Technology, attitude and mathematics: a descriptive examination of the literature spanning three decades

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Abstract: An extensive literature base exists on the use of technology in mathematics and its effect on student learning; however, no comprehensive reviews have been published on how affective characteristics (specifically attitude) might factor into these results. This review presents a thorough descriptive examination of the literature on attitude and achievement of elementary and middle school students when using technology in mathematics. The literature was examined from 1983 to 2013 to synthesise (a) populations, (b) settings, (c) types of technology used, (d) operational definitions of attitude, (e) assessment of attitude and mathematical content domains, (f) research designs used, and (g) length of interventions. Twenty-five datasets, representing 25 published manuscripts, were included in the review. Implications of the findings are discussed.

Keywords: technology; mathematics; affective characteristics; attitude; elementary; middle.


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Technology, attitude and mathematics

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1 Introduction

The importance of using innovative and educationally beneficial technology in the classroom is widely recognized (National Governors Association Center for Best Practices and Council of Chief State School Officers, 2010; Noeth et al., 2004; U.S. Department of Education, 2010). Technology has changed drastically in the past several decades evolving from use for drill and practice in the 1980s to current day application. Currently, technology plays numerous roles in classrooms across the nation and “varies dramatically depending on the funding priorities of the states, districts, and schools and individual educators’ understanding of how to leverage it in learning in meaningful ways” (U.S. Department of Education’s National Education Technology Plan, 2010, p.9). Technology can accelerate students’ rate of learning, reduce costs associated with program delivery, better utilise teacher time, and help level the playing field - particularly across racial, gender, and geographic divides (Noeth et al., 2004; U.S. Department of Education, 2010). The advent of universal design has made technology increasingly accessible for all types of learners (Center for Applied Special Technology [CAST], 2012). Despite such promise, research reveals mixed results regarding the effectiveness of technology as it relates to educational equity and achievement (Barton, 2001; CEO Forum on Education and Technology, 2001; Cuban, 2001; Fitzgerald et al., 2008; Slavin and Lake, 2009). Experts attribute these findings to numerous variables, including the types of supports provided by the technology (Crawford et al., 2016), teacher and/or student training, effective use of technology as an instructional tool (Noeth et al., 2004), and the ability of students to independently use technology (Mulwa et al., 2010).

The National Council of Teachers of Mathematics (NCTM) Technology Principle states, “Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances student learning” (2000, p.24). It can be a
powerful tool used to promote critical, analytic, and higher-order thinking skills, provide drill and practice, and engage students in real-world problem solving (Cemal Nat et al., 2011). Several meta-analyses and best evidence syntheses have been conducted in recent years examining the use of technology in elementary and secondary mathematics education (Cheung and Slavin, 2013; Li and Ma, 2010; Rosen and Salomon, 2007; Tamim et al., 2011). Findings from these studies reported small to moderate overall effect sizes when using technology in mathematics education. For example, Li and Ma (2010) provided promising evidence for the use of technology in enhancing mathematics achievement in K-12 (ES = .28), and Cheung and Slavin (2013) reported that educational technology applications produced a positive, but small effect (ES = .15) on mathematics achievement.

1.1 Technology use, student learning, and the role of attitude

Existing research provides a thorough examination of the relationship between technology use in mathematics and achievement; however, other student-specific factors must be considered when incorporating technology into learning environments, such as student affective characteristics. Affective characteristics are described as “human qualities that are primarily emotional in nature: attitudes, interests, values, preferences, self-esteem, focus of control, and anxiety are but a few” (Anderson and Anderson, 1982, p.524). These characteristics influence students’ learning behaviours, interests, and impact their academic achievement (Marzano, 2000; McMillan, 2011). Establishing a positive affect toward learning and content area subjects such as mathematics early in a student’s academic career can enhance the development of an individual’s willingness to learn and engage in instructional content (Marzano, 2000; Rimland, 2013). Therefore, creating positive attitudes, self-efficacy, and motivation in primary education proves necessary to promote engagement in secondary mathematics education. However, many have pointed out that very little attention has been given to systematically assessing these characteristics in the classroom (McMillan, 2011; McMillan et al., 1999; Stiggins and Conklin, 1992).

One affective characteristic that has been consistently examined is attitude. Historically, attitude has been deemed one of the most important constructs to examine due to several factors including the role it plays in predicting future behaviour (Allport, 1935; Fishbein and Ajzen, 1975; McGuire, 1969; Pratkanis et al., 1989). Attitudes reflect a way of thinking or feeling that can be revealed in a person’s behaviour. In the classroom, positive attitudes are reflected in increased efforts in learning engagement, and greater persistence (Marzano, 2000; Pierce et al., 2007). Although attitude has proven to play a crucial role in the learning process, a universal operational definition is non-existent which can make some findings difficult to measure, interpret or generalise.

1.2 Students’ attitude in mathematical learning

Perceptions, attitudes, and expectations of students regarding mathematical concepts and teaching have been considered to be significant factors underlying school experience and achievement (Borasi, 1990; Kılıç et al., 2009; Ma, 1999; Mato and De La Torre, 2010; Shoenfeld, 1985). Eshun (2004, p.2) defines an attitude toward mathematics as “a disposition towards an aspect of mathematics that has been acquired by an individual through his or her beliefs and experiences but which could be changed.” These emotional dispositions directly relate to individual behaviour – if an individual has confidence in a subject or finds it useful they are more likely to be successful (Eshun, 2004; Zan and
Martino, 2008). Therefore, positive attitudes toward mathematics are desirable because of the direct relationship between attitude, one’s willingness to learn, and the benefits one can derive from mathematics instruction (Eshun, 2004).

Student attitudes toward mathematics and their understanding of the relevance of mathematics topics to future aspirations affect their enthusiasm for studying mathematical content (National Science Foundation [NSF], 2015). Moreover, establishing a positive attitude towards mathematics is a factor in having strong performance in mathematics, high mathematical self-perception, and persistence on difficult tasks (Adelson and McCoach, 2011; Limbaco, 2015; Ma and Kishor, 1997). Positive attitudes toward mathematics influence motivation to learn mathematics and pursue STEM careers (Maltese and Tai, 2011; NSF, n.d.; Thorndike-Christ, 1991). It has been consistently reported that students’ attitudes towards mathematics become more negative over time (Murugan and Rajoo, 2013). Therefore, research shows the importance of establishing positive attitudes towards mathematics early in a student’s academic experience.

1.3 Attitudes towards the use of technology

Students’ attitudes toward technology are indicative of a willingness to incorporate it into the learning process and use it as resource or strategy when acquiring knowledge (Alghazo, 2006; Fco and Garcia, 2001; Pelgrum, 1996; Sanders and Morrison-Shetlar, 2001). An individual’s attitude towards technology can be based on a number of factors, including computer self-efficacy, anxiety, quality and perceived use of the learning platform, teacher attitude towards technology use, as well as a student’s computer skill level (Aixia and Wang, 2011; Christiansen, 2002; Chu and Chu, 2010; Fuller et al., 2006; Pituch and Lee, 2006; Sun et al., 2008). Studies have shown that students perceive technology to be relevant in their lives and feel positive about using technology when learning (Furlong et al., 2000; Jones and Issroff, 2005; Pelgrum, 1996; Rhema and Miliszewska, 2014). Therefore, we can conclude that technology has academic benefits as well as the potential to positively affect student attitudes about learning.

1.4 Purpose

The integration of technology into mathematics education has been effective and continues to be recognised as a priority for influencing student outcomes (Cheung and Slavin, 2013; Ke, 2008; Li and Ma, 2010; NCTM, 2000). Affective characteristics, such as attitude, are considered to be a fundamental element for student learning and engagement (Galbraith and Haines, 1998; Picard et al., 2004; Rimpland, 2013). Attitude is known to predict future behaviour, and thus establishing positive attitudes early in a student’s academic career is crucial for academic success. Several individual studies have been conducted with elementary and middle school populations examining the use of technology in mathematics and how this affects a students’ attitude and mathematical outcomes. However, no comprehensive understanding of literature in this area exists. The purpose of this review was to gain a better understanding of studies which have examined attitudes and achievement when using technology in mathematics for elementary and middle school students. Given the important role of attitude, it is critical to understand how this construct is defined and assessed with respect to mathematics and technology use (e.g. attitude towards math, attitudes towards technology), changes in this construct when technology is used to support mathematics learning, and if studies report
changes to students’ mathematical achievement or skills. A secondary and related purpose involved investigating the characteristics of each study (i.e. type of research designs used; technology used, intervention duration, sample size, demographics, measures) in order to provide suggestions for future research that explores the use of technology in mathematics and the importance of student attitude as related to technology use and mathematical learning.

2 Method

The literature review had two distinct phases. Phase one included the creation of the initial database to organise articles, generating operational definitions for variables used in the review, database search, initial eligibility screening of articles, a secondary document search (e.g. ancestor search), and final eligibility determination of all identified articles. Phase two focused on the coding of multiple variables from each article.

2.1 Phase one: search and identification of eligible articles

2.1.1 Initial search strategies

The first search method for the literature review was an electronic database search of PsychINFO, ERIC, JSTOR, Academic Search Complete and SAGE. The following search terms were used with mathematic* in one search field technology* in the second search field, and one of three topics (motivation, self-efficacy, and attitude) in the third field. The * is a “wild-card” term that was used to search for suffixes (i.e. al, s). The initial electronic database search resulted in 12,922 articles. Next, researchers read the title and abstract of each article for further inclusion, using the following initial eligibility criteria: (a) technology was the primary intervention, (b) article was published in a peer-reviewed journal from 1983 to 2013 (to capture three decades of research), (c) study included sample of students that were between the grades of kindergarten through Grade 8, and (d) study included the construct of attitude and mathematics discussed in the abstract. Inter-rater reliability was established among raters until a criterion of 80% reliability was met. Inter-rater reliability agreements were calculated for 20% of the abstracts and titles. Agreements were above 80% (see below for details on reliability agreement procedures). This initial eligibility screen resulted in 66 articles meeting the criteria for further review.

2.1.2 Secondary document search strategies

To be certain that all possible articles were included in the review, the reference sections for all 66 articles meeting the initial eligibility screening process were reviewed for additional relevant publications. For all articles that were located through this ancestor search, reference sections were also checked for any additional articles that appeared to meet the established criteria. These secondary search strategies resulted in the identification of seven additional articles, resulting in a total of 73 articles that met the initial eligibility criteria.
2.2 Phase two: coding procedures for information in articles

The next step was to identify the articles that met the full-inclusion criteria for the review of interventions using technology in mathematics and assessed the construct of attitude using a systematic coding process. Three graduate students independently read through assigned articles to determine if it satisfied all inclusion criteria. This included that the study: (a) assessed mathematics in some capacity (e.g. overall achievement, specific concepts or skills), (b) assessed attitude related to mathematics or technology use, and (c) used a form of technology as the primary intervention.

2.2.1 Coding approach

All articles were coded using a systematic set of procedures (Duppong Hurley et al., 2014; Reid et al., 2004). A total of 29 variables were coded for each article. Six variables provided initial information about the article, eight were related to the study population, eight were related to the methods portion of the study, three were used for the study’s results, and four were related to technology (see Table 1). The coding data were entered into a web-based program (Qualtrics), exported to MS Excel (Microsoft, 2010) for data cleaning, inspection, and analyses, and summarised using SPSS (IBM Corp, 2013). After applying these full-inclusion criteria, 48 of the original 73 articles were removed from the process.

Table 1 Coded variables

<table>
<thead>
<tr>
<th>Article information</th>
<th>Study population</th>
<th>Study methods</th>
<th>Study results</th>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Year published</td>
<td>1) Age or grade level reported for participants</td>
<td>1) Operational definition present</td>
<td>1) Effect size reports</td>
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<tr>
<td>2) Author(s)</td>
<td>Sample size</td>
<td>2) Affective constructs assessed</td>
<td>2) Individual data analysis results</td>
<td></td>
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<tr>
<td>3) Location of article (database, ancestor)</td>
<td>Gender</td>
<td>3) Mathematical content strand and concept</td>
<td>4) Personalised</td>
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<tr>
<td>4) Affective constructs focused on in the article</td>
<td>Ethnicity</td>
<td>4) Technology intervention used</td>
<td>Environment</td>
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<td>5) Exclude article</td>
<td>Disability status</td>
<td>5) Mode of intervention delivery</td>
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<tr>
<td>6) Reason for exclusion</td>
<td>Occurred in the USA</td>
<td>6) Duration of intervention</td>
<td>3) Additional findings</td>
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<tr>
<td></td>
<td>Type of school environment</td>
<td>6) Design of the study</td>
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<tr>
<td></td>
<td>Where the study took place</td>
<td>7) Dependent measures</td>
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<td>8) Data analytic approaches</td>
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</table>

Note: Study design was coded based on author report; however, if a design was not identified, researchers coded the article design using definitions found in Salkind (2012).
The 48 articles that did not meet full criteria for this review were excluded for the following reasons: mathematics was not directly assessed (39.5%), attitude was not assessed (41%), technology was not the primary intervention (21.0%), participants were too old (5.4%), study took place outside of the 30-year parameter discussed previously (2.6%), or was not an actual research study (2.6%). For the 25 remaining articles that did meet criteria, 16% were published between 1985 and 1994, 8% were published between 1995 and 2004, and 76% were published between 2005 and 2013.

2.2.2 Reliability

All articles were double coded and inter-rater agreement was assessed on 12 of the articles. Inter-rater agreement required two reviewers to read and code the articles. The decisions were then compared for each variable on the coding sheet and disagreements were discussed. In the event of an inconsistency, a third reviewer read and coded the article (Reid et al., 2004). Prior to coding independently, a threshold of 80% inter-rater reliability was established.

3 Results

This review of the literature resulted in the identification of 25 articles containing one study each that assessed elementary and middle schools students’ use of technology in mathematics as related to achievement and at least one of three affective characteristics. The results presented in Table 2 provide information from coded variables as well as the findings within each respective study.

3.1 Population

Of the included studies the majority of studies reported grade level (92%), just over half of the studies (52%) were conducted with elementary students (i.e. kindergarten through 5th grade), well over half of the studies reported gender (60%), and reported race/ethnicity (56%). Three of the studies included or reported on disability status of participants. Finally, sample sizes ranged 15 to 358 participants.

3.2 Dependent variables

None of the studies conveyed an operational definition for the construct of attitude. Twelve studies evaluated attitudes about mathematics, seven examined attitudes about technology, and six evaluated attitudes about both mathematics and technology. Six studies evaluated a combination of affective characteristics which included the construct of attitude. This consisted of three examining motivation and attitude and three examining attitude and self-efficacy.

When examining achievement and skills with respect to mathematical content areas, the NCTM Content Standards (NCTM, 2000) and related concepts were used to collapse information. Fifteen studies focused on Numbers and Operations, three were on Algebra content, one on Geometry, one on Data Analysis and Probability, one Expressions and Equations, four had multiple content areas, and one did not specify a content area.
<table>
<thead>
<tr>
<th>Authors</th>
<th>Subjects</th>
<th>Intervention</th>
<th>NCTM domain &amp; concept area</th>
<th>Dependent variable(s)</th>
<th>Measures</th>
<th>Study design &amp; results</th>
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</thead>
<tbody>
<tr>
<td>Anand and Ross, 1987</td>
<td>(N = 96)</td>
<td>5th and 6th grade</td>
<td>Duration: One instructional session, length of time varied by participant</td>
<td>Numbers and Operations: Fractions</td>
<td>- Achievement: California Achievement Test (3 subscale scores)</td>
<td>Quasi-Experiment Results – Positive Personalised group scored significantly higher on achievement post-test and had more positive attitudes than other intervention groups and control group</td>
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<td></td>
<td></td>
<td>- Technology-assisted instruction</td>
<td></td>
<td>- Mathematics Achievement</td>
<td>- Attitude: 8 item, 5-point Likert Scale</td>
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<td></td>
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<td>- Type of Technology: Computer</td>
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<td>- Four Groups: 1) Personalised background context for questions</td>
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<td>2) Concrete context for questions</td>
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<td>3) Abstract context for questions</td>
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<td>4) Control group: no extra instruction</td>
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<tr>
<td>Chen and Liu, 2007</td>
<td>(N = 165)</td>
<td>4th grade</td>
<td>Duration: Four weeks, one session per week, 50 min per session</td>
<td>Numbers and Operations: Word Problems</td>
<td>- Skills: 24 item (16 one-step; 8 two-step) math problem-solving</td>
<td>Quasi-Experiment Results – Positive Students using personalised computer programs made larger gains in math skills and had more positive attitudes than non-personalised programs</td>
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<td></td>
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<td>- Technology-assisted instruction</td>
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<td>- Mathematics Skills</td>
<td>- Attitude: pre/post-test 11 item four scale survey measuring both math and technology</td>
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<td>- Type of Technology: Computer</td>
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<td>- Attitude about math &amp; technology</td>
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<td>- Two groups: 1) Personalised CAI</td>
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<td>2) Non-personalised CAI</td>
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<tr>
<td>Dalton and Hannafin, 1988</td>
<td>(N = 117)</td>
<td>8th grade</td>
<td>Duration: Three sessions</td>
<td>Geometry</td>
<td>- Achievement: 10 item test on area of circle, 20 item multiple choice post-test on area</td>
<td>Experiment Results – Mixed Remediation methods were significantly more effective than non-remediation methods in improving math skills; students showed the most improvement in achievement when initial instruction different from remediation; no differences in attitude for all groups</td>
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<td></td>
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<td>- Technology-assisted instruction</td>
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<td>- Mathematics Achievement</td>
<td>- Attitude: Revised Math Attitude Scale, 5-point Likert Scale</td>
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<td>- Type of Technology: Computer</td>
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<td>- Attitude about math</td>
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<td>- Five groups: 1) Traditional instruction &amp; traditional remediation</td>
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<td>2) Traditional instruction &amp; computer remediation</td>
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<td>3) Computer instruction &amp; traditional remediation</td>
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<td>4) Computer instruction &amp; computer remediation</td>
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<td>5) Control group – instruction only, no remediation</td>
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<tr>
<td>Authors</td>
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</table>
| Gillispie et al., 1992 | $N = 28$ (6th-8th grade 11-14 years old) | - Duration: Three sessions, 40–60 minute per session  
- Technology-assisted instruction  
- Type of Technology: Computer  
- One group used DimensionM 3-D mathematics instructional game | Algebra              | - Mathematics Achievement  
- Attitudes about math & video games | - Achievement: 10 item multiple choice  
- Attitude: 10 item 4-point Likert Scale; 2 open ended items  
- Researcher observations  
- Interviews | Pre-Experiment (One Group Pre/Post-Design); Mixed Methods Data  
Results – Mixed significant gains on math achievement; no gains in attitude; analysis of observations and interviews note a positive impact on students’ attitude and performance |
| Hennessy, 2000   | $N = 48$ (13–14 years old) | - Duration: Three weeks, six sessions, 55 minutes per session  
- Technology-assisted instruction  
- Type of Technology: Pocket Book (PDA with word processing, graphing, spreadsheets, & calculator)  
- One group used Pocket Book to record, graph, and predict weather | Data Analysis and Probability: Graphing | - Mathematics Skills  
- Attitude about technology, computer use | - Skills: student data collected from Pocket Book related to topic (e.g., mean, calculating intercept); 6 skills assessed for 14-year-olds, 4 skills assessed for 13-year-olds  
- Attitude: 8 item 5-point Likert Scale | Pre-Experiment (One Group Pre/Post-Design); Qualitative Data  
Results – Mixed gains in 5 of 6 mathematical skills for 14-year-olds and all 4 math skills for 13-year-olds; no significant overall gains in attitude |
| Hwang et al., 2006 | $N = 36$ (6th grade) | - Duration: One semester, 90 minutes per week  
- Technology-assisted instruction  
- Type of Technology: Multimedia whiteboard system  
- One group used the multimedia whiteboard | Numbers and Operations: Fractions | - Mathematics Skills  
- Attitude about technology | - Skills: students’ correctness of response when using the whiteboard during intervention  
- Attitude: 25 item 5-point Likert Scale | Quasi-Experiment (One group pre/post-design), Mixed Methods Data  
Results – Mixed gains in attitude about using technology; no significant difference in correctness |
<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Jackson et al., 2013</td>
<td>(N = 53) 4th grade</td>
<td>- Duration: 15 weeks, 2 sessions per week, 30–40 min per session, interacted with technology for 10 min/session - Technology-assisted instruction - Type of Technology: Computer Supported Collaborative Learning (CSCL) interactive tabletop - Two Groups: 1) CSCL 2) Regular instruction</td>
<td>Numbers and Operations: Fractions</td>
<td>- Mathematical Knowledge - Attitude about technology, group work, or classmates</td>
<td>- Knowledge: student’s overall math grade throughout the school year - Attitude: 16 item 5-point Likert Scale</td>
<td>Experiment Results – Mixed: No change in attitudes across time or group; mixed support for increasing knowledge (significant increases for boys)</td>
</tr>
<tr>
<td>Kay and Edwards, 2012</td>
<td>(N = 136) 6th–8th grade</td>
<td>- Duration: Session began with pre-test, 10-minute video, then post-test - Technology-based instruction - Type of Technology: Computer – video podcasts - One group</td>
<td>Expressions and Equations</td>
<td>- Mathematics Performance - Attitudes about technology</td>
<td>- Performance: Pre/post-test targeting the concepts addressed in the video - Attitude: 17 item 5-point Likert Scale</td>
<td>Pre-Experiment Results – Positive: Significant gain in learning performance; positive attitudes towards podcasts</td>
</tr>
<tr>
<td>Ke, 2008a</td>
<td>(N = 15) 4th and 5th grade 10–13 years old</td>
<td>- Duration: Five weeks in summer, 10 sessions, 2 hours per session - Technology-assisted instruction - Type of Technology: Computer - One group played ASTRA EAGLE computer game</td>
<td>Numbers and Operations: Computation Skills</td>
<td>- Mathematics Skills - Attitudes about math</td>
<td>- Skills: Game Skills Arithmetic Test (GSAT), 30 items - Attitude: Attitudes Toward Math Inventory (ATMI), 40 item, 5-point Likert Scale - In-field observation - Document Analysis - Think-a-loud verbal protocol</td>
<td>Mixed Methods Results – Positive: Attitudes towards math more positive over the course of the intervention; no significant gains in math skills</td>
</tr>
<tr>
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</table>
| Ke, 2008b               | (N = 358) 5th grade | - Duration: Four weeks, two sessions per week, 45 minutes per session  
- Technology-assisted instruction  
- Type of Technology: Computer  
- Six Groups:  
  1) ASTRA EAGLE – Cooperative  
  2) ASTRA EAGLE – Competitive  
  3) ASTRA EAGLE – Individualistic  
  4) Paper/pencil drills – Cooperative  
  5) P/P drills – Competitive  
  6) P/P drills – Individualistic | Numbers and Operations: Computation Skills | - Mathematics Skills  
- Attitudes about math | - Skills: GSAT, 30 items  
- Attitude: ATMI, 40 item, 5-point Likert Scale  
- In-field observations  
- Think-aloud protocols | Quasi-Experiment with Qualitative Data Results – Mixed  
Computer games significantly improved attitudes; no overall difference in skills; cooperative groups were more motivated than competitive and individual groups |
| Ke and Grabowski, 2007  | (N = 125) 5th grade | - Duration: Four weeks, two sessions per week, 45 minutes per session  
- Technology-assisted instruction  
- Type of Technology: Computer  
- Three groups:  
  1) ASTRA EAGLE – Cooperative  
  2) ASTRA EAGLE – Competitive  
  3) P/P drills only | Numbers and Operations, Geometry, and Probability | - Mathematics Skills  
- Attitudes about math | - Skills: GSAT, 30 items  
- Attitude: ATMI, 40 item, 5-point Likert Scale | Experiment Results – Mixed  
Both game groups made significant gains in skill than the p/p group; cooperative game group had most positive attitudes |
| Kopcha and Sullivan, 2008 | (N = 99) 6th and 7th grade | - Duration: Three 45-min class periods, one per day on consecutive days  
- Technology-based instruction  
- Type of Technology: Computer, instructional program Operations with Integers  
- Two groups:  
  1) Learner controlled  
  2) Program controlled | Numbers and Operations | - Mathematics Achievement  
- Attitudes about math & technology | - Achievement: 12 item pre-test, 24 item post-test, content specific  
- Attitude: 14 item questionnaire to assess attitudes about learning math on the computer and instruction received, Likert Scale  
- Electronic data tracking  
- Interviews | Quasi-Experiment Results – Mixed  
No significant differences between groups in mathematical skills; learner controlled group significantly higher on attitudes than program controlled group |
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| Ku et al., 2007          | (N = 104) 6th–8th grade | - Duration: Three sessions, 42 minutes per session  
- Technology-based instruction  
- Type of Technology: Computer  
- Two groups:  
  1) Personalised CBI program  
  2) Non-personalised CBI program | Numbers and Operations, and Algebra | - Mathematics Skills  
- Motivation  
- Attitude about technology | - Skills: 16 computational items, 2 word problems  
- Motivation & Attitude: 11 item survey about technology use | Quasi-Experiment Results – Positive  
Significant math skill gains and gains in attitude for students in personalised group vs. non-personalised group |
| Ogbuehi and Fraser, 2007 | (N = 101) 8th grade | - Duration: Nine weeks  
- Technology-based instruction  
- Type of Technology: Computer  
- Two groups:  
  1) Understanding Mathematics (Umath)  
  2) Regular instruction | Algebra | - Mathematics Skills  
- Attitude about math | - Math Skills: content specific (systems of linear equations)  
- Attitude: Test of Mathematics Related Attitudes (TOMRA): 20 item | Quasi-Experiment Results – Positive  
Treatment group scored significantly higher on the math skills test and reported significantly more positive attitudes |
| Okolo, 1992              | (N = 41) 4th–6th grade | - Duration: Nine sessions, 20 minutes per session  
- Technology-assisted instruction  
- Type of Technology: Computer  
- Four groups:  
  1) Math Masters game, high attitude  
  2) Math Masters game, low attitude  
  3) Drill, high attitude  
  4) Drill, low attitude | Numbers and Operations: Computations | - Mathematics Skills  
- Attitudes about math  
- Motivation | - Skills: timed test of arithmetic facts: 80 single-digit addition and multiplication  
- Attitude: Estes Attitude Scale-Elementary form, 14 items 3-point Likert Scale | Quasi-Experiment Results – Mixed  
Drill participants completed significantly more problems than game students; no significant differences for attitude |
| Panoutso-polus and Sampson, 2012 | (N = 59) 13–14 years old | - Duration: Unknown  
- Technology-assisted instruction  
- Type of Technology: Computer  
- Two groups:  
  1) Played Sims 2 – Open for Business video game  
  2) Regular instruction | Numbers and Operations: Computations | - Mathematics Achievement  
- Attitudes about math & technology | - Achievement: post-test of various items  
- Attitude about technology: 31 item Likert Scale  
- Attitude about math: 10 item Likert Scale | Quasi-Experiment Results – No Significant Findings  
No significant differences between groups on achievement or attitude |
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| Pareto et al., 2012 | (N = 47) 3rd grade, 9-10 years old | - Duration: Nine weeks, seven sessions, 35 minutes per session  
- Technology-based instruction  
- Type of Technology: Computer  
- Two groups:  
  1) Master-Apprentice Model game  
  2) Regular instruction | Numbers and Operations: Place-value, Computation  
- Mathematics Skills  
- Attitude | - Skills: 13 questions, content specific (place value)  
- Attitude: 7 item 6-point Likert Scale | Quasi-Experiment  
Results – Mixed  
Significant differences in change from pre/post for both groups; game-playing group made more gains; no significant differences in attitude |
| Pili and Aksu, 2013 | (N = 55) 4th grade | - Duration: 12 weeks, two hours per week  
- Technology-assisted instruction  
- Type of Technology: Computer  
- Two groups:  
  1) Frizbi Mathematics 4 instructional software  
  2) Regular instruction | Numbers and Operations: Multiplication, Division, Fractions  
- Mathematics Achievement  
- Attitudes about math & technology | - Achievement: three 25 item multiple choice  
- Attitude about math: Math Attitude Scale, 20 items 5-point Likert  
- Attitude about technology: Computer Assisted Learning Attitude Scale, 10 items 3-point Likert | Quasi-Experiment  
Results – Positive  
Both groups made gains in achievement; treatment group had significantly more positive attitudes than control group |
| Reimer and Moyer, 2004 | (N = 19) 3rd grade | - Duration: Two weeks  
- Technology-assisted instruction  
- Type of Technology: Computer  
- One group used Virtual Manipulatives (from National Library of Virtual Manipulatives) | Numbers and Operations: Fractions  
- Mathematics Skills  
- Attitudes about technology | - Skills: 4 item conceptual knowledge test; 14 item procedural knowledge test  
- Attitude: Likert scale questionnaire | Pre-Experiment  
(One group pre/post-design)  
Results – Mixed  
Significantly higher scores on conceptual knowledge; no significant differences on procedural knowledge; 59% of participants had positive responses on use of virtual manipulatives |
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| Riconscente, 2013       | (N = 122) 5th grade | - Duration: Five consecutive sessions, 20 minutes per session  
- Technology-assisted instruction  
- Type of Technology: Computer – iPad  
- Two groups:  
1) Used Motion Math app, after 5 days took a mid-test, then received regular instruction  
2) Regular instruction, after 5 days took mid-test, then used Motion Math for 5 days | Numbers and Operations: Fractions | - Mathematics Skills  
- Attitudes about math  
- Self-efficacy in math | - Skills: 34 item fraction knowledge test  
- Attitude: 4-point Likert scale  
- Self-efficacy: 4-point Likert scale | Experimental  
Repeated Measures  
Crossover Design  
Results – Mixed  
Significant differences in mathematical knowledge scores at midtest; significant differences in fraction attitudes and fraction self-efficacy at midtest; no significant differences at post-test for any measure between groups or schools |
| Ritzhaupt et al., 2011  | (N = 225) 6th-8th grade | - Duration: 16 weeks, one session per week  
- Technology-assisted instruction  
- Type of Technology: Computer  
- Two groups:  
1) DimensionM education game series  
2) Regular instruction | Pre-Algebra and Algebra | - Mathematics Skills  
- Attitudes about math  
- Self-efficacy in math | - Skills: 35 items  
- Attitudes: 11 item 4-point Likert scale  
- Self-efficacy: 4-point Likert scale | Quasi-Experiment  
(One group pre/post-design)  
Results – Mixed  
No significant differences in math achievement from pre/post-test; significant change in attitudes and self-efficacy towards math for those in game playing group |
| Shin et al., 2012       | (N = 37) 2nd grade 7–8 years old | - Duration: Three conditions: 615 minutes, 585+ minutes, 480+ minutes  
- Technology-assisted instruction  
- Type of Technology: Gameboy  
- Three groups:  
1) 3x/week for 5 weeks, then 2x/week for 13 weeks  
2) more than 3x/week over 13 weeks  
3) more than 4x/week for 8 weeks | Numbers and Operations | - Mathematics Skills  
- Attitudes about math & technology | - Skills: 70 item test  
- Attitude (math): 23 yes/no items  
- Attitude (technology): 8 yes/no items | Quasi-Experiment  
Results – Mixed  
Game positively impacted mathematics learning regardless of ability level; attitudes towards game playing and math were significant predictors of math scores |
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| Tsuei, 2011     | 10-11 years old | - Duration: Two academic semesters; three math sessions per week, 40 minutes per session  
- Technology-assisted instruction  
- Type of Technology: Computer  
- Two groups:  
1) G-Math synchronous peer tutoring  
2) Face-to-face peer tutoring | Numbers and Operations | - Mathematics Skills  
- Attitudes about math  
- Self-efficacy in math | - Skills: Math proficiency, eight 10-item CBM probes  
- Attitude: 12 item 5-point Likert scale  
- Self-efficacy: 8 item 5-point Likert Scale | Quasi-Experiment Results – Positive  
G-Math group had significantly greater increase in math scores and self-efficacy and significantly more positive attitudes |
| Weiss et al., 2006 | Kindergarten 4-7 years old | - Duration: 5 months 28 hours  
- Technology-based instruction  
- Type of Technology: Computer  
- Three groups:  
1) I Study Math Multimedia interactive environment – Cooperative Learning  
2) I Study Math Multimedia interactive environment – Independent Learning  
3) Control group – no media | Numbers and Operations | - Mathematics Skills  
- Attitudes about technology | - Skills: 23 item mathematical achievement test  
- Attitude: learning style 10-point Likert Scale questionnaire | Quasi-Experiment Results – Positive  
All groups made significant gains in math achievement; two experimental groups outperformed the control group; significant interaction between group type and attitude towards learning style |
| Yang and Tsai, 2010 | 6th grade | - Duration: 16 class periods, 40 minutes per period  
- Technology-based instruction  
- Type of Technology: Computer  
- Two groups:  
1) Web-based learning resources  
2) Regular instruction | Numbers and Operations | - Mathematics Skills  
- Attitudes about math | - Skills: 50 item web-based number sense pre/post-test  
- Attitude: Survey of Attitudes Towards Mathematics Learning 30 item, 5-point Likert Scale | Quasi-Experiment Results – Positive  
Significant academic gains for treatment group; significant post-test differences, students in treatment group had more positive attitudes towards math learning than students in control |
3.3 Measures

Measures used to assess dependent variables varied across studies. All 25 studies reported on some aspect of mathematics achievement or skills, 12 included some measure of attitude about mathematics, seven involved attitudes about technology, and six measured attitude within the context of technology. Eighteen studies included information on the psychometric properties of measures used to assess the dependent variables for each study. Eight studies included psychometric information for all measures used to assess dependent variables, 10 reported psychometrics for at least one of the measures and seven did not report any psychometric information. Of the 18 studies that included information on the psychometric properties, 10 reported psychometrics for attitude measures. The same measure was used to assess attitude in mathematics (Math Attitude Scale) on only two occasions and none of the studies used the same measure to assess attitude towards technology. Similar to the findings on assessing attitude, all studies utilised different measures when examining mathematics achievement or skills. When measuring attitude, the majority of studies used Likert-type items with scales ranging from 3 to 10. The number of items included on each measure varied and few provided scoring details or interpretation guidelines.

3.4 Study design and grouping

A variety of design techniques were implemented to examine attitude and mathematical outcomes when using technology in mathematics. Fourteen studies employed a quasi-experimental design. However, two of these studies did not include a control group and thus implemented a one-group pre/post design. Two additional studies used a one-group pre/post design as well. Furthermore, three studies identified themselves as being experimental and one used an experimental repeated measures crossover design. Five studies employed mixed methods, with two of these being quasi-experimental and three being a one-group pre/post design, all with qualitative methodology employed as well.

Six studies involved one group of students, 12 involved two groups of students, three had three groups, two had four groups, and two had five or more groups. Of the 19 studies that used multiple groups, 13 had at least one control group that did not receive any technology, and six studies involved all students receiving technology, with the treatment in the technological variation (e.g. personalised vs. non-personalised computer program).

3.4.1 Technology interventions

The technology medium varied across studies; however, the majority (88%) implemented some form of computer (e.g. laptop, desktop, tablet) and 12% reported the use of some other technology (e.g. multimedia whiteboard, video, podcast). The majority of studies (72%) reported that technology was used as a supplemental or assistive tool. In 16% of the studies technologies were personalised to students and the majority of studies (84%) promoted an individualised use of technology as opposed to a collaborative or competitive structure.
3.4.2 Study duration

Twenty-three studies (92%) reported on the duration of the intervention, which varied from one session to an academic school year. For 26.1% of these 23 studies, students were engaged in the intervention for 6–10 sessions, 34.8% of the studies were between 1 and 5 sessions, 17.4% had more than 20 sessions, 8.7% lasted between 16 and 20 sessions, and 13.0% of the interventions consisted of 11–15 sessions.

3.5 Reported results

When considering the overall results, 44% of the studies reported that technology had a positive impact on both students’ mathematics achievement and attitude, 12% of studies reported positive effects of technology on mathematics achievement, but no significant results for attitude, and 28% of studies reported positive influences of technology on attitude, but not achievement. Furthermore, 12% of studies reported mixed achievement and/or mixed results on student attitude, and 4% reported no significant effects on either area.

3.5.1 Mathematical achievement

All studies included in this review assessed mathematical outcomes in some capacity. Different terms were used across articles for achievement (e.g. achievement, skills, knowledge, performance; see Table 2 for specific terms used in each study). For the purpose of this review, the term “mathematical achievement” will be used henceforth. For studies that measured between group differences, 64.7% found the treatment group was significantly higher on mathematical achievement than the control group or alternative treatment group. For the studies that measured change over time, 42.8% found that the treatment group gained over time (this percentage excludes the studies where the control gained as well). Figure 1 displays all results for mathematical achievement broken out by the type of study used in each article.

Figure 1 Results for mathematics achievement broken down by type of study

- Between Group Differences Only ($n = 17$)
  - Treatment condition showed higher mathematics achievement than control ($n = 11$)
  - No differences were found between groups ($n = 4$)
  - Improvement in mathematics measured at one point, but effect disappeared ($n = 4$)
- Both Between and Within Group Change ($n = 2$)
- Within Group Change Only ($n = 6$)
  - Treatment condition changed over time ($n = 3$)
  - Mixed results ($n = 2$)
  - No gains for group ($n = 3$)
3.5.2 Attitude about mathematics

Twelve studies examined student attitudes about mathematics, and of these, nine looked at group differences and three looked at change in attitude over time. Six of the studies that examined differences between groups found that treatment groups have more positive attitudes than those in the alternative technology or control groups. Interestingly, two of these treatments involved having a personalised or cooperative-based learning approach. Three of the studies, however, did not find any group differences. All three studies that examined change over time found that the treatment groups’ attitude about mathematics improved over the course of the intervention, whereas the secondary technology or control groups stayed roughly the same.

3.5.3 Attitude about technology

Seven articles focused specifically on students’ attitudes about technology, and of these, five looked at change in student attitude over time, one looked at group differences, and one looked at both group differences and change. Four studies found an improvement in student's attitude about technology over time, and two found no change. The two that examined group differences used multiple technologies; one study found that a personalised computer program improved students’ attitudes above a non-personalised program, and another study found that a cooperative group had more positive attitudes than an individualised group.

3.5.4 Attitude about technology in mathematics

Six studies specifically examined student’s attitudes about using technology in the context of learning mathematics. Four studies looked at the differences between two groups, and for three of these studies, students in the treatment conditions had more positive attitudes about using technology in mathematics than students in the control or secondary treatment conditions; one study found no differences between the groups. Furthermore, one study looked at change over time in one group, but found no change in students’ attitude about using technology in mathematics. Finally, one study examined how students’ attitudes predicted mathematics scores, finding that students’ positive attitudes towards gaming predicted higher mathematics achievement scores.

4 Discussion

Technology has become an essential component in mathematics classroom instruction and has demonstrated a strong influence on learning outcomes. Furthermore, student-related factors, such as attitude are also critical elements to outcomes, given that a clear link between attitude and learning has been established (Marzano, 2000; McMillian, 2011; Ormrod, 1999; Rimland, 2013). The present review examined studies that incorporated the use of technology into mathematics instruction for elementary and middle school students as well as evaluated student attitude related to technology or mathematics originally published or revised from 1983 to 2013.

One key finding was the lack of operational definitions and psychometrically validated measures for attitude. Only eight of the studies reported psychometric information for all of the measures used within the study. Ten of the studies included
psychometric information for the measures assessing attitude; however, none of them operationally defined the construct for that study. Given that attitudes can be challenging to operationally define and assess (Pratkanis et al., 1989), it makes interpreting the results across studies focused on attitude difficult to interpret and therefore, draw comprehensive conclusions for practice and future research. This finding is also similar to the results reported by Ma and Kishor (1997), when they found a non-significant correlation between attitude and achievement across 113 studies, attributed primarily to the measurement of constructs. Furthermore, all of the measures assessing attitude varied across studies and only one measure (Math Attitude Scale) was used more than once. To have a clear understanding of how attitude may be affected, a need is present for the development of reliable and valid assessments of attitude. These assessments would include an alignment of the construct to a theory, the generation of an operational definition, and establishment of strong psychometric characteristics.

Another finding from this review was the varied outcomes for both mathematics and attitude based on specific program design features and instructional format. For example, of the few studies that examined personalised versus non-personalised instruction or delivery of feedback, all found that personalisation had more positive effects than non-personalisation. Another feature that manifested itself in a small number of studies was cooperative learning versus individual or competitive learning, and findings are overwhelmingly in favor of cooperative learning. This aligns with a large-scale national study examining technology implementation and performance which reported that collaborative environments increase learning productivity and engagement (Greaves et al., 2010). Given that these features relate specifically to a student’s affective characteristic, such as attitude, it is important to consider constructs such as attitude when programmes are being designed and selected for classroom implementation. Furthermore, an in-depth research review involving these specific features could inform the fields of technology and mathematics education.

Finally, only ten of the studies reported on a specific subgroup of students (i.e. disability group, gender, race, socioeconomic status). The advent of universal design has made technology increasingly accessible for all types of learners (CAST, 2012). Studies have shown that the use of technology interventions have improved course completion and high-stakes test scores as well reduced dropout rates for various subgroups of students including, struggling readers, individuals with disabilities, and English-language learners (Greaves et al., 2010). However, there is a need to better understand how technology use contributes to the achievement of diverse subgroups and how their affective characteristics factor into these outcomes.

4.1 Limitations

The search and coding procedures used in this review reveal limitations that may have affected the results. First, specific criteria were used to locate articles from the electronic databases to allow for replication of the findings. While the criteria allowed for an extensive search of the literature, it is possible that some articles were unintentionally left out. Also, because of the years searched, the majority of studies in this review used computers as their method of delivery, which limits the generalisability of the results to computer-based learning environments. However, with the increased use of interactive whiteboards, schools where students are allowed to bring their own device (e.g. smart phone, tablet, or laptop), and other ever-evolving forms of technology, future research
will need to investigate the effect of different methods of delivery on students’ affective characteristics and mathematical achievement. Second, this review focused on the specific population of elementary and middle school students. Undoubtedly, studies exist that have examined mathematics achievement and affective constructs in secondary populations; thus, further literature reviews should include these studies in order to fully understand how using technology in mathematics can influence the achievement and affective characteristics of students in grades K-12.

Third, this review was also limited to the construct of attitude, however, as many as 14 affective characteristics involved in student learning have been studied in academic settings (McMillan, 2011). Future research should also consider assessing how these constructs compare to the present ones and if additional information could be relevant to key stakeholders with respect to using technology in mathematics and related student achievement. Last, this review examined just under 30 variables per article; however, several other aspects within each article could be scrutinised. For example, a little more than one quarter of the studies reported effect sizes in the results. This study only examined this as a dichotomous variable (i.e. yes, no) and did not further explore or interpret meaning of these effect sizes. Future research should consider systematically examining these results and what information they can offer to the field of mathematics and technology-based education.

4.2 Implications

The results of this literature review comprehensively examined studies that have reported the effects of technology on mathematics achievement and the relationship of technology and students’ attitude for elementary and middle school populations. This review has implications for key stakeholders including educational researchers, software or technology developers, as well as education professionals. Several factors should be considered when designing new educational software or technology, deciding which type of technology to buy for a school, implementing technology in the classroom, or conducting research on the effects of these technologies.

First, because a need exists to develop and empirically validate innovative educational technologies that increase student independence and achievement, findings from this review provide technology developers with information on how students’ attitudes contribute to learning in technological environments. Moreover, it sheds light on critical program components and design features such as the format for delivery (personalised versus non-personalised), number of lessons or student sessions, and the type of support it provides (technology-based, technology-assisted). A careful balance of minutes per session, program length, and delivery should be considered when developing instructional programmes or supports into mathematics education in ways that grow students’ attitude and support their achievement. Because the vast majority of these studies used computers as the medium to deliver the program, this information is critical when developing computer-based or computer-assisted software. However, a need exists to study students’ attitudes and mathematics achievement when using other methods of delivery to support learning (e.g. graphing calculators, interactive whiteboards).

Second, administrators and educators need to consider both achievement and attitude when choosing which technologies to implement in the classroom. As previously mentioned, this review found that subtle differences in technology implementation, such as the instructional format or time spent in a session, can influence the effects of
technology use on mathematics achievement and attitude. This information would be important for building or district level personnel considering technology purchases related to mathematics. At the classroom level, teachers should account for the time students are asked to work with technology in addition to grouping purposes if a format promotes a collaborative or competitive learning environment.

Third, this review focused specifically on mathematics; however, the influence of technology on students’ attitudes and achievement in other content areas (e.g. science, reading, writing) needs to be considered as well. Several studies, including meta-analyses and best evidence syntheses have been conducted examining the impacts of technology on the achievement of students within content areas (Lou et al., 2001; Slavin and Lake, 2009), but little research has examined affective characteristics such as attitude. Therefore, a systematic synthesis examining the effect of technology on mathematics achievement and various affective characteristics is warranted, in addition to a thorough review of the literature in other content areas evaluating similar aspects of the current study. Furthermore, this review only considered elementary and middle school populations because research shows the sooner individuals can develop positive attitudes about mathematics, the more likely they are to connect to the content and pursue careers in the area (McMillian, 2011). Thus, an initial need was present to evaluate this specific population in order to better understand what contributes to developing positive affective characteristics when using technology in mathematics.

Finally, researchers need to focus on developing psychometrically sound measures that assess attitude. Although attitude has been difficult to operationally define due to the idiosyncratic nature (McMillan, 2011); attitude plays a critical role in student learning (Marzano, 2000; McMillan, 2011; Ormrod, 1999). A need exists for researchers to place emphasis on developing measures that build on attitude theory and tested with diverse samples. This should include using the latest research findings, developing items around an operationally defined construct, utilising interviews or observations during the development phase, collecting peer reports, and examining differences in each for paper or electronic administration for improving ease of implementation and interpretation of results (McMillan, 2011). Using strategies such as these would begin to help meet the need for developing assessments that evaluate attitude with acceptable psychometric properties that can be used confidently across content areas for both practice and research.

5 Conclusion

The evolution and use of technology in education has changed the way students learn and influenced critical components, such as affective characteristics, that students bring to this process. Technology provides an avenue for increasing engagement and learning in subject areas such as mathematics that students may not always have positive attitudes or feel confident about. This review depicts the overt and subtle influences of technology on mathematical achievement and attitude, as well as the difficulty of accurately defining and assessing both mathematical achievement and affective characteristics. The effects of technology are hard to measure in that development of technology tools and the use of technology in the classroom rapidly changes and improves. By studying effects of today’s technology on student achievement as well as additional factors that may contribute, we inform the development and use of tomorrow’s technologies. If we know
the technology that works and how students’ attitudes may or may not contribute to what works, we can design more effective future technologies for classroom use. Technology, like many other educational tools, is often put into place without fully realising its potential and possible drawbacks. As researchers, developers, and educators, it is imperative that we continue to critically analyse the effects of technology on student achievement while acknowledging the role of students’ affective characteristics on their use of technology and subsequent learning.

References


Microsoft. (2010) Microsoft Excel [computer software], Author, Redmond, WA. 


