% to 100%. When examined in light of the different implementations between the trials, it is evident that both the use of a resource in class and the association of a grade with its use impact on usage. Thus, two factors that encourage usage are identified from this data; namely, *'Use in class'* and *'Grade associated with its use'*.

5.2 Survey Data

A total of 637 students responded to the surveys, almost 39% of the total student population involved in the trials, see Table 1. The student responses were analysed using Excel and SPSS. In addition to examining the frequency and percentage of positive responses to the Likert Scale items, Mann Whitney and Fisher exact tests were used to compare responses to particular items across the different trials. The detailed analysis is beyond the scope of this paper (see Ní Shé, 2021); instead, we present here a sample of the analysis completed, so as to demonstrate the approach taken throughout. We illustrate below the contribution of the survey data to the factors *'Use in class'* and *'Grade associated with its use'*.

As indicated in the methods section, not all items were asked in all surveys. Apart from background data, there were four items common to each of the seven trials (see Table 1):

- One Usability item
  - ***Easy to Use*** ('For me it was easy to use the resource')
- Two Learning items
  - ***Enhanced Learning*** ('Using the resource enhanced my learning of the subject')
  - ***Resource Useful*** ('I found the resource useful')
- One Confidence item
  - ***Increased Confidence*** ('Using the resource has increased my confidence in my ability to complete 1st year mathematics successfully')

The possible responses to these items were Strongly Agree (SA), Agree (A), Neutral (N), Disagree (D) and Strongly Disagree (SD). The number of respondents who selected SA and A was aggregated for each of these items and an overall percentage of positive responses per trial was calculated (see Figure 1).

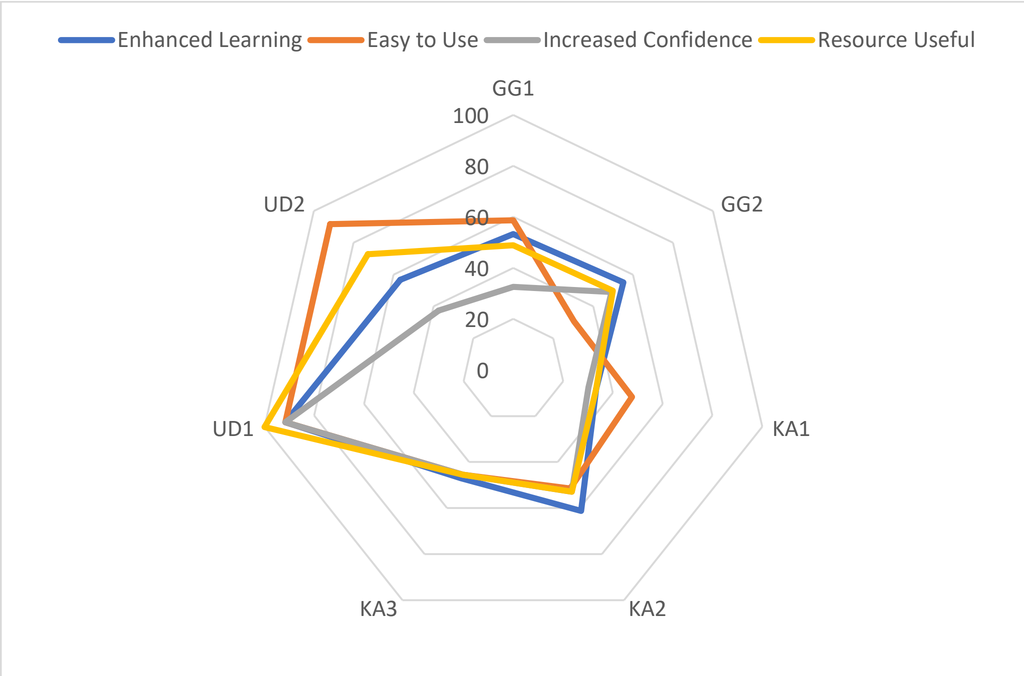

Figure 1. Positive responses for the four common items in the seven trials

From this diagram, it is clear that UniDoodle was the most highly rated resource overall. For example, a greater percentage of UniDoodle respondents rated the items '*For me it was easy to use the resource'* and '*I found the resource useful*' than for all other trials. Fisher exact tests were used to compare the distribution of responses (SA, A, N, D and SD) for the different resource types, as well as between trials of the same resources. Some significant differences were found, in particular between the three KA trials (see Ní Shé, 2021). Figure 2 compares the seven common items across the three KA trials.

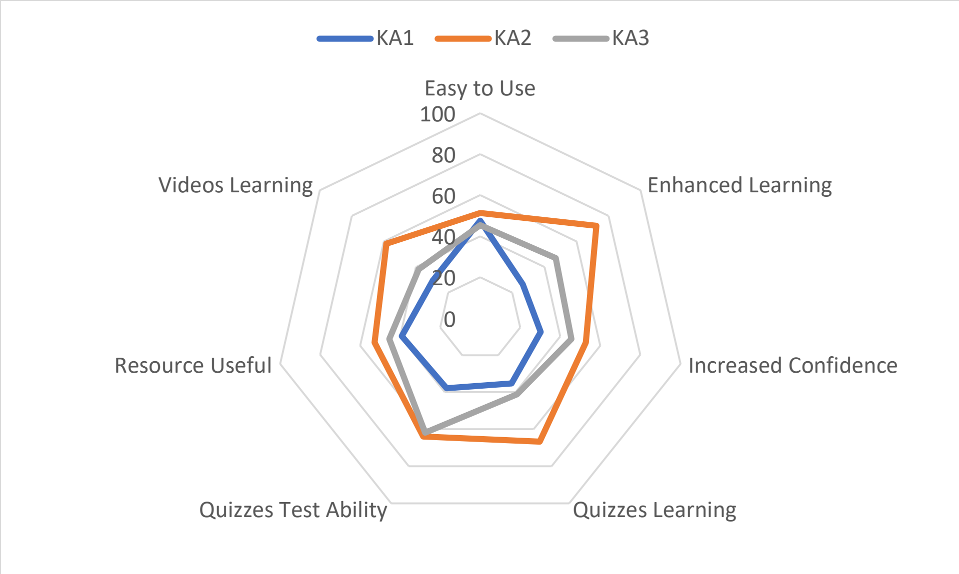

Figure 2. Positive responses for the seven common items in the KA trials.

In Figure 2 we see that the students in the KA2 trial rated the use of the resource higher than in the other two trials. Recall that the KA2 trial was the only one which was used in class and had a grade associated with its use. In a similar way, the analysis of the full survey results (see Ní Shé, 2021) was used to support the two factors found using the usage data, namely *'Use in class'* and *'Grade associated with its use'*.

The survey data was also used to identify five new factors: *'Class size'*; *'Ease of use'*; *'Purpose'*; *'Instructions on use'*; and *'Did not need'*. For example, the class size of UD2 (165- see Table 1) was considerably bigger than that of UD1 (12 – see Table 1) and use of the UniDoodle app was rated higher by the smaller UD1 class than the UD2 class (Figure 1), thus *'class size'* emerged as a factor. These seven factors, along with the particular survey outcomes that support them, are shown in Figure 3.

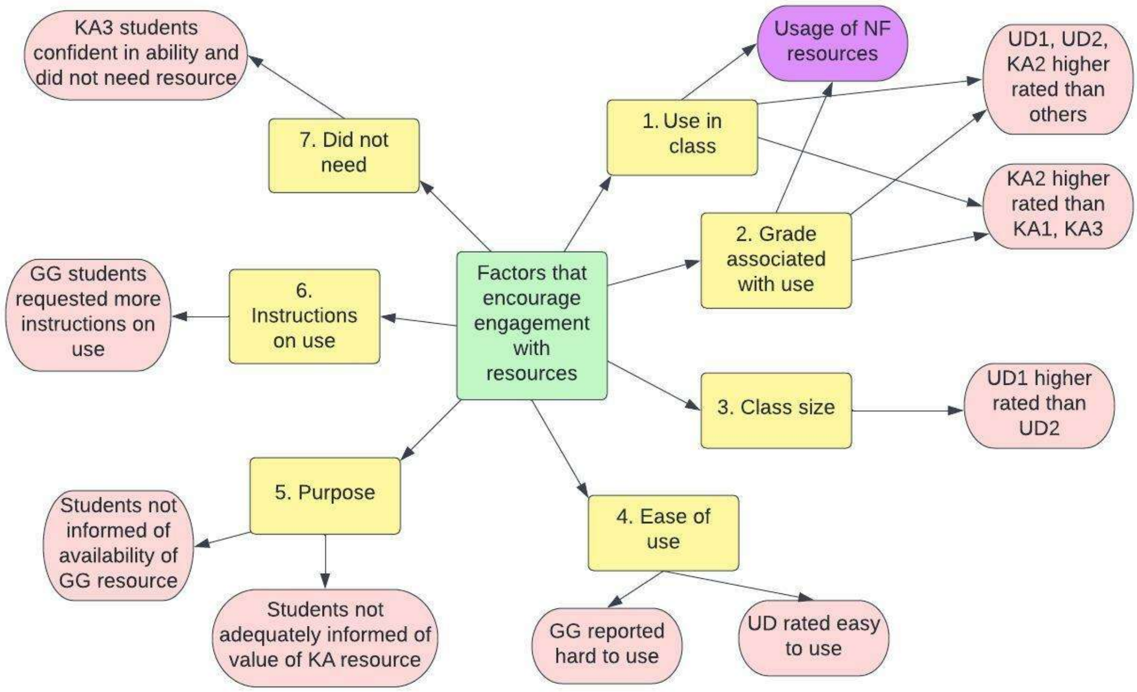

Figure 3. Survey and usage data outcomes that support the identified factors

5.3 Focus Group Interviews

Having identified seven factors from the usage data and survey results, the focus group interview transcripts were then coded within NVivo using general inductive analysis. Segments of the data were coded into themes that emerged from the transcripts, and where relevant, segments were coded to more than one theme, using Thomas's (2006) general inductive approach outlined in section 4.2. The themes that emerged were then structured to focus on addressing the research question for this section of the study. Recall that the focus groups dealt solely with the GeoGebra trials. Note for clarity, reference to a '*named factor'* will be italicised with quotes, and a 'named theme' will be in quotes.

Four relevant themes emerged: (1) 'Benefits of GeoGebra'; (2) 'Encourage GeoGebra use'; (3) 'Used – Why GeoGebra was used'; and (4) 'Not Used – Why GeoGebra was not used'. The relationships between these themes and their subcategories were explored. In order to determine if the student background or the particular GeoGebra task impacted on engagement with the resources, two additional themes were created in NVivo: 'Student background'; and 'GeoGebra tasks'. The first contained the segments of data relating to student background, course and their opinions on their mathematical ability. The second contained the segments of transcripts relating to each individual GeoGebra task. Figure 4 illustrates the themes identified and their associated categories, created in NVivo, along with the number of segments of data coded to each node.

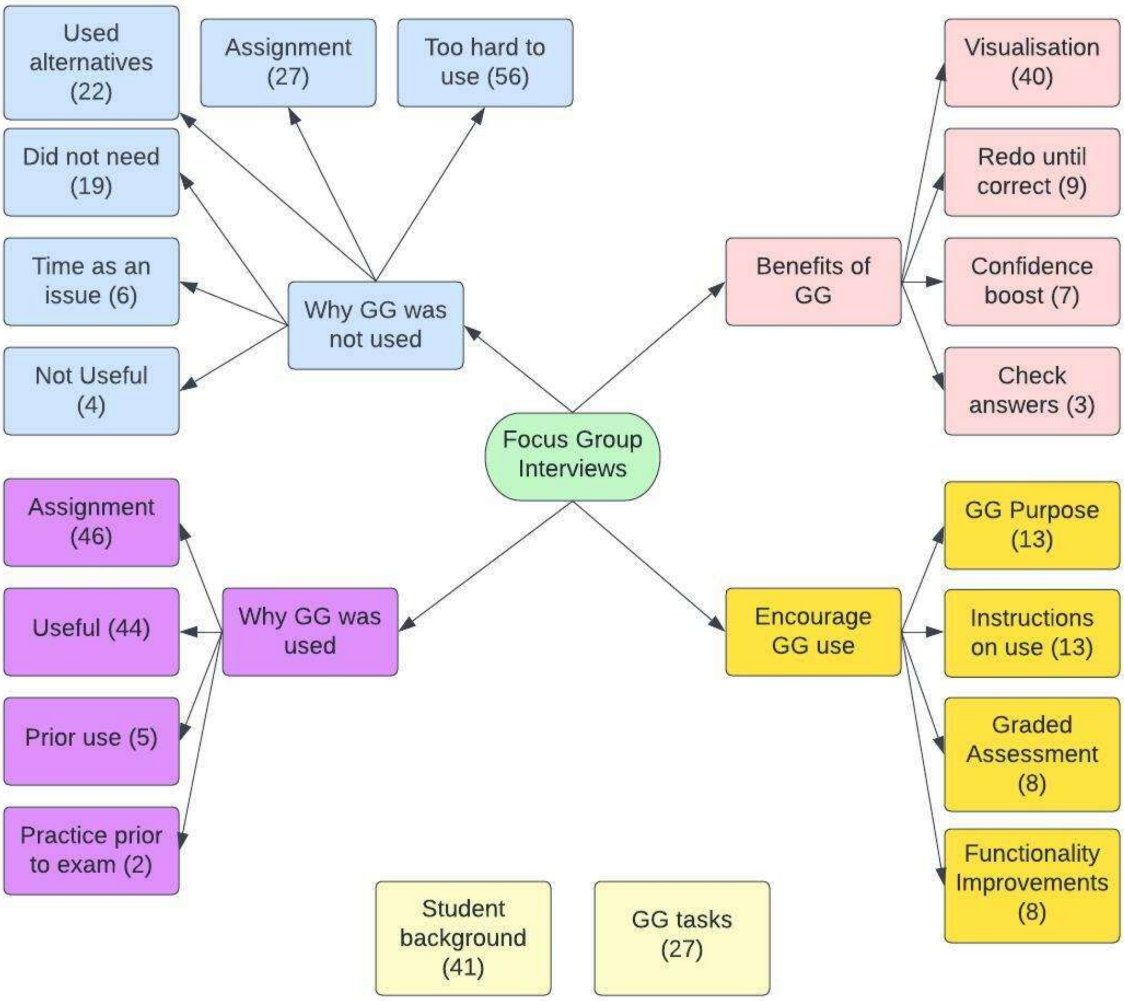

Figure 4. Themes and associated node categories.

Again, the full analysis of these is beyond the scope of this paper (see Ní Shé, 2021), but in order to illustrate how the data was used to consider factors that encourage student engagement with technology, the 'Used – Why GeoGebra was used' theme will be explored in detail here.

The usage data for GeoGebra (see Table 1) illustrates that the most accessed tasks were those graded or associated with a grade; in other words, those considered "assignments" by the students. This was also evident in the focus group interviews, where 46 segments were coded to the 'Assignment' category within the 'Used- Why GeoGebra was used' theme (see Figure 4). The relationship between the 'Assignment' category and the 'GeoGebra tasks' theme (see Figure 4) was examined, showing that students mainly discussed using GeoGebra in relation to the graded tasks (or assignments). There was a clear indication from the students that they would always try to access the tasks that related to assignments. For example, one student said that they used GeoGebra tasks *'when we were given assignments*'. This was echoed by another student who stated *'if something is not on the test … I just don't have the time, it's not on my priority'*. An exploration of the data coded in the category of 'Graded Assessment' (within the 'Encourage GeoGebra use' theme) showed that all of the students supported the assertion that students will engage with technology-enhanced resources when there is a grade associated with its use. A third student summed it up by saying *'Honestly like, unless it says on the assignment "do this", most people won't…'*, and the two other students in the interview agreed. All this evidence from the analysis of the 'Use – Why GeoGebra was used' combines to support the premise that *'Grade associated with its use'* is a factor (factor 2 in Figure 3) in encouraging students' engagement with technology.

A similar process was carried out for the remainder of the focus group themes, and the complete analysis supported six of the seven factors that had been identified thus far (see Figure3), with the exception of *'Class size'*, which was not discussed within the focus group interviews . For example, recall that students rating of UD as easy to use, and GG hard to use, led to the identification of the *Ease of Use* factor (see Figure 3). Within the focus group interviews, students mentioned specific experiences they had with the usability of GeoGebra that impacted upon its ease of use (see Figure 4, Functionality Improvements). This supported and expanded the *'Ease of use'* factor to include many aspects of usability, and thus it was relabelled '*user experience'* (which aligns with a term often used in learning design, see for example, Schmidt et al. (2020). In addition a new factor emerged, which was identified through the subcategories relating to the 'Benefits' theme (see Figure 4), this eighth factor was labelled *'Affordances'* of the technology.

5.4 Lecturer Narrative Analysis

At this point, eight different factors had been identified, and it was time to consider the input of the lecturers involved in the project. Having received a report regarding the evaluation of the resource they had implemented, a discussion was held with each lecturer to further probe the results. Both lecturers involved with UniDoodle expressed their satisfaction with the use of the app in class. With a class size of 12, the UD1 lecturer was able to give students individual feedback on their responses to questions within the scheduled class time. With a class size of 165, the UD2 lecturer indicated that the volume of responses meant that he could only deal with a limited number of incorrect responses and focussed on the most frequent errors. Thus, the level of feedback in the larger class was not as high as in the smaller class. Class size was also important to the lecturer in the KA2 trial. This lecturer used the weekly feedback from the KA class application to modify her in-class teaching. She felt that she would not have been able to manage the formative assessment elements with a bigger class (n=80).

These opinions support *'Class size'* as a factor that impacts student engagement with technology. A ninth factor, '*Formative assessment'*, was identified for the first time, as a number of lecturers referred to the impact class size had on their ability to give essential feedback to students. Initially, a factor entitled '*Did not need'* was identified from students' opinions in the survey and focus group interviews. However, lecturers referred to their students as holding particular views and/or taking certain actions in relation to studying mathematics, such as being unaware of their low skill levels and therefore rarely accessing the supports that are provided, or only being focussed on attaining a pass in the module. This led to the original factor of *'Did not need'* being incorporated into a newly-expanded factor of '*Student cohort'* (see Ní Shé, 2021 for full analysis).

At this point, the four different sources (usage data, survey data, focus group analysis, and lecturer narrative analysis) have contributed to the development of the nine factors identified thus far, namely *'Use in class', 'Grade associated with its use', 'Class size', 'Ease of use – User Experience*', *'Purpose', 'Instructions on use', 'Student cohort*', *'Affordances'* and *'Formative assessment'.* See Figure 0.1 for an illustration how each of these four sources have contributed to the identification of the factors.

5.5 Factors from the literature

Having identified these nine factors, it was now appropriate to conduct a focussed analysis of the literature to determine if other features of technology integration had been identified that are known to impact student engagement and success in mathematics education. While some of the features discussed in the literature were also identified as factors during our resources' evaluations, others emerged from the literature. For example, Drijvers (2015) and Thomas et al. (2017) identified teacher privileging or '*use in class'* as impacting on the effectiveness of technology integrations. Task design when using technology emerged from the literature as a pedagogical feature that impacts students' success (Drijvers, 2015; Pierce & Stacey, 2010). Handal et al. (2012) referred to the fact that different technologies afford different levels of task complexity, and hence the selection of the type of technology is important when matching it to the task. Thus, task design, technology affordance and technology type are all pedagogical features of technology integrations that impact on student engagement. The pedagogical factors that emerged from the literature (see Ní Shé, 2021 for full analysis) are listed below with a reference to the similar factor, where relevant, identified in our resource evaluations:

- Didactical contract (purpose, use in class, grade towards assessment)
- Educational background (student cohort)
- Instrumental Orchestration (instructions on use)
- Technology affordances (affordances)
- Technological communication (formative assessment)
- Technology type
- Task design
- Collaboration with peers

Thus, it can be seen that the last three of these (technology type, task design, and collaboration with peers) were new factors identified in the literature that did not emerge from our resource evaluation, bringing the final total of factors to 12 and providing us with an answer to our research question, which will be further discussed below. Table 3 illustrates the research used to identify each of the 12 factors.

Table 3. Final research instruments that contributed to the identification of the factors

The final 12 factors	Resource usage	Surveys (student opinions)	Focus groups (student opinions)	Lecturer opinions	Literature review
Use in class	X	X	X		
Grade associated with use	X	X	X		
Class size		X		X	
User experience		X	X		
Purpose		X	X		
Instructions on use		X	X		

Did not need	X	X	X	
Affordances		X		
Formative assessment			X	
Technology type				X
Task design				X
Collaboration with peers				X

6. Discussion and Conclusion

Our research question stated “What are the factors of technology implementations that impact on student engagement with such resources?”. To answer this, we compiled the factors identified using the NF resource evaluations and those identified through the examination of the relevant literature, to establish the following final set of 12 factors that influence first-year undergraduate students’ engagement with technology in non-specialist mathematics modules. The first nine factors emerged from the evaluations of the resources, the latter three from the literature alone, as shown in Table 3 (or Figure 0.1).

Many of the factors which emerged from the analysis of the evaluations in this study corroborate those identified in the literature (Pierce & Stacey, 2010; Thomas et al., 2017; Trenholm et al., 2015; Kanwal, 2020). However, some new factors emerged in our research. A number of usability issues were identified, such as the lack of clear labels in GeoGebra and the use of colour in UniDoodle. These issues have not been to the fore in the evaluation of technology in education (Zaharias & Poylymenakou, 2009), though they are of increasing concern (JISC, 2015; Morville, 2016). In their micro-level model of the influences of the learning environment and technology on student engagement, Bond and Bedenlier (2019, fig. 3) include usability as a factor. Thus, the factor of ‘user experience’ has been identified in this study. Students rated UniDoodle higher on the User Experience scales than the other resources and both recorded and reported usage of UniDoodle was relatively high. Students using the GeoGebra tasks found them hard to use which impacted student engagement with those resources. Other factors that have not been widely considered within previous studies include ‘class size’, ‘purpose’, and ‘student cohort’. ‘Class size’ is significant in that it can impact on the level of formative assessment received by students while using the technology, as indicated by students using UniDoodle and KA in the smaller class sizes. While knowledge of the relevance of the learning material is known to impact the successful use of technology (Bond & Bedenlier, 2019), the importance of informing students of the ‘purpose’ of an optional resource has not been discussed. It was clear from the evaluations that students in the GG trial reported not being clear on the ‘purpose’ of completing the GG tasks which impacted on their engagement with them. Finally, ‘student cohort’, or the educational background of the student, was shown to impact on their engagement with supplementary resources. Students involved in both the KA and GG trials expressed that they did not need the resource. While it is known that students from many different educational backgrounds disengage from supplementary resources, it is important to pay attention to educational background as it can impact student engagement with technology (Drijvers, 2015; O’Sullivan et al., 2014).

When considered together, this list of 12 factors provides a comprehensive response to Drijvers (2015) question as to “what works and why” in terms of technology integration in mathematics education. These 12 factors are encompassed in the three essential factors of the design (‘task design’, ‘affordances’ of the different ‘technology types’), the role of the teacher (provision of ‘purpose’, ‘instructions on use’, ‘formative assessment’, and ‘collaboration with peers’), and the educational context (‘student cohort’, implementation settings such ‘as use in class’ and ‘grade associated with use’) articulated by Drijvers (2015, p. 147). In addition, this research has identified the importance of the user experience and class size when integrating technology in mathematics education.

7. Significance and future work

The data collection and analysis for this research was completed prior to COVID-19 and focussed on in-person teaching and related literature. Recently, much research has focussed on technology use during COVID-19 and the sudden move to online teaching and learning, for example see the research papers in the special issues of Teaching Mathematics and its Applications (https://academic.oup.com/teamat/issue/40/4) and in this journal (https://www.tandfonline.com/toc/tmes20/53/3). A common feature across many of these papers is poor student attendance and low quality engagement within this online environment. As researchers and practitioners consider the implications of this dramatic shift online for the future of technology use in the teaching and learning of service mathematics, our work provides an important foundation from which to investigate the influences on student engagement in these new pedagogical environments.

The measures used to evaluate the resources resulted in the identification of both positive and negative engagement actions and reactions of the students. For example, the students in the GG focus groups indicated their desire to do well in the assignments. Desire to do well has been recognised as an indicator of positive affective engagement (Bond & Bedenlier, 2019). On the other hand, attendance, operationalised as technology usage, had a negative impact on behavioural engagement in the GG tasks. Difficulties associated with measuring engagement have been recognised as relating to how student engagement has been operationalised in research studies on engagement (Henrie, Halverson et al., 2015). An analysis of all the measures used in this study and how they relate to student engagement will contribute to a holistic approach to student engagement with technology supports, which we report on in a further paper.

The identification of factors that impact student engagement with technology addresses some of the concerns identified in the literature around the successful integration of technology in higher education; such as the need to determine the decisive factors that impact on benefits (Drijvers, 2015) and educator ability to leverage the affordances of the different technologies (Conole, 2013; Goodyear, 2015); and how best to implement the technology to achieve the pedagogical benefits of using technology (Bayne, 2014; Conole & Alevizou, 2010; Selwyn, 2010). The latter can be addressed by the use of these factors to help practitioners plan the provision of technology-enhanced support resources within their mathematics modules. These factors identified can be grouped together to describe different aspects of technology-enhanced resource integrations within mathematics modules. For example, the factors 'use in class', 'grade associated with its use', 'class size', 'and 'student cohort' are all associated with the implementation of the resource in a particular context or setting. The factors of 'purpose' and 'instructions on use' will help determine the didactical practices put in place by the lecturer while integrating the resource. The selection of the technology to use will be determined by the 'affordances' of different 'technology types' and the particular 'task design' that supports the required mathematical learning.

The research in this study focussed on first year undergraduate students attending non-specialist mathematics modules, and while the factors identified acknowledge the importance of the context and setting, future work with other cohorts, such as students with learning disabilities or students in more senior years, may help identify further factors that impact on the use of technology in mathematics education.

In order for practitioners to consider each of these factors comprehensively and efficiently, a framework or model that encapsulates all of these factors is required to support the successful integration of technology-enhanced resources. Such a framework will enable practitioners to consider together the factors that influence the leveraging of the pedagogical benefits of using technology in mathematics education, a need identified in the literature on the integration of technology in mathematics education (Attard & Holmes, 2020; Jaworski & Matthews, 2011;

Thomas et al., 2017). This next step has been investigated through the development of the Technology-enhanced Resources for Mathematics Education (TeRMEd) classification framework. The development and use of this framework is described in a companion paper that emerged subsequent to the initial research work described in this paper.

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