

# A scale for monitoring students' attitudes to learning mathematics with technology

Robyn Pierce<sup>a,\*</sup>, Kaye Stacey<sup>b</sup>, Anastasios Barkatsas<sup>b</sup>

<sup>a</sup> University of Ballarat, P.O. Box 663, Ballarat, Victoria 3353, Australia

<sup>b</sup> University of Melbourne, Australia

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## 9 Abstract

10 The *Mathematics and Technology Attitudes Scale* (MTAS) is a simple scale for middle secondary years  
11 students that monitors five affective variables relevant to learning mathematics with technology. The sub-  
12 scales measure mathematics confidence, confidence with technology, attitude to learning mathematics with  
13 technology and two aspects of engagement in learning mathematics. The paper presents a model of how  
14 technology use can enhance mathematics achievement, a review of other instruments and a psychometric  
15 analysis of the MTAS. It also reports the responses of 350 students from 6 schools to demonstrate the  
16 power of the MTAS to provide useful insights for teachers and researchers. 'Attitude to learning mathemat-  
17 ics with technology' had a wider range of scores than other variables studied. For boys, this attitude is cor-  
18 related only with confidence in using technology, but for girls the only relationship found was a negative  
19 correlation with mathematics confidence. These differences need to be taken into account when planning  
20 instruction.

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23 education

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\* Corresponding author. Tel.: +61 3 53 279283; fax: +61 3 53 279289.  
E mail address: [r.pierce@ballarat.edu.au](mailto:r.pierce@ballarat.edu.au) (R. Pierce).

## 25 1. Introduction

26 Technology offers enticing possibilities for new approaches to teaching and hence for learning  
27 across the curriculum. The research and professional literature suggests that the new approaches  
28 may enhance learning through cognitive, metacognitive and affective channels. The cognitive and  
29 metacognitive channels for improving learning by using technology are clearly strong and impor-  
30 tant to study. This paper provides a tool, the *Mathematics and Technology Attitudes Scale*  
31 (MTAS), to examine the role of the affective channel, which is also important in improving learn-  
32 ing, and it reports some results from the use of MTAS in six schools.

33 For learning and doing mathematics, technology in the form of ‘mathematics analysis tools’ (such  
34 as certain computer software, calculators, graphics calculators, computer algebra systems, spread-  
35 sheets, statistics programs) can assist students’ problem solving, support exploration of mathemat-  
36 ical concepts, provide dynamically linked representations of ideas and can encourage general  
37 metacognitive abilities such as planning and checking. In addition, information technology in the  
38 form of ‘real world interfaces’ such as digital cameras, video cameras and data loggers can bring  
39 to life in the classroom those outside situations to which mathematics is applied (see, for example,  
40 Oldknow, 2003). With substantial investment in providing information technology to assist in teach-  
41 ing and learning mathematics, it is important to monitor students’ reactions and decide how best to  
42 use both forms of technology, the mathematics analysis tools and the real world interfaces.

43 Reports of almost any major teaching innovation of the last 25 years include data on students’  
44 attitudes to the innovation as well as their mathematical achievement. McLeod (1992), who pro-  
45 vides a careful analysis of previous research on affect in mathematics education, is adamant that  
46 affective issues play a central role in mathematics learning and that ‘mathematics education research  
47 can be strengthened if researchers integrate affective issues into studies of cognition and instruction’  
48 (p. 575). The literature published since 1992 also affirms that affective factors and beliefs impact on  
49 student learning: in general positive attitudes and beliefs and intrinsic motivation are reflected in  
50 increased effort in learning and greater persistence. Ruffell, Mason, and Allen (1998) are concerned  
51 that attitudes may not be sufficiently well defined conceptually or sufficiently stable to be reliable  
52 but “‘influenced by social and emotional context and personal construction of these’ (p. 15). We  
53 would agree with Ruffell et al. that attitudes can ‘flip’ from negative to positive and in particular  
54 that ‘good teaching’ can have such an effect, but we disagree that this means that monitoring atti-  
55 tude will not prove fruitful for mathematics education research. Since attitudes can be affected by  
56 recent experience, a series of experiences promoting positive or negative attitude can indeed contrib-  
57 ute to the development of more persistent attitudes and even beliefs which are deeply held and  
58 strongly influence future behaviour. Attitudes are commonly distinguished from beliefs in that atti-  
59 tudes are moderate in duration, intensity and stability and have an emotional content, while beliefs  
60 become stable and are not easily changed (Mayes, 1998; McLeod, 1992; Pajares, 1992). In this pa-  
61 per, we do not make a strict distinction between attitudes and beliefs, but use the terms ‘attitude’ and  
62 ‘affective’ to encompass both feelings and opinions about doing and learning mathematics.

### 63 1.1. The hypothesized model

64 This paper reports the development of a scale to monitor affective changes which result from  
65 technology use and which are likely to have an impact on improving learning. Fig. 1 outlines a

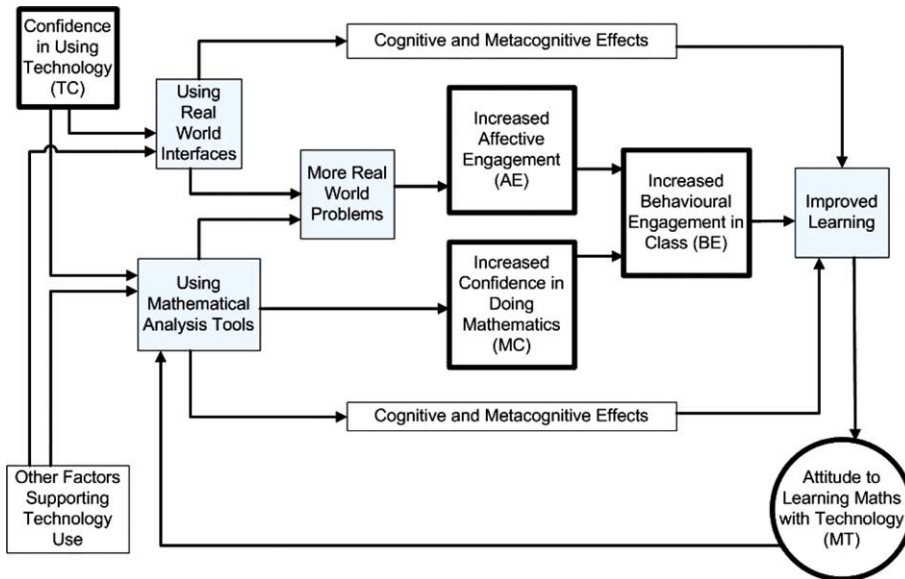


Fig. 1. Illustration of hypothesized affective channel for technology use to improve mathematics learning. (Variables measured in MTAS in heavily outlined boxes: MC, TC, AE, BE, MT).

hypothesized model. The main row of boxes across the centre of Fig. 1 shows that we hypothesize that information technology in the classroom can enable more real world problem solving. Both forms of technology, the mathematics analysis tools and the real world interfaces, contribute. More real problem solving, making mathematics more relevant to students' lives and more interesting, is in turn hypothesized to lead to increased 'affective engagement' (defined below). Use of mathematical analysis tools is, in addition, hypothesized to lead to increased confidence in doing mathematics because these can take some of the computational burden from students. These effects combine to improve students' behavioural engagement (defined below) during lessons and hence improve learning. Confidence in using technology (extreme left side box) is seen as predisposing students to full participation in lessons using technology, along with a number of unspecified factors (e.g., having suitable equipment and a teacher willing and able to use it). Similarly, both forms of technology have cognitive and metacognitive effects (elongated top and bottom boxes) which will impact on learning but are not of concern here. On the bottom right hand side, a positive attitude to using technology to learn mathematics is shown as an outcome of improved learning. However, a favourable attitude also provides a feedback loop, making further effective use of technology for learning likely. Evidence for this is provided from the multiple case studies reported by Pierce and Stacey (2004). This paper aims to provide a simple instrument which can be used to explore whether these links are evident in practice, although there is no attempt in this paper to fully test the model.

85 This study is linked to the RITEMATHS project (HREF1), which is conducting a series of curriculum design experiments for middle secondary school teaching of mathematics. Based on the broad experience of the teaching and research team and relevant literature, we plan to make strategic use of technology to facilitate the use of real world problems in mathematics classes, aiming

89 to increase students' engagement and confidence and thereby increase achievement as shown in  
90 Fig. 1. Consequently, we wish to track changes in the attitudes and engagement of students in  
91 their learning of mathematics, in response to the altered learning environment and to consider  
92 how best this use of technology can be implemented. The five heavily outlined boxes in Fig. 1  
93 show the constructs measured by the MTAS, all of which are relevant to our proposed RITE-  
94 MATHS curriculum changes.

95 In a curriculum design experiment like the RITEMATHS project, it is important to monitor  
96 student attitudes throughout the project. The malleable nature of attitudes means that it may  
97 be possible to create repeated episodes engendering positive attitudes and so, in time, contribute  
98 to these students establishing positive stable beliefs and behaviours for their mathematics learn-  
99 ing. The need to assess students' attitudinal response before and after each teaching experiment  
100 prompts the requirement for a minimally intrusive method of collecting data. For this reason a  
101 simple questionnaire approach was chosen as the primary source of data. This will, of course  
102 be 'self-report' data and any claims of changes over time will need to be confirmed by classroom  
103 observation, and teacher and student interviews.

104 For our study we want subscales which allow us to monitor the five variables highlighted in Fig.  
105 1: mathematics confidence (MC), affective engagement (AE), behavioural engagement (BE), con-  
106 fidence in using technology (TC) and attitude to the use of technology to learn mathematics (MT).  
107 The rest of this paper discusses some of the available scales, our choices of items, and the psycho-  
108 metric analysis of the resulting MTAS, which is given in Appendix A. We then demonstrate the  
109 power of MTAS to provide useful insights for teachers, by reporting on differences between  
110 schools and between genders. We will begin by considering relevant literature and establishing  
111 the need for a new scale for ongoing monitoring of students.

## 112 2. The need for another scale

113 Attitudes have been studied in various ways, with data collected from individual interviews, fo-  
114 cus groups, diaries, observation and questionnaires. Since the research of Fennema and Sherman  
115 in the 1970s, questionnaires have become standard tools for assessing student attitudes, especially  
116 when attitudes alone are not the focus of the study but rather viewed as one factor to be moni-  
117 tored when assessing the likely success of a curriculum or teaching innovation. The literature does  
118 not support one approach over another. In every case the act of asking questions will prompt  
119 thoughts in the mind of some students which they may not have otherwise had and they will feel  
120 obliged to answer. Asking students to pause and reflect briefly to respond to a questionnaire may  
121 therefore provide data which would not be obvious through observation and would take too  
122 much time to collect by interviewing every student.

123 We need an instrument that is suitable for students as young as fourteen, with widely vary-  
124 ing scholastic abilities. Since the project will monitor curriculum innovations, the instrument  
125 will need to be administered regularly without taking too much class time. Some well known  
126 instruments are too long and complex for our purpose. For example, the classic Fennema and  
127 Sherman (1976) scale, which measures some constructs of interest to us, has 108 items and  
128 according to Tapia and Marsh (2004) one needed to allow students up to 45 min. Scales also  
129 become dated. Shades of meaning of words change and, while older scales provide most help-

ful models, new items need to be constructed which will be immediately understood by the current student cohort. Other recent research in our Australian context provides resources on which a suitable scale may be built. For example, Galbraith and Haines (1998) provide a contemporary resource but their subjects were tertiary students and their focus, related to particular courses, meant that items were not immediately transferable to our study. Similarly, Fogarty, Cretchley, Harman, Ellerton, and Konki (2001) validated a questionnaire to measure tertiary students' mathematics confidence, computer confidence and attitudes towards the use of technology for learning mathematics. Their scale, focused on just these three constructs, has 37 items including a number of long statements, making it unsuitable for direct transfer to our setting. Chapman (2003), on the other hand, produced a validated scale for use with primary aged students. Her 'How I feel About Maths' scale focuses mainly on the construct we will describe below as 'affective engagement'. The items in this scale provide exemplars of brief, simply worded statements which each address one idea but the scale does not cover the breadth of attitudes we consider important for our study. Vale and Leder (2004) report a study of the relationship between gender and attitudes to using computers for learning mathematics using a questionnaire as one source of data. While their scale is targeted at the same age range as our study (early/middle secondary years), and the issue of gender may emerge as an important variable, we want to look more broadly. The Vale and Leder scale had 11 items for 'attitude to computer-based mathematics' and only one item for each of four other variables.

While acknowledging the advantage of building on previous research without modification, none of the available scales was deemed suitable for repeated monitoring of students' attitudes in a diversity of middle secondary years classes. However the scale we have constructed has many ideas and some items in common with other published scales. We have minimised the number of items and constructed short statements. In addition, we have avoided the use of negatively worded items, for two reasons. First, we want students to be able to complete the questionnaire quickly and accurately and negative items often cause some hesitation or incorrect responses due to the logic of double negatives etc. Second, since a student may complete this questionnaire many times over three years, we do not want to seed negative thinking. While negatively worded items are commonly included in order to address possible acquiescence in response to items this was not considered to be a major problem with our participants, who operate within a school culture where they feel their opinions are valued and criticism (implied or direct) of authorities is common.

### 3. Key concepts considered

Defining the composition of attitudes is not simple. In the literature referenced in this paper there is general agreement that confidence and engagement are important but certainly not precise agreement as to their measurable features. Students' vocabulary and behaviour indicating confidence and engagement will be dependent on local culture and context, age and stage. These factors need to be taken in to consideration in wording the statements to which we ask students to respond. The section which follows includes the items we constructed, the meaning we have assigned to each construct and where that fits in relation to definitions used in other recent studies.

171 3.1. *Mathematics confidence*

172 Vale and Leder (2004) view students' attitudes to mathematics as being defined by the students'  
173 perceptions of their achievement (self-efficacy) and their aspiration to achieve in the disciplines.  
174 Galbraith and Haines (1998) see mathematics confidence as evidenced by students 'who believe  
175 they obtain value for effort, do not worry about learning hard topics, expect to get good results,  
176 and feel good about mathematics as a subject' (p. 278).

177 We have restricted our meaning of the term 'mathematics confidence' to a student's perception  
178 of their ability to attain good results and their assurance that they can handle difficulties in math-  
179 ematics. The students' views are canvassed directly through five brief items shown in Table 1. The  
180 item numbers include the letter p (for preliminary) to indicate it is the numbering of items in the  
181 preliminary questionnaire, rather than the final MTAS, which is given in Appendix A. Since we  
182 wish to monitor change over time rather than take a single snap shot of student attitudes, we have  
183 framed items that seek their immediate reactions rather than asking students either to reflect on  
184 the past or consider their aspirations for the future. We have decided that whether or not students  
185 'feel good about mathematics' (as in Galbraith and Haines' construct above) is sufficiently impor-  
186 tant to be separated from confidence and is considered under 'affective engagement'.

187 3.2. *Confidence with technology*

188 In this construct, Vale and Leder (2004) follow Forgasz (1995) in viewing students' attitudes  
189 to technology (in their case computers) as being defined by the students' perceptions of their  
190 achievement (self-efficacy) and their aspiration to achieve in these disciplines. This parallels  
191 the components of their construct of mathematics confidence. Galbraith and Haines (1998)  
192 take a different view, seeing technology confidence (again in their case this is computer confi-  
193 dence) as evidenced by students who 'feel self-assured in operating computers, believe they can  
194 master computer procedures required of them, are more sure of their answers when supported  
195 by a computer, and in cases of mistakes in computer work are confident of resolving the prob-  
196 lem themselves' (p. 278). The meaning we have assigned to this construct closely matches that  
197 of Galbraith and Haines and differs from Vale and Leder. Table 2 lists the items we chose.  
198 Within the time of this project it is anticipated that many of the students involved will use  
199 a variety of technology in their mathematics classes. For this reason we included item 2p which  
200 canvasses their confidence to use a broad range of commonly available technology. This also  
201 pointed to the construct of confidence with technology relating to life outside as well as inside  
202 the classroom.

Table 1  
Items in preliminary questionnaire assessing mathematics confidence (MC)

Item number	Statement for response (given five point scale)
5p	I have a mathematical mind
11p	I can get good results in mathematics
12p	I know I can handle difficulties in mathematics
16p	I am confident with mathematics
18p	I have less trouble learning mathematics than other subjects



Table 2

Items in preliminary questionnaire assessing confidence with technology (TC)

Item number	Statement for response (given five point scale)
1p	I am good at using computers
2p	I am good at using things like VCRs, DVDs, MP3s and mobile phones
3p	I can fix a lot of computer problems
4p	I would be more confident of my school work with a computer to help me
19p	I can master any computer programs needed for school

### 203 3.3. Attitude towards use of technology for learning mathematics

204 **Vale and Leder (2004)** measured ‘attitude to computer-based mathematics’ with 11 items, defin-  
 205 ing it as ‘the degree to which students perceive that the use of computers in mathematics provides  
 206 relevance for mathematics, aids their learning of mathematics and contributes to their achieve-  
 207 ment in mathematics’ (p. 291). **Galbraith and Haines (1998)** define a similar construct which they  
 208 call ‘computer and mathematics interaction’. They claim that in their context ‘Students indicating  
 209 high computer and mathematics interaction believe that computers enhance mathematical learn-  
 210 ing by the provision of many examples, find note-making helpful to augment screen based infor-  
 211 mation, undertake a review soon after each computer session, and find computers helpful in  
 212 linking algebraic and geometric ideas’ (p. 279).

213 In this case, our construct is closer to that of **Vale and Leder (2004)** than **Galbraith and Haines**  
 214 **(1998)**. We have focused broadly on interest and assistance to learning without expecting the more  
 215 sophisticated and specific reflections which Galbraith and Haines sought from tertiary students.  
 216 In this quick survey we do not expect 14 and 15-year-old students to analyse the ways in which  
 217 technology contributes to their learning of mathematics. If and when this level of detail may be  
 218 helpful, we will use interviews which allow for clarification of both questions and the students’  
 219 responses. While the simple items we constructed, shown in **Table 3**, use the term ‘graphics calcu-  
 220 lator’ other versions of this questionnaire replace this term with ‘computer’ or ‘computer algebra  
 221 system’, depending on the mathematical analysis tools used by the specific group of students sur-  
 222 veyed. Only items related to this construct are varied in this way.

### 223 3.4. Affective and behavioural engagement

224 Next we consider the two aspects of engagement. **Fredricks, Blumenfeld, and Paris (2004)** pro-  
 225 vide a comprehensive overview of literature relating to school engagement in general. They see

Table 3

Items in preliminary questionnaire assessing attitude towards use of technology for learning mathematics (MT)

Item number	Statement for response (given five point scale)
8p	I like using graphics calculators for mathematics
9p	I learn more when I use graphics calculators in mathematics
14p	Using graphics calculators in mathematics is worth the extra effort
15p	Mathematics is more interesting when using graphics calculators
20p	Graphics calculators help me learn mathematics better

Graphics calculator version; replace with computer or other technology as appropriate.

engagement as multifaceted with three components: *behavioural engagement* (positive conduct at school, involvement in learning and academic tasks, and participation in school-related activities), *emotional engagement* (affective reaction to school and classroom activities including boredom, happiness, and feelings of belonging) and *cognitive engagement* (psychological investment in learning or cognition and strategic learning). In our context (the learning of subject matter), we are concerned only with that part of school engagement which lies within the cognitive arena. Within this arena, we have decided to examine how students feel about the subject (which we call affective engagement, AE) and how they behave in learning the subject (which we call behavioural engagement, BE).

Vale and Leder (2004) refer to a concept similar to affective engagement as ‘girls/boys pleasure and computers’ but in their study data on this was collected from classroom observations rather than by questionnaire. Chapman (2003) constructed a scale to specifically measure affective engagement. She did this by having students’ respond on a five-point scale to items such as “Mathematics is boring” and “I like mathematics”. The items we see as assessing affective engagement are listed in Table 4. Like Chapman (2003) we have also chosen to construct simple items but allow for the fact that middle secondary years students have years of experience of learning mathematics and, based on this experience, have started to develop views about their learning.

Items for our scale of behavioural engagement (see Table 5) examine what students do to learn in class. Galbraith and Haines (1998) discuss a related concept of ‘mathematics engagement’. “Students who score highly on this scale [mathematical engagement] prefer to work through examples rather than learn given material, like to test understanding through exercises and problems, try to link new knowledge to existing knowledge, like to elaborate material with notes, and review their work regularly” (p. 280). We chose instead to focus on learning behaviour rather than on learning strategies, although the two concepts are related. This was in order to keep the con-

Table 4  
Items in preliminary questionnaire assessing affective engagement (AE)

Item number	Statement for response (given five point scale)
6p	I am interested to learn new things in mathematics
7p	In mathematics you get rewards for your effort
10p	Learning mathematics is enjoyable
13p	Mathematics is boring
17p	I get a sense of satisfaction when I solve mathematics problems

Table 5  
Items in preliminary questionnaire assessing behavioural engagement (BE)

Item number	Statement for response (given five point scale indicating how often)
21p	I really make an effort in my mathematics lessons
22p	I concentrate hard in mathematics
23p	I try to answer questions the teacher asks
24p	If I make mistakes, I work until I have corrected them
25p	If I can't do a problem, I keep trying different ideas
26p	I test my understanding by doing exercises and problems
27p	In mathematics I try to link new ideas to knowledge I already have



250 cepts canvassed in the questionnaire simple, leaving deeper exploration to other data collection  
251 devices. Our choices of items related to engagement were also informed by interviews with 10  
252 teachers who are involved with the project. We asked these teachers what they would see as evi-  
253 dence of increased student engagement with mathematics. Their responses were dominated by  
254 behavioural features similar in nature to the items shown. For the items listed in Table 5 we  
255 ask students to reflect on how frequently they behave in various ways in their mathematics classes.

#### 256 4. Compiling the scale

257 As indicated by Tables 1–5 above, the trial instrument consisted of 27 items. It was planned  
258 around five subscales: mathematical confidence [MC], confidence with technology [TC], attitude  
259 to learning mathematics with technology (whether computers, graphics calculators or computer  
260 algebra systems) [MT], affective engagement [AE] and behavioural engagement [BE]. A Likert-  
261 type scoring format was used for each of the subscales: MC, TC, MT and AE. Students were  
262 asked to indicate the extent of their agreement with each statement, on a five-point scale from  
263 strongly agree to strongly disagree (scored from 5 to 1). A different but similar response set  
264 was used for the BE subscale. Students were asked to indicate the frequency of occurrence of dif-  
265 ferent behaviours. A five-point system was again used – nearly always, usually, about half of the  
266 time, occasionally, hardly ever (scored again from 5 to 1). The content validity and face validity of  
267 the scale are assured by the development process, with all three authors debating the suitability of  
268 items, many of which were derived from previously published scales. A test–retest study of reli-  
269 ability has not been carried out.

#### 270 5. Evaluating the scale

271 This scale was trialled with 350 students from 17 intact classes in grades 8–10 at 6 secondary  
272 schools. These schools are typical of the range of secondary schools in Victoria (Australia) and  
273 include two private co-educational schools, two state co-educational schools and one girls' private  
274 school and one girls' state school. The schools vary from upper middle to low socio-economic sta-  
275 tus. For this trial we were not concerned with the unit of work being studied or to explore the  
276 hypothesized model of links between the variables in Fig. 1, merely to check the ease of admin-  
277 istration and to examine the psychometric properties of the subscales. Administration proved sim-  
278 ple, with few queries from teachers or their students, who completed it within 10–15 min.

##### 279 5.1. Factor structure and reliability of the preliminary and MTAS scale

280 The items for the scale were constructed with five factors in mind, as indicated above. Factor  
281 analysis of the preliminary scale confirmed the five-factor structure, with all but a few items (dis-  
282 cussed below) contributing as planned to the scale. However, the factor and reliability analysis,  
283 together with examination of inter-item correlations, further suggested that the scale could be sim-  
284 plified to five factors with four items per factor. This modification results in a scale which is both  
285 quick and very easy to use. We call the selected item set *Mathematical and Technology Attitudes*

286 *Scale* (MTAS) and it is included as [Appendix A](#). Users of the MTAS can easily obtain each sub-  
287 scale score by adding the responses to the four items. Students can complete it within 10 min.

288 After the initial factor analysis and reliability analysis, seven items were deleted from the set.  
289 Omitting items 4p, 18p and 21p from the TC, MC and BE sets led to increased Cronbach's alpha  
290 in the respective subscales. In the MT subset, item 9p correlated highly with items 4p, 8p, 15p and  
291 20p and was therefore redundant and hence could be omitted. In the initial factor analysis, item  
292 13p ("Mathematics is boring") linked more closely with MC than with its intended AE. Item 13p  
293 was also the only negatively worded item and as such was open to coding error by future users. It  
294 was therefore omitted. While there was no strong positive or negative statistical consequence of  
295 the choice of the two further items to delete from the BE subset, items 26p and 27p focus on deeper  
296 aspects of learning style and cognitive engagement than other items, and are therefore omitted.  
297 Factor analysis and reliability analysis were then re-applied to the resulting 20-item MTAS.

298 Statistical analysis using data from 350 complete students' responses to the 20 items forming the  
299 MTAS indicates that this data satisfies the underlying assumptions of Principal Components  
300 Analysis and that together five factors (each with eigenvalue greater than 1) explain 65% of the  
301 variance, with almost 26% attributed to the first factor, MC. Reliability analysis yields satisfactory  
302 Cronbach's alpha values for each subscale (MC, .87; MT, .89; TC, .79; BE, .72 and AE, .65). This  
303 indicates a strong or acceptable degree of internal consistency in each subscale.

## 304 **6. Using the MTAS to explore school and gender variation**

305 MTAS subscale scores can be calculated by simple addition of responses. With a maximum  
306 possible score on any subscale of 20 and a minimum of 4, we consider scores of 17 or above to  
307 be high, indicating a very positive attitude, 13–16 to be moderately high and 12 or below to be  
308 a low score reflecting a neutral or negative attitude to that factor.

### 309 *6.1. Variation of MTAS scores amongst schools*

310 In this section we report on the responses of different schools on the MTAS variables (20 items  
311 only), again from the sample of 350 students. [Fig. 2](#) gives the box plots for all subscales, and then,  
312 for each of the schools, on each MTAS subscore. The number of students responding at each  
313 school varies from 16 (School F) to 152 (School C) with an average of 59 students per school.

314 The boxplots for the school results show no obvious links between the five subscales. Scores on  
315 three of the subscales (affective engagement AE, behavioural engagement BE and confidence with  
316 technology TC) have similar medians at all schools, and students have generally high or moder-  
317 ately high scores. Whilst the high scores for the self-reported behavioural engagement might be  
318 expected, it is good to see that only in one school (E) did more than 25% of students score less  
319 than 12 in affective engagement (AE) (i.e., lower average than the neutral response), and in all  
320 of the schools at least 75% of students scored more than 12 on confidence with technology  
321 (TC). Given the uniform means on the first three subscales, it is interesting to observe the varia-  
322 tion between schools in mathematics confidence (MC) and attitude to learning mathematics with  
323 technology (MT).

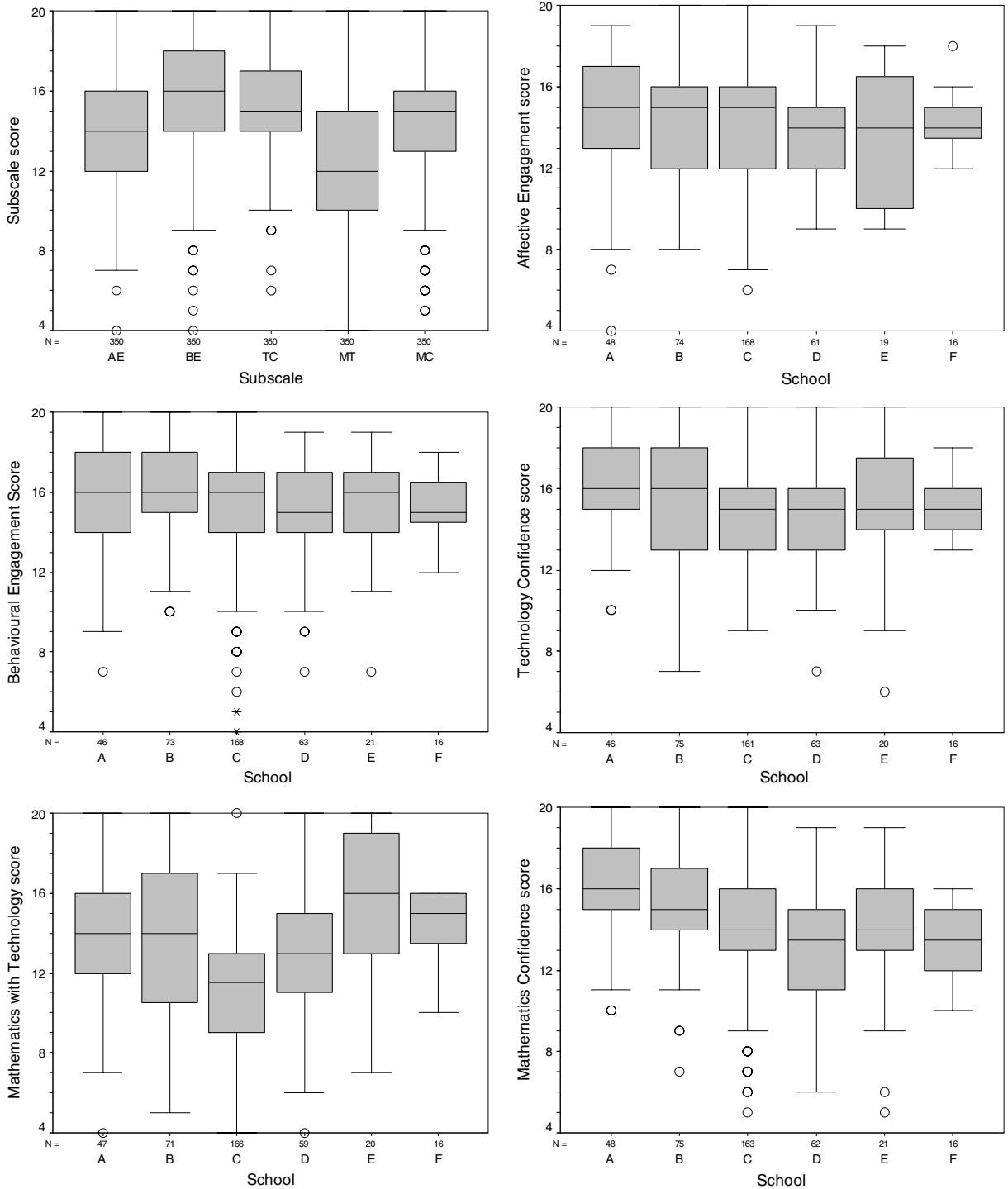


Fig. 2. Box plots showing distribution of MTAS subscale scores for 350 students and for each subscale by school.

324 The scores on MT are the most interesting for this paper. At four schools, some students gave  
325 the maximum possible score. At two schools, some students gave the minimum possible score.  
326 Students' opinions on learning mathematics with technology are therefore divided, even within  
327 schools. We might discount the results from School C because at the time of the survey, these stu-  
328 dents had little experience of learning mathematics with technology. However, we cannot discount  
329 the results from School B, where technology use is well established in mathematics classes. At the  
330 time of the survey, School E had just finished their first experience of using graphics calculators in  
331 mathematics: this good experience may explain the high scores, although the long tail is also pres-  
332 ent once again indicating that there is considerable variability in students' evaluations of learning  
333 mathematics with technology. Some of this variability may be due to consistent differences be-  
334 tween boys and girls. For example, in their study of a small sample of students of a similar age  
335 and similar location to the present study, [Vale and Leder \(2004\)](#) found that boys view com-  
336 puter-based mathematics lessons more favourably than girls. Gender differences are therefore  
337 examined in the next section.

## 338 6.2. Gender differences

339 Gender differences in attitudes to mathematics have long been of interest ([Fennema & Sherman](#)  
340 [\(1976\)](#) is an early study), and a question of current interest is whether using technology to learn math-  
341 ematics exacerbates differences. This section therefore reports results on the five subscales by gender.  
342 In order to remove between-school influences from the data, only the responses from the four co-  
343 educational schools are considered in this section. This means that the boys and girls in the sample  
344 have experienced the same learning environments. One hundred and forty-one (70 boys and 71 girls)  
345 completed all items although more students (152 total) completed all items of some subscales.

346 The breakdown of these scores by gender, illustrated in [Fig. 3](#), reveals that boys have statisti-  
347 cally significantly higher scores than girls for each subscale except BE ( $t = -.005$ ,  $df = 151$ ,  
348  $p = .996$ ). The differences are greatest for TC ( $t = 6.84$ ,  $df = 152$ ,  $p = .000$ ) and MC ( $t = 6.13$ ,  
349  $df = 155$ ,  $p = .000$ ) with MT ( $t = 2.85$ ,  $df = 149$ ,  $p = .005$ ) and AE ( $t = 2.56$ ,  $df = 152$ ,  $p = .011$ )  
350 demonstrating less difference. While 50% of boys score 16+ on MC, this was true for only 25%  
351 of girls. TC scores are even more strongly higher for boys, with approximately 75% of boys scor-  
352 ing 16+ and only 25% of the girls. These results reflect the common finding that boys express  
353 greater confidence than girls, but they contrast with those of [Vale and Leder \(2004\)](#) who found  
354 gender differences only on their variable corresponding to MT. It is important to note that not  
355 all the students with negative attitudes to learning mathematics with technology are girls. The dis-  
356 tributions of MT have a long tail for both boys and girls and high inter-quartile ranges (the high-  
357 est for the boys' scores). The high variability in MT is therefore not explained by gender  
358 differences: we need to look beyond learning environment and gender to explain the range of stu-  
359 dents' evaluations of the effectiveness of learning with technology.

360 [Table 6](#) presents the correlations between the subscale scores for the 141 students from the co-ed  
361 schools, and also for males and females separately. There are statistically significant positive corre-  
362 lations (weak or moderate) between all pairs of AE, BE, MC and TC. The correlations between AE,  
363 BE and MC may be explained by their common concern with school mathematics. The correlations  
364 with TC are perhaps surprising, but may possibly be explained by a home background factor, link-  
365 ing inclination to school mathematics with technical interests and equipment in the home.

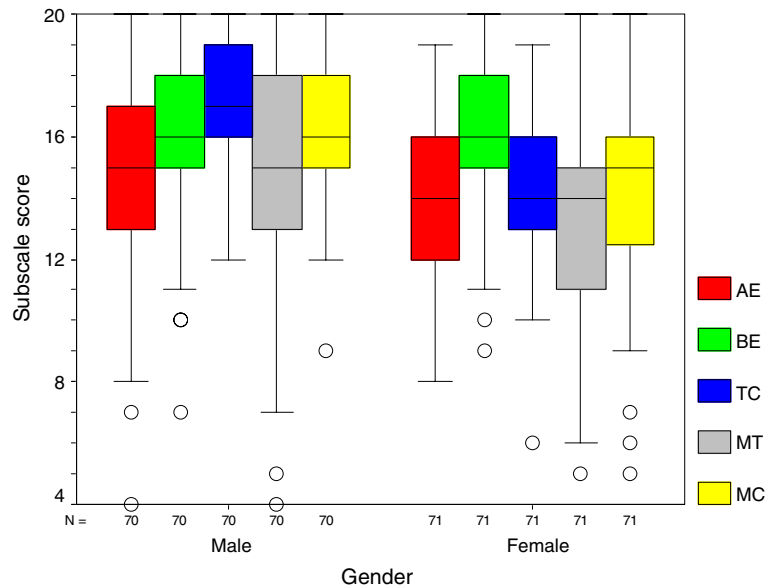


Fig. 3. MTAS scores for subscales by gender.

Table 6  
Correlations for males and females between MTAS subscale scores

		BE	TC	MT	MC
AE	Combined	.471**	.308**	.021	.549**
	Male	.307**	.266*	.171	.605**
	Female	.506**	.284**	-.082	.529**
BE	Combined		.240**	.012	.452**
	Male	1	.289*	.131	.271*
	Female		.217**	-.047	.492**
TC	Combined			.240**	.509**
	Male		1	.358**	.489**
	Female			.064	.427**
MT	Combined				-.033
	Male			1	.116
	Female				-.223**

\* Correlation is significant at the .05 level (2 tailed).

\*\* Correlation is significant at the .01 level (2 tailed).

366 The variable MT is, with two exceptions, not significantly correlated with the others. How-  
 367 ever, it is correlated positively with TC for boys and negatively with MC for girls. The posi-  
 368 tive correlation for boys is consistent with the findings of Vale and Leder (2004), although as  
 369 noted above, their measure of “computing achievement” is somewhat different. The significant  
 370 negative correlation for girls with mathematics confidence is in the opposite direction to the

(non-significant) correlation found in the Vale and Leder study. We have two explanations for its negative direction. It may be that there is a weak tendency for those girls whose confidence is based on their self-perception that they can learn to follow rules diligently, not to value technology for learning mathematics because it may take over from them this same accurate performance of routine procedures. An alternative explanation is that there is a weak tendency for girls who do not feel confident about mathematics to value using technology for learning mathematics more. Both of these situations have been reported in case study data by Pierce and Stacey (2004). The data available does not provide conclusive evidence to decide which, if either, of the two explanations applies more frequently and hence might cause the negative correlation. However, examination of the scattergram for MT and MC for girls demonstrates that group of the lowest confidence girls generally value technology for learning, lending support to the second explanation. However the scattergram also shows that the most confident group of girls exhibit a range of valuing of technology, which may be due to different reactions from girls whose high confidence is differently based; which is consistent with the first explanation. These explanations therefore warrant further investigation. Whereas boys may experience learning mathematics more positively simply because technology is present, some girls may value it when they feel it has the potential to compensate for self-perceived shortcomings.

In interpreting all the gender differences, it is important to note that only a few girls actually expressed negative responses (total score less than 12) to any of the factors. It is not that the girls' scores are very low, rather that there was a more highly positive response from the boys.

In every school, most students agreed rather than disagreed that it was better to learn mathematics with technology. These results suggest that this scale is proving to be suitable for discriminating differences between cohorts of students and hopefully for indicating change over time with repeated administration.

## 7. Conclusion

This paper outlines the rationale for, construction, analysis and application of a simple scale for assessing students' attitudes to mathematics, technology and the learning of mathematics with technology. The Mathematics and Technology Attitudes Scale (MTAS) questionnaire consists of only 20 short items and can be administered in less than 10 min. The analysis is simple, since the scores on the items are simply added to get the subscale scores. Modification of the last four items tailors the scale for students who regularly use computers, graphics calculators or other mathematical analysis tools. If desired, the MT items can be repeated in different versions to measure attitudes to learning with another technology. They are placed last on the scale to make this easier.

Administering the scale to students in 6 schools provided information about differences between schools and genders, and also gave some clues as to what variables contribute and do not contribute to students' evaluation of the effectiveness of learning mathematics with technology. As we work through the potential opportunities offered by technology for enhancing the teaching and learning of mathematics it is important that all aspects are monitored. This scale provides an instrument that can be used in classrooms by either teachers or researchers interested in trialling teaching innovations which include the use of new technology.



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416 **Appendix A. Mathematics and Technology Attitudes Scale**

417 (Final version showing the usually invisible subscale membership of items)

418 **FIVE SUBSCALES:** mathematics confidence [MC], confidence with technology [TC], attitude  
 419 to learning mathematics with technology [MT], affective engagement [AE] and behavioural  
 420 engagement [BE]. To tailor MT items to a particular class, change the words “graphics calcula-  
 421 tors” to the technology used by that class (e.g., computers, graphics calculators, computer algebra  
 422 systems). Do not change TC items.

423

		Hardly Ever	Occasionally	About Half the time	Usually	Nearly Always
1.	I concentrate hard in mathematics [BE]	HE	Oc	Ha	U	NA
2.	I try to answer questions the teacher asks [BE]	HE	Oc	Ha	U	NA
3.	If I make mistakes, I work until I have corrected them. [BE]	HE	Oc	Ha	U	NA
4.	If I can't do a problem, I keep trying different ideas. [BE]	HE	Oc	Ha	U	NA
		Strongly disagree	Disagree	Not sure	Agree	Strongly agree
5.	I am good at using computers [TC]	SD	D	NS	A	SA
6.	I am good at using things like VCRs, DVDs, MP3s and mobile phones [TC]	SD	D	NS	A	SA
7.	I can fix a lot of computer problems [TC]	SD	D	NS	A	SA
8.	I am quick to learn new computer software needed for school [TC]	SD	D	NS	A	SA
9.	I have a mathematical mind [MC]	SD	D	NS	A	SA
10.	I can get good results in mathematics [MC]	SD	D	NS	A	SA
11.	I know I can handle difficulties in mathematics [MC]	SD	D	NS	A	SA
12.	I am confident with mathematics [MC]	SD	D	NS	A	SA
13.	I am interested to learn new things in mathematics [AE]	SD	D	NS	A	SA
14.	In mathematics you get rewards for your effort [AE]	SD	D	NS	A	SA
15.	Learning mathematics is enjoyable [AE]	SD	D	NS	A	SA
16.	I get a sense of satisfaction when I solve mathematics problems [AE]	SD	D	NS	A	SA

(continued on next page)

Appendix A (continued)

		Hardly Ever	Occasionally	About Half the time	Usually	Nearly Always
17.	I like using graphics calculators for mathematics [MTg]	SD	D	NS	A	SA
18.	Using graphics calculators in mathematics is worth the extra effort [MTg]	SD	D	NS	A	SA
19.	Mathematics is more interesting when using graphics calculators. [MTg]	SD	D	NS	A	SA
20.	Graphics calculators help me learn mathematics better [MTg]	SD	D	NS	A	SA

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