Int J Technol Des Educ (2019) 29:37–56
https://doi.org/10.1007/s10798-017-9434-z

Perceptions and attitudes of pupils towards technology: In search of a rigorous theoretical framework

Piet Ankiewicz[1]

Accepted: 4 December 2017 / Published online: 5 February 2018

Abstract The perceptions and attitudes of pupils towards technology have been researched for just over three decades. Recently, following an extensive review of the available literature, Ankiewicz (in: De Vries (ed) Handbook of technology education, Springer International Handbooks of Education, 2016. https://doi.org/10.1007/978-3-319-38889-2_43-1) provided an overview of the current state of research, in a chapter in the Springer Handbook of Technology Education. However, due to length restrictions the chapter had to be concise and thus focused primarily on the mainstream instruments and their derivatives. More detailed descriptions of the perceptions and attitudes of students as well as discussions of unconventional and non-related instruments therefore had to be omitted. Consequently, the purpose of this article is to extend the chapter concerned by providing a more extensive and nuanced review of the total substantive body of knowledge that has been generated in just over three decades. The following research question underpinned the literature review: How may the existing research and subsequent findings be systematised into a more rigorous theoretical framework that may assist scholars in navigating their way through the current research on the perceptions and attitudes of students towards technology? In addition to the previous findings made and conclusions drawn in the chapter, it was found that such a theoretical framework should be informed by the following guiding insights: viewpoints concerning the construct of attitudes towards technology, as well as measuring such attitudes; the mainstream instruments in The Pupils' Attitudes Towards Technology (PATT) studies and their derivatives, as well as problematic aspects associated with these; unconventional, PATT-related instruments; new, non-related instruments for ascertaining students' attitudes and concepts; the general research findings on students' attitudes; means that may positively develop students' attitudes; and unidimensional versus multidimensional studies studying the effect of all characteristics or determinants of all aspects of learners' attitudes. Such a rigorous theoretical framework may serve as a valuable resource for future researchers embarking on this area of research, as it provides a

✉ Piet Ankiewicz
pieta@uj.ac.za

[1] Department of Science and Technology Education, Faculty of Education (APK Campus), University of Johannesburg, P.O. Box 524, Auckland Park 2006, South Africa

synopsis that may assist in enhancing an understanding of research that has been done and work that needs to be done in order to contribute to developing new knowledge in the field of design, technology, and engineering education. It also indicates gaps in this research area, notably in researching the behavioural component of attitudes.

Keywords Technology education · Attitudes · Concepts · Behaviour · Attitude measurement

Introduction

The perceptions and attitudes of pupils towards technology have been researched for just over three decades. Recently, following an extensive review of the available literature, Ankiewicz (2016) provided an overview of this research in a chapter in the Springer Handbook of Technology Education. He acknowledged that the most noted study of students' attitudes towards technology has probably been the work pioneered by Prof Jan Raat and Marc de Vries as part of "Project Physics and Technology" in the Department of Physics Education at Eindhoven University of Technology in the Netherlands in 1984 (De Vries 1988; Volk and Yip 1999). The Pupils' Attitudes Towards Technology (PATT) instrument used in the Netherlands, referred to as PATT-NL, was the first instrument specifically designed for this purpose. Results in the Netherlands were so significant that an international extension of the research was the logical next step (Ardies et al. 2013). Ankiewicz (2016) also addressed several viewpoints concerning the construct of attitudes towards technology, such as definitions of attitude and fundamental reasons for measuring students' attitudes. The chapter mainly presented the PATT-NL and the PATT-USA as mainstream instruments associated with the classical PATT studies, as well as the PATT Short Questionnaire (PATT-SQ) as a recent adaptation of PATT-USA. It also focused on new, non-related instruments such as the Attitudinal Technology Profile (ATP) questionnaire, based on regional and contextual factors. The latter part of the chapter provided general research findings from the PATT studies on students' attitudes towards technology, as well as examples of recent unidimensional versus multidimensional studies.

However, due to length restrictions the chapter focused primarily on the mainstream instruments and their derivatives. Hence, extensive and more detailed descriptions of the perceptions and attitudes of students as well as discussions of unconventional and non-related instruments had to be omitted, at the expense of a fully nuanced account of the available literature. The purpose of this article is thus to extend the chapter by providing a more extensive review of the relevant, substantive body of knowledge that has been generated in just over three decades. The following research question underpinned the literature review: How may the existing research and subsequent findings be systematised into a more rigorous theoretical framework that may assist scholars in navigating their way through the current research on the perceptions and attitudes of students towards technology? It is suggested that the article be read in conjunction with the chapter in the Springer Handbook of Education, in order to develop a holistic theoretical framework for the perceptions and attitudes of students towards technology.

In addition to the fundamental reasons for measuring students' attitudes and the definitions of attitude that were addressed previously (Ankiewicz 2016) the measuring of attitudes will be discussed in the next section.

Measuring attitudes

Researchers are interested in measuring students' attitudes towards technology for a myriad of reasons (Ankiewicz 2016). Researchers in technology education often acknowledge, either implicitly or explicitly, the traditional approach to attitudes. According to the traditional approach, an attitude towards a concept such as technology thus is the person's collection of beliefs about it (cognitive component) and associated episodes linked with emotional reactions (affective component). The stimulation of these reactions results in decisions to engage in behaviour (behavioural component), which includes a person's predisposition or readiness for action, as well as his or her actions concerning the 'behavioural object' (Ankiewicz 2016).

Attitudes, despite the multidimensionality of the construct as well as the challenges posed by it, have commonly been measured in PATT studies using questionnaires consisting of Likert scale items, which are ordinal scales used to determine students' levels of agreement or disagreement. Concepts have been measured using three-point scales, usually treated as dichotomous scales (Ankiewicz 2016; Jeffrey 1993, 1995).

Cronbach's alpha (α) is used as an index of the reliability of Likert-type scales and denotes the "repeatability, stability or internal consistency" (Jack and Clarke 1998: 177) of the data generated by the specific scale. The Kuder-Richardson formula 20 (KR20) is used as an index of homogeneity, based on the proportion of correct and incorrect responses on the items of the **concept scales** (Jeffrey 1993, 1995).

Factor analysis was the most popular statistical technique used to determine a questionnaire's underpinning constructs in PATT studies. Principal Component Analysis (PCA) as a form of Exploratory Factor Analysis (EFA) is typically used to identify the main or principal constructs of a questionnaire while still under development. Confirmatory Factor Analysis (CFA) usually allows further testing of the constructs underlying a validated questionnaire (Boser et al. 1998).

A questionnaire is very rarely unidimensional and PCA is geared at identifying the principal underlying component (factor) that "explains" most of the variance and ensuing components that account for less variance. In a non-rotated PCA, most items should "load" onto, or correlate with the principal component. However, to assist in identifying and interpreting prospective further components (factors), Varimax and Oblimin rotations are used, each of which "maximizes the loadings of variables with a strong association with a factor, and minimizes those with a weaker one" (Boser et al. 1998; Ferguson and Cox 1993; Rattray and Jones 2007: 239).

Mainly two methods are used to decide upon the number of factors, namely Kaiser's criterion for factors with an eigenvalue of more than 1.0 and a scree test. A scree test, represented as a scree plot, is the graphic representation of Kaiser's criterion. Usually only eigenvalues higher than 0.30 (Rattray and Jones 2007) are used to identify items which load onto a factor. Either the Gutman (Bame et al. 1993) or Mokken (as a non-parametric version of the first) (De Klerk Wolters 1989b) analysis is usually applied to the dichotomous items of the concept scale for which one or the other response is designated as "positive".

The two independent samples *t* test is used to determine if there are statistically significant differences between the scores of two groups or sub-groups of participants, by comparing the means of the scores of the two samples. ANalysis Of VAriance (ANOVA) tests are applied in unidimensional studies to determine whether there are statistically significant differences among the scores for the dependent variables (e.g. interest, careers) of several (more than two) groups or sub-groups of students (e.g. between boys and girls at different age levels) (Bame et al. 1993; Dean and Illowski 2008). Multivariate ANalysis Of VAriance (MANOVA) tests are used in multidimensional studies to determine whether multiple levels of independent variables on their own or in combination with one another have an effect on the dependent variables (Ankiewicz et al. 2001; Bame et al. 1993; Boser et al. 1998; Gaotlhobogwe 2010; Meide 1997; Van Rensburg et al. 1999).

Various instruments for ascertaining students' attitudes towards technology

The Pupils' Attitudes Towards Technology (PATT) mainstream instruments for ascertaining students' attitudes

The main part of the chapter presented the PATT-NL and the PATT-USA as mainstream instruments associated with the classical PATT studies (Ankiewicz 2016). Classical PATT studies generally made use of the following five instruments:

1. An attitude questionnaire.
2. A concept questionnaire.
3. Qualitative methods like essays with the topic "What do you think technology is?" (age group 13–15); drawings (age group 10–12) and open-ended questions (age group 16–18) to get more information on students' attitudes and concepts.
4. The Technology Attitude Scale (TAS).
5. The Teacher Attitude Questionnaire (Ankiewicz 2016; De Klerk Wolters 1988a, 1989a).

In the next section PATT-NL as well as the unconventional instruments associated with it will be discussed more extensively.

The PATT-Netherlands instrument (PATT-NL) and its associated instruments

PATT-NL

De Klerk Wolters (1988a: 41) described attitudes as "a certain negative or positive feeling towards technology based on certain knowledge of and ideas about technology that may lead to a certain behaviour with reference to technology". In this context, attitude was used as a collective term for someone's affinity, behaviour and conceptualization in relation to technology (Rohaan et al. 2010), in accordance with the traditional approach and consistent theories of attitudes (De Klerk Wolters 1989a).

PATT-NL consisted of two questionnaires, measuring the affective component and the cognitive component. The **attitude questionnaire** comprised Likert-type items containing a five-point response format, with six subscales measuring affective components of attitude such as interest, gender, consequences, difficulty, curriculum and careers in technology (De Klerk Wolters 1988a; Rennie and Jarvis 1995a; Rohaan et al. 2010; Van Rensburg et al. 1999). Based on his own research and parallel international research, De Vries (1988) defined five different dimensions, namely interest in technology; aspirations for a technological career; perceived consequences of technology; perceived difficulty of technology; and students' perception of technology as a subject suitable for both genders.

These dimensions of attitude served as basis for the six subscales of the affective component (Ardies et al. 2015b; De Klerk Wolters 1988a).

The **concept questionnaire** had a three-point response format, known as Mokken scales (De Klerk Wolters 1989b), with four subscales measuring the cognitive or knowledge component of attitudes towards technology, based on the five general characteristics of technology. The characteristics of technology as a feature of every human being and of technology and society were combined to form a single subscale, namely relationship between technology, human beings and society, which accounted for the five characteristics represented by four subscales (Jeffrey 1993). The other subscales were the following: relationship between technology and science (technology and science); skills in technology (technology and skills); and the raw materials or "pillars" of technology (technology and pillars) (Bame and Dugger 1989a; Becker and Maunsaiyat 2002; De Klerk Wolters 1989a, b; De Vries 1992; Jeffrey 1993; Rennie and Jarvis 1995a; Rohaan et al. 2010; Van Rensburg et al. 1999).

In its early form, PATT-NL included an **essay (qualitative) section**. This read: *Technology can mean different things to different people. When you read the word "technology" what comes into your mind?* to ascertain students' cognitive views of technology (Ankiewicz 2016; Luckay and Collier-Reed 2014).

PATT-NL was originally developed for students aged 13–15 years, but was also modified for other age groups. De Klerk Wolters (1989b) describes the use of some of the scales for students aged 10–12 years, while Rennie and Treagust (1989) describe the adaptation of the scales for 9 to 12-year old students. The scales have also been used with adults (De Vries 1991; Moore and Songun 1991; Rennie and Jarvis 1995a). De Klerk Wolters (1989a) mentioned only with the PATT-NL version for younger students that the attitude questionnaire also measured the behavioural component. Earlier he had stated pertinently that the original PATT-NL did not measure the behavioural component (De Klerk Wolters 1988a). The author of this article is of the opinion that this might have been an oversight. The questionnaire can only measure students' readiness for action, and not the action itself.

From the large-scale PATT-NL studies concluded that students had only a vague concept of technology; that the relationship of technology to physics was very obscure to students, particularly girls; and that girls were less interested in technology and viewed it as less important (Boser et al. 1998; Raat and De Vries 1985).

The Technology Attitude Scale, the Technology Attitude Questionnaire and the Teacher Attitude Questionnaire which are unconventional instruments associated with PATT-NL will be discussed next.

Unconventional instruments associated with PATT-NL

It is important for technology teachers to form part of small-scale action research and determine their students' attitudes towards and perceptions of technology. Such information enables them to plan and adapt their technology lessons accordingly (Jeffrey 1995). The three-part **Technology Attitude Scale (TAS-NL)** was developed in 1987 and was revised by Coenen-Van den Bergh in 1988 and 1989. It was a shorter version of the PATT-NL, consisting of 26 attitude items divided over six subscales and 28 concept items divided over four subscales, specifically for use by classroom teachers. The scale also measured the knowledge and concepts (as the cognitive component) of technology at a relatively abstract level (Becker and Maunsaiyat 2002; De Klerk Wolters 1988a, b, 1989a). The TAS-NL was applied in Finland, Poland and the Netherlands (De Klerk Wolters 1989a) as well as in Portugal (Martins 1991). Students' perceptions of technology were often found to be vague and distorted.

The **Technology Attitude Questionnaire (TAQ)** consisting of 74 Likert-type items with a four-point scale covering eight subscales was developed by Moore and used with secondary school students in the UK. As the TAQ did not measure students' concepts of technology, it was versatile and could be used with students following various courses. A translated version was used with post-secondary technical vocational students in Turkey, of whom more than a third (37%) were more than 20 years of age. The TAQ identified statistically significant differences between the attitudes of students following different technical courses (Moore and Songun 1991; Mottier et al. 1991).

Considering that students often do not have a clear understanding of technology it is important to determine teachers' attitudes towards and perceptions of technology. Teachers may play a vital role in directly influencing students' attitudes and advancing their perceptions of technology (Rennie 1988; Volk and Yip 1999). Hence, the **Teacher Attitude Questionnaire (PATT Teachers-NL)** consisting of 74 items to ascertain teachers' views of technology and technology education was developed by Coenen-Van den Bergh. The items related to a number of aspects of technology and were comparable to the students' questionnaire. It was applied in Finland, Poland and the Netherlands (De Klerk Wolters 1989a), after which Moore adapted and shortened it to 60 items for use in the UK (Bame 1989).

The PATT-NL, in accordance with the traditional approach to attitudes, only ascertained students' technological concepts (cognitive component) and attitudes (affective component) as crucial prerequisites for technological activities (behavioural component) that result in technological objects Ankiewicz et al. 2001; De Klerk Wolters 1988a; Van Rensburg et al. 1999).

The subsequent adaptation of PATT-NL for use in other parts of the world, for example the USA, as well as the unconventional instruments associated with it will be discussed briefly in the next section.

The PATT-USA instrument (PATT-USA) and its associated instruments

PATT-USA

The original PATT-NL was translated and modified by Bame et al. (1993) for use in the USA (Ankiewicz 2016; Volk and Yip 1999). A large-scale research effort comprising both pilot and survey studies was undertaken by Bame et al. (1993). Over 10,000 students from seven states participated in the study, with 67 per cent of them between the ages of 13 and 15 years (Bame and Dugger 1989a; Boser et al. 1998; De Klerk Wolters 1988a, 1989a; Householder and Bolin 1993; Volk and Yip 1999; Zuga 1997).

Five attitude sub-scales were defined, namely general interest in technology; attitude towards technology (negative attitude); technology as an activity for boys and girls (gender differences); consequences of technology; and technology is difficult. The attitude factors comprised only 42 of the 58 items. The 31 items on concept of technology represented a single sub-scale, namely knowledge about technology (Ardies et al. 2013; Bame and Dugger 1989a; Bame et al. 1993; Boser et al. 1998).

The PATT-USA scales differed somewhat from other PATT studies, as the six original attitude scales were apparently not valid for the USA study. Interest, curriculum and career were combined into two scales, namely one for positive attitude, labelled as general interest, and one for negative attitude, labelled attitude towards technology. Students could not distinguish any of the four original concept scales and due to validation problems only one scale was possible and the total score for all concept items was used (Bame and Dugger 1989a; Bame et al. 1993).

The PATT-USA study indicated that students were interested in technology; that boys were more interested in technology than girls, that students in the US thought of technology as a field for both girls and boys, that girls were more convinced that technology was a field for both genders and that parents' technological profession influenced students' attitudes positively. It also indicated that US students' concepts of technology became more accurate with increasing age and that they were strongly aware of the importance of technology. The US had a rather low score on items measuring the concepts of technology compared to other industrialized countries. Students who had attended industrial arts/technology education classes had more positive attitudes on all sub-scales and the existence of technical toys in the home had a significantly positive impact on all attitude scales (Bame 1991; Bame and Dugger 1989a; Bame et al. 1993; Boser et al. 1998; Mottier et al. 1991; Zuga 1997).

The Students' Attitudes towards Technology (SATT) instrument, the Secondary Students' Attitudes Towards Technology instrument (SSATT), the Technology Attitude Scale-USA and the Teacher Attitude Questionnaire (PATT Teachers-USA), are associated with PATT-USA. These unconventional instruments will be discussed next.

Unconventional instruments associated with PATT-USA

PATT-USA was developed for middle school students and was not suitable for primary school students. Dunlap conducted a study with a shortened version of PATT-USA, called **Students' Attitudes towards Technology (SATT)**, for ascertaining third and fourth grade students' attitudes towards technology. Overall girls had a more positive attitude towards technology than boys (Dunlap and Dugger 1991). Bolin developed the **Secondary Students' Attitudes Towards Technology (SSATT)** over eight factors for older, secondary students (Fleming 2005; Jeffrey 1995).

The TAS-NL instrument was adapted and validated by Jeffrey in 1993 for use by US classroom teachers (Becker and Maunsaiyat 2002; Jeffrey 1993, 1995). The first section of the **Technology Attitude Scale-USA (TAS-USA)** was designed to obtain demographic information about the respondents. The two remaining sections were similar to the attitude and concept scales of the TAS-NL (Becker and Maunsaiyat 2002). The TAS-USA accorded teachers the opportunity for action research by ascertaining their students' attitudes towards and concepts of technology and to apply the knowledge to their teaching of technology (Jeffrey 1993).

A **Teacher Attitude Questionnaire (PATT Teachers-USA)** was developed consisting of 60 items grouped under nine scales, similar to those by Coenen-Van den Bergh and Moore (Bame 1989). At the time the US teachers surveyed did not view technology as being male dominated; there was strong support for technology being an integral part of the middle school curriculum; and the teachers had an extensive concept of technology. A translated version of PATT Teachers-USA was also used in Greece, with the findings mirroring those in the USA (Androulidakis 1991; Mottier et al. 1991).

The application of PATT-USA in South Africa, as an example of a developing context; adaptations used in Asia (Hong Kong), Flanders and Sweden; as well as associated instruments will be discussed in the next section.

Application of PATT-USA and associated instruments in other parts of the world

Van Rensburg et al. (1999) analysed the data collected with the PATT-USA attitude questionnaire (affective component) among 1010 students in South Africa (Ankiewicz 2016). These researchers labelled some of the factors/scales differently and identified six factors. Five factors corresponded to the PATT-USA factors, while the additional sixth factor mostly contained items that had not been loaded to any of the PATT-USA factors.

For **PATT-Hong Kong (PATT-HK)**, the PATT-USA instrument was translated into Chinese and specific items were adapted (e.g. relevant technological toys). Examining the concept of technology was omitted because of problems with the nature of the concept items and due to the time required to administer the survey. The attitude questionnaire was similar to the PATT-USA, with 58 items over six scales. In line with the results in other developed countries, significant attitudinal differences existed between girls and boys in junior secondary schools (Volk and Yip 1999). The PATT-USA attitude questionnaire (affective component) was also translated into Turkish, **PATT-Turkey (PATT-TR).** It yielded similar factors/scales than the application of PATT-USA in South Africa (Yurdugül and Askar 2008). The PATT-USA instrument was modified for elementary school students by updating the dated technological terminology and utilising inter-rater analysis. In a pilot study among grade 5 students in elementary school **PATT-ELEM** yielded similar factors as those established with PATT-USA in lower secondary schools (Holter 2016).

The attitude questionnaire (affective component) of the PATT-USA instrument as developed in the 1990s was recently reconstructed and revalidated in Flanders by Ardies et al. (2013). This resulted in the shorter **PATT-SQ** instrument with six sub-factors (career aspirations, interest in technology, tediousness, positive perception of effects of technology, perception of difficulty, and perception of technology as a subject for boys or for boys and girls) and 24 items of attitude towards technology (Ankiewicz 2016). Because of the clear distinction in content, the first sub-factor was defined as *technological career aspirations* and the second as *interest in technology*. The factor attitude towards technology was changed to *tediousness* as the revised version defined attitude as *the extent to which technology was found boring*, given that all the items were formulated negatively (Ardies et al. 2013).

The six sub-factors were in accordance with the original factors identified by Bame and Dugger (1989a, b), although containing fewer items. Five of the factors produced an acceptable internal consistency (> 0.70), while only one, difficulty, had uncertain internal consistency. The gender factor (i.e. the attitude of whether technology was for boys and girls, or only boys) was the only sub-factor that showed no correlation with the other sub-factors. All other factors at least marginally correlated with three other sub-factors (Ardies et al. 2013; Metsärinne and Kallio 2015). Ankiewicz et al. (2001) raised concerns about both boys and girls having to respond to the same gender-biased items, which will be alluded to in the next section on problems with PATT.

Recently a translated, Swedish version of PATT-SQ, labelled **PATT-SQ-SE** was administered to 173 students (aged 12–15) followed by an interview with six respondents to explain and interpret the quantitative data. Mixed-method research as advocated long before (Ankiewicz et al. 2001; Gaotlhobogwe 2010, 2012; Van Rensburg et al. 1999) was followed. The results of this study implied that the PATT-SQ survey could be used mostly unchanged. However, the *gender category* could not be used as intended as it did not measure what it was supposed to and might be gender-biased. The *interest category* could be reduced to four items to focus on school technology, which would indicate how deep a student's well-developed individual interest was. The *career category* seemed to only detect students who were considering a career in technology, while other students lacked knowledge about what such a career might be and were therefore not interested in such a career (Svenningsson et al. 2016).

The PATT studies were adapted for measuring the attitudes of students in upper secondary school towards and concepts of **engineering** as part of Science, Technology, Engineering and Mathematics (STEM) education. Some of the background variables were related to engineering, for example experience with technology (toys, computers, museums); engineers among relatives; and the presence of a school subject on engineering in their curriculum. The questionnaire consisted of 65 items, of which 33 dealt with attitude. The remaining 32 items were aimed at measuring concept of engineering. In contrast to studies carried out amongst students in lower secondary school levels, a reasonably clear concept of engineering was found. The gender differences related to engineering found in lower secondary education were not found in upper secondary education. The study indicated that students had a fairly positive image of engineering (Kőycű and De Vries 2016).

The **Technology Attitude and Concept Scale (TACS-Thai)** was adapted from the TAS-USA and PATT-USA for use in Thailand. The first section, designed to obtain demographic information about the respondents, included nine items not part of the original TAS-USA. The two remaining sections were similar to the TAS-NL. Differences in students' attitudes in the USA and Thailand may be attributed to contextual factors such as culture and pedagogical factors such as the educational system, especially the teacher-centred pedagogy used in Thai classrooms. Overall, the pattern of attitudes and concepts of US and Thai students were similar (Becker and Maunsaiyat 2002). Like Van Rensburg et al. (1999), these researchers also emphasised the effect of context, such as language and culture, on the validation of instruments.

The exposure of students to technologically-rich environments may have an effect on their achievement and their attitudes towards technology. Subsequently, the **TEC-Lab questionnaire** was developed, based on the PATT-NL, PATT-USA and the instrument by Fife-Schaw et al. (1987). Additional items falling within the context of factors identified previously, resulted in an instrument consisting of 65 items that could be ranked by senior high school students (grades 9–12) immersed in a technologically-rich environment (TEC-Lab). A ten-point Likert-type scale was used and eight factors were identified. The exposure indicated positive attitudes towards technology. The shift was consistent, appearing in each of the factors as well as the overall attitude scale (Householder and Bolin 1993).

In some of the PATT studies described above, researchers alluded to problems experienced with the PATT instruments, some of which will be discussed in the next section.

Problems with the PATT instruments

Researchers experienced some contextual problems; problems with students' understanding and interpretation of the qualitative section of the PATT instrument; the length; the construction of the items; and how students dealt with the middle category of the Likert-type items.

Results in the USA Bame and Dugger (1989a, b) suggested that the essay (qualitative) section of the original instrument was not well understood by respondents. In Hong Kong (Volk et al. 2003) this section was explicitly excluded from the study. It is suggested that a phenomenographic research approach should be followed first to explore students' conceptions of technology (Luckay and Collier-Reed 2014). The need to supplement quantitative research approaches with qualitative ones (e.g. ethnographical studies) had also been expressed previously (Ankiewicz et al. 2001; Gaotlhobogwe 2010, 2012; Van Rensburg et al. 1999).

Context may influence the validity and reliability of some components or of the total PATT instrument (Otieno 1988; Prime 1991). Van Rensburg et al. (1999) had reservations about complicated technology-related constructs as part of some of the items (items 20, 22, 23 and 37); "high tech" terminology such as Lego and computers (items 6 and 18) and value-laden words such as smart, difficult, important, boring (items 13, 14, 15, 21, 26, etc.). They were also concerned about gender-biased items, such as "girls cannot do technology" (items 30, 41, 47 etc.); negative perceptions such as "I am not interested in technology" (items 33, 42, 46, etc.) and the majority of items focusing on traditionally accepted boys' activities. These researchers suggested that the responses of boys and girls should rather be compared to a specific gender-neutral descriptive item by using gender as a control variable or predictive characteristic (Ankiewicz et al. 2001). Recently some of the results obtained with the PATT-SQ-SE confirmed this concern regarding the gender category (Svenningsson et al. 2016).

In the USA, students struggled to understand the logic of the negatively-worded items; hence all were loaded onto one factor (Bame and Dugger 1989a). This supported one of the concerns raised by Van Rensburg et al. (1999) regarding the use of the negatively formulated items, specifically in a developing context.

Anderssen and Myburgh (1988) emphasised that concepts and terminology, frame of reference, culture and how an item has been formulated, all influence empirical research (Van Rensburg et al. 1999). The beliefs linked to emotions or attitudes were generally propositions, which White (1988) categorised as either prescriptive or descriptive. "Descriptive propositions reflect and affect attitudes through secondary associations … there are many formulae in physics, people have to do lots of problems in physics. Descriptive propositions reflect and affect attitudes through secondary associations. If the person dislikes formulae and problems, then the examples represent a negative attitude to physics, but that is reversed if the person likes them. Thus, the same descriptive propositions held by two people can stand for opposed attitudes, depending on the secondary associations" (White 1988: 102). Ankiewicz et al. (2001) advocated that in the technological context of developing countries and contexts where students choose English as Second Language (ESL) (or any other language than their vernacular) as medium of instruction, affective-related items based on descriptive propositions should rather be used.

Rennie (1988) and other researchers have drawn attention to the frequent use of the middle category by girls. Results based on mean scores may erroneously imply that girls have less positive attitudes than boys, while their responses in fact demonstrate non-commitment (Jarvis and Rennie 1998; Mawson 2010; Rennie and Jarvis 1995a).

New instruments which are non-related to the PATT studies, designed for the measurement of students' attitudes towards technology will be discussed briefly in the next section, without referring to the results of these instruments.

New instruments other than PATT to measure attitudes

In resolving the contextual and formulation problems mentioned, Van Rensburg et al. (1999) designed the **Attitudinal Technology Profile (ATP) questionnaire** to be used in the lower secondary school (ages 13–14) (Ankiewicz 2016).

The Test of Technical Attitudes (TTA) measured primary school students' attitudes towards technology. It consisted of three subtests. The student had to choose between construction and non-construction toys (TTA1) and between "feminine" and "masculine" toys (TTA2). Attitude was assessed by five scales, namely interest of technology (options); interest for technology (activities); image of technology; role model (general) and role model and work (Doornekamp 1991).

It was found that boys preferred "masculine" and construction toys. The presence of gender differences with regard to attitudes towards technology at the age of 10–11 years showed that the gender role socialization was already active during primary education. The socialization process started before children entered primary school and gender differences regarding attitude towards technology were already present in 5-year old children. Factors such as high level of training and/or occupation of the parents; parents' interest in technology; and technology education at primary school level had a positive effect on the attitudes of both boys and girls. By familiarizing children with technology, one may influence the selection process in favour of technology (Doornekamp 1991).

Technology in the Finnish education system provides two important scenarios to ascertain students' attitudes towards technology. Firstly, where technology education is taught voluntarily as part of vocationally oriented education, and secondly, where it is obligatory and offered as a cross-curricular theme in general education. The **Finnish National Board of Education (FNBE) attitude test** aimed at the assessment of Finnish secondary school students' attitudes towards Sloyd as a vocationally-oriented subject. In Finland, technology education is taught as part of Sloyd and can be viewed as Craft, Design and Technology. The FNBE attitude test is a shortened and modified version of the Fennema and Sherman (1976) attitude test that was originally developed for measuring attitudes in mathematics. The three factors of Fennema and Sherman's original nine factors used were *liking Sloyd as a school subject*; *self-concept in Sloyd*; and *experiencing utility in Sloyd*. The findings indicated that students' attitudes towards Sloyd were not generally positive but depended on the task and the motivation for undertaking it. A positive attitude was not based on the pleasure created by performing routine tasks or mechanical work but on valuing the importance of constructing information for production activities and for valuable products. The findings suggested more student-centred pedagogies for developing students' attitudes (Metsärinne and Kallio 2015).

Teachers are not obliged to teach technology as a subject in grades 7–9 as part of general education in Finland. However, the National Framework Curriculum (NFC) requires that cross-curricular themes be included in studies of various subject areas. One such cross-curricular theme is the Human Being and Technology (HBT). This means that the teaching of technology has also become obligatory. The **HBT questionnaire** was devised in order to examine students' learning related to the HBT cross-curricular theme among grade 9 students. It was divided into three sections, namely questions on students' knowledge about technology (cognitive component), their attitudes towards technology (attitude component) and their activity know-how (behavioural component). Issues related to attitudes towards technology were studied by means of 20 items which students assessed using a five-point Likert scale (Järvinen and Rasinen 2015). The HBT questionnaire appears to be the first instrument to include a section that measures students' actions or technological activities directly as part of the behavioural component of attitudes, and not only students' readiness for action as with the various PATT questionnaires. It includes 14 questions and a single open-ended section. This is an extension of the ATP questionnaire, which measured the readiness for action as part of the behavioural component (Ankiewicz et al. 2001). The Finnish students' attitudes towards technology showed similar trends as in the PATT studies. A cross-curricular approach does not seem to be conducive to the development of students' expected behavioural activities as these students felt that they had not developed technology or technological applications (Järvinen and Rasinen 2015).

A remedial teaching model was implemented as an intervention or effect study to remedy secondary school students' lack of knowledge of (cognitive component) and interest in (attitude component) technology in Switzerland. Güdel et al. (2015) identified four personality trait variables as facets of the construct "Affinity for technology" (AFT). They operationalized these in the online **AFT-Switzerland** done among 483 students aged 12–14 (grade 7 or 8) in Switzerland. Their findings indicated that more than 80% of the students perceived the intervention as positive. Despite their AFT on average decreased slightly between grade 7 and 9, an increase was established under certain teaching conditions.

Primary schools in the Netherlands had to implement science and technology as part of the **Programme for the Expansion of Technology in Primary Education (VTB)** with the aim to change students' attitudes towards science and technology positively. Since 2008, an online system (www.vtbportaal.nl) has been introduced to ascertain on a large scale the attitudes of Year 8 students (aged 11–12) in all VTB schools in the Netherlands. The results confirmed, inter alia, previously found gender differences in attitudes towards science and technology as well as the problem of gender stereotyping in primary schools (Schendstok 2009).

Previously, the focus has been on ascertaining students' concepts of technology mainly quantitatively by means of the PATT and PATT-related concept instruments (Refer to the previous sections on the PATT-NL, as well as PATT-USA and their associated instruments). There are also other, mainly qualitative new instruments for ascertaining students' concepts of technology, which are non-related to the PATT studies. These will be discussed briefly in the next section.

New instruments other than PATT to ascertain younger students' concepts of technology

Jarvis and Rennie (1996a) developed and validated three instruments to elicit and describe younger students' perceptions of technology. These were a writing/drawing activity designed for students of all ages in lower and upper primary school, a picture quiz devised for young students in lower primary school and a technology questionnaire initially for older students in upper primary school (aged 10–12 years) but later for even younger students. A combined writing/drawing activity, which complemented the questionnaire or quiz, was available for students of both age groups in lower and upper primary school (Jarvis and Rennie 1998; Mawson 2010; Rennie and Jarvis 1995a, c).

The **Writing/Drawing Activity** drew on the essay topic from PATT-NL. To this was added the instruction: *Please tell us what technology means to you by writing about it or by drawing a picture. You might like to do both* (Jarvis and Rennie 1998; Mawson 2010).

The **Picture Quiz** consisted of 28 pictures based on the descriptive framework intended to represent a wide range of possible ideas about technology. Some that would not be considered technology were included (e.g. a bridge, a telephone, a rose). Students had to tick the pictures they thought were related to technology (Jarvis and Rennie 1998; Mawson 2010: Rennie and Jarvis 1995b).

The so-called **Attitudes and Perceptions About Technology (APAT)** questionnaire was developed by Rennie and Treagust (1989), based on the outcomes of early pilot studies of the PATT instrument in Western Australia. The PATT scales for students 9–12 years old were adapted for this purpose. The **Technology Questionnaire** selected items from the three APAT subscales related to interest, diversity and design. An additional scale related to social aspects of technology was also derived, using items from the PATT instrument. This questionnaire had 20 statements divided into two parts. Part A, called *what is technology?* related to the cognitive component of attitudes, and contained 10 statements with items from the Diversity and Design scales presented alternately. Part B, *What do you think about technology?* related to the affective component of attitudes It also contained 10 statements, with items from the Interest and Social Aspects scales presented alternately (Rennie and Jarvis 1995a, b; Mawson 2010).

Interviewing is another effective way of probing students' perceptions and understandings. Interviews were used during the development stage of the PATT study, as a means of providing validity for the scales (Raat and De Vries 1987). De Klerk Wolters (1989b) described how 10 to 12-year olds were at ease talking about technology in interviews with researchers (Rennie and Jarvis 1995a). Students were encouraged to talk about their responses to the writing/drawing activity. They were then requested to consider their answers on the picture quiz and explain why they had chosen certain items and rejected others. They were also questioned about where they had come across the term 'technology' and whether they did technology at school (Jarvis and Rennie 1998).

Kent and Towse (1996) devised a qualitative open-ended questionnaire with nine items to ascertain students' perceptions of technology, as well as of the impact of technology, in Lesotho and Botswana. Contrary to the quantitative nature of attitude instruments in general, the emphasis was on their detailed responses and not on "ticks in boxes".

A general finding (Ankiewicz 2016) was that students' attitudes towards technology may be attributed to various determinants or predictive characteristics (Ankiewicz et al. 2001; Becker and Maunsaiyat 2002; Van Rensburg et al. 1999) such as context, gender, students' age, the technological nature of the family's professions and the technological toys and facilities at home (Ardies et al. 2015a). Knowing what determinants or predictive characteristics affect learners' attitudes towards technology leads to an understanding of how to develop attitudes, which will be discussed in the next section.

Means to develop students' attitudes towards technology

Affective behaviours may undergo far more sudden transformations than cognitive behaviours (Boser et al. 1998). Attitudes are formed through direct or vicarious means, with the former being stronger and less resistant to change. Direct means include first-hand experiences with parents, friends, teachers, objects or situations. Vicarious means include attitudes formed through influences such as mass media and advertising campaigns. Technology is ubiquitous in students' daily lives and attitudes about it are formed by a myriad of both direct and vicarious means (Ankiewicz et al. 2001; Volk and Yip 1999).

Various direct means of developing students' attitudes towards technology are suggested in the literature. Rennie (1988) suggests five interacting variables that determine students' attitudes and suggests focusing on those one has immediate control over, e.g. classroom experiences. A first direct means is to create more opportunities for girls to participate in technology. The inclusion of girls in technology education at the earliest opportunity has a positive impact on their attitudes towards technology, with the differences between boys' and girls' attitudes disappearing for some categories (Mammes 2004; Rennie 1988; Volk and Yip 1999; Volk et al. 2003). A second direct means is to avoid gender discrimination and stereotyping. Teachers should present technology in such a way that it is equally attractive to boys and girls (Ankiewicz et al. 2001; Jarvis and Rennie 1998; Rennie 1988; Van Rensburg et al. 1999; Volk and Yip 1999). A third direct means is to advance the content knowledge of technology teachers. The way teachers are prepared is of paramount importance in influencing the attitudes of all students (Volk and Yip 1999). Teacher knowledge, specifically pedagogical content knowledge (PCK) affects teaching, and in turn affects students' concept of and attitude towards technology (Ardies et al. 2015b; Jarvis and Rennie 1996b; Rohaan et al. 2010; Volk and Yip 1999; Williams 2013).

Other direct means are the nature of curricula, the types of programmes, pedagogy and resulting learning experience. The technology education profession should strive to develop curriculum materials and activities that stimulate the interest and meet the technological needs of all students (Boser et al. 1998; Rohaan et al. 2010; Williams 2013; Yu et al. 2012). Programmes that are more innovative and less craft and skills based are more successful in influencing attitudes (Volk et al. 2003). More student-centred, as opposed to teacher-centred pedagogies (Metsärinne and Kallio 2015), for example, project-based learning (PBL) are highly motivating for students, also leading to significant changes in their attitudes (Ardies et al. 2015b; Becker and Maunsaiyat 2002; Lou et al. 2011; Mioduser and Betzer 2008).

Conclusion

In addition to the previous findings made and conclusions drawn (Ankiewicz 2016) a systematised, rigorous theoretical framework, based on the current state of affairs in studies of the perceptions and attitudes of students towards technology, should be informed by the following guiding insights:

Researchers are interested in measuring students' attitudes towards technology for many different reasons. Studies into students' attitudes towards and concepts of technology mostly contained information on students' ideas when entering technology education (Kőycű and De Vries 2016). The PATT instrument used in the Netherlands, referred to as PATT-NL, was the first instrument specifically designed for this purpose (Ankiewicz 2016). Based on contextual factors such as language and age, the initial PATT-NL, measuring the cognitive and affective components of attitudes, was followed by the translated and modified PATT-USA, also focusing on both components. PATT-NL and PATT-USA may be regarded as mainstream instruments in PATT studies, and of high significance. Of lessor importance, and considered unconventional, PATT-related instruments such as the Technology Attitude Scale (TAS-NL), the Technology Attitude Questionnaire (TAQ) and the Teacher Attitude Questionnaire (PATT Teachers-NL) are associated with PATT-NL. The Students' Attitudes towards Technology (SATT), the Secondary Students' Attitudes Towards Technology (SSATT), the Technology Attitude Scale (TAS-USA) and the Teacher Attitude Questionnaire (PATT Teachers-USA), which are also unconventional instruments, are associated with the mainstream PATT-USA.

A number of related instruments were derived from the mainstream PATT-USA. Based on the revision of PATT-USA, the development of PATT-HK, PATT-Taiwan, PATT-Turkey and PATT-ELEM followed. The shorter PATT-SQ was also based on the reconstruction and revalidation of PATT-USA, but only measuring the affective component of attitudes. PATT-SQ-SE was a translated, Swedish version of PATT-SQ. The Technology Attitude and Concept Scale (TACS-Thai) and TEC-Lab questionnaire were developed in similar ways. New instruments, which were non-related to the PATT studies, such as the ATP, the Test of

Table 1 Categories of instruments

PATT mainstream instruments	Instruments associated with PATT mainstream instruments	Unconventional instruments	New attitude instruments, non-related to PATT	New concept instruments, non-related to PATT
1. PATT-NL (attitude questionnaire; concept questionnaire; essay section)		Associated with PATT-NL 1. Technology Attitude Scale (TAS-NL) 2. Technology Attitude Questionnaire (TAQ) 3. Teacher Attitude Questionnaire (PATT Teachers-NL)		
2. PATT-USA (attitude part; concept part; brief statement of what the students thought technology was)	1. PATT-Hong Kong (PATT-HK) 2. PATT-Taiwan 3. PATT-TR 4. PATT-ELEM 5. PATT-Engineering (as part of STEM education) 6. Technology Attitude and Concept Scale (TACS-Thai) 7. TEC-Lab questionnaire	Associated with PATT-USA 1. Students' Attitudes towards Technology (SATT) 2. Secondary Students' Attitudes Towards Technology (SSATT) 3. Technology Attitude Scale-USA (TAS-USA) 4. Teacher Attitude Questionnaire (PATT Teachers-USA)		
3. PATT-SQ (based on the attitude part of PATT-USA)	1. PATT-SQ-SE			

Table 1 (continued)

PATT mainstream instruments	Instruments associated with PATT mainstream instruments	Unconventional instruments	New attitude instruments, non-related to PATT	New concept instruments, non-related to PATT
			1. Attitudinal Technology Profile (ATP) questionnaire 2. The Test of Technical Attitudes (TTA) 3. Finnish National Board of Education (FNBE) attitude test 4. Human Being and Technology (HBT) questionnaire 5. Affinity for technology (AFT)-Switzerland 6. Programme for the Expansion of Technology in Primary Education (VTB)	
				1. Writing/Drawing Activity 2. Picture Quiz 3. Attitudes and Perceptions About Technology (APAT) questionnaire 4. Technology Questionnaire 5. Interviewing 6. Qualitative open-ended questionnaire (Kent and Towse 1996)

Technical Attitudes (TTA), The Finnish National Board of Education (FNBE) attitude test, the online AFT-Switzerland and HBT questionnaires were also developed, as were more qualitative instruments to ascertain younger students' concepts of technology, such as the Writing/Drawing Activity, the Picture Quiz, the Attitudes and Perceptions About Technology (APAT) questionnaire and the Technology Questionnaire, as well as interviewing. The various categories of the aforementioned instruments are listed in Table 1. All the instruments have been categorised according to their relationship with the mainstream PATT instruments which have been developed over time. Holter (2016) compiled a timeline (in Appendix B) for the development of the abovementioned PATT mainstream and associated instruments.

Attitude is a broad concept with different definitions and interpretations. Thus, in order to measure attitudes, a clear understanding of the concept is necessary (Ankiewicz 2016). Researchers in technology education often acknowledge, either implicitly or explicitly, the traditional approach to attitudes. The PATT-NL instrument and its derivatives were aligned to the traditional approach to attitudes with an integrated three-dimensional nature. These instruments ascertained students' technological concepts (cognitive component) and attitudes (affective component) as crucial prerequisites to technological activities (behavioural component) that would result in technological objects (Ankiewicz et al. 2001; Van Rensburg et al. 1999). However, these instruments did not ascertain the behavioural component of students' attitudes. Except for the HBT questionnaire the closest that other instruments came to ascertaining the behavioural component (activities) was to measure readiness for action (Ankiewicz 2016). The overwhelming majority of instruments have been focusing on the cognitive and/or affective component of attitudes, neglecting the behavioural component. Students' attitudes towards technology should perhaps in future be ascertained more holistically by also focusing on the behavioural component as one of the three components of attitudes. The researchers involved in the recent HBT questionnaire have done some ground-breaking work in this regard. Furthermore, statistical techniques such as factor analyses require researchers to have a clear understanding of the three components of attitude and the interrelationships of these, as well as of the underlying theoretical framework on which the test items of a specific questionnaire are based. An insufficient understanding could impede the identification, labelling and interpretation of the various subscales and scales obtained by factor analyses.

Students' attitudes are formed by a variety of both direct and vicarious means. It has been found that students generally have a positive attitude towards but a limited concept of technology. Their attitudes towards technology may be attributed to various determinants or predictive characteristics such as gender; technological nature of family's professions; and the availability of technological toys and facilities at home (Ankiewicz 2016). Technology teachers may however access and apply some direct means to positively develop students' attitudes towards technology.

Research has now evolved to a stage where researchers are interested in small to medium scale multidimensional (multivariate, multilevel) studies to determine the effect of all characteristics or determinants on all aspects of students' attitudes as opposed to the effects of one characteristic on a specific aspect of attitude only (Ankiewicz 2016).

In closing, such a rigorous theoretical framework may serve as a valuable resource for future researchers embarking on this area of research, as it provides a synopsis that may assist in enhancing an understanding of research that has been done and work that needs to be done in order to contribute to developing new knowledge in the field of design, technology, and engineering education. It also indicates gaps in this research area, notably in researching the behavioural component of attitudes.

References

Anderssen, E. C., & Myburgh, C. P. H. (1988). Problems of questioning in Southern Africa. *Questioning Exchange, 2*(3), 281–287.

Androulidakis, S. (1991). Greek teachers' attitudes towards technology, A first approach. In *PATT 5 conference proceedings* (pp. 219–223). Eindhoven, The Netherlands.

Ankiewicz, P. (2016). Perceptions and attitudes of pupils toward technology. In M. J. de Vries (Ed.), *Handbook of Technology Education, Springer International Handbooks of Education*. https://doi.org/10.1007/978-3-319-38889-2_43-1.

Ankiewicz, P., Van Rensburg, S., & Myburgh, C. (2001). Assessing the attitudinal profile of South African learners: A pilot study. *International Journal of Technology and Design Education, 11*(2), 93–109. https://doi.org/10.1023/A:1011210013642.

Ardies, J., De Maeyer, S., & Gijbels, D. (2013). Reconstructing the pupils attitude towards technology-survey. *Design and Technology Education: An International Journal, 18*(1), 8–19.

Ardies, J., De Maeyer, S., & Gijbels, D. (2015a). How do male and female secondary students' attitudes towards technology evolve?. In: *PATT 29 conference proceedings* (pp. 26–34). Marseille: Presses Universitaires de Provence.

Ardies, J., De Maeyer, S., Gijbels, D., & Van Keulen, H. (2015b). Students' attitudes towards technology. *International Journal of Technology and Design Education, 25*(1), 43–65.

Bame, E. A. (1989). What do American teachers think of technology. In *PATT 4 conference proceedings* (pp. 320–323). Eindhoven, The Netherlands.

Bame, E. A. (1991). PATT-USA: A report of findings. In *PATT 5 conference proceedings* (Vol. 2, pp. 202–218). Eindhoven, The Netherlands.

Bame, E. A., & Dugger, W. E. (1989a). Pupils' attitude towards technology: PATT-USA. In *PATT 4 conference proceedings* (pp. 309–319). Eindhoven, The Netherlands.

Bame, E., & Dugger, W., Jr. (1989b). Pupils' attitude toward technology: PATT-USA Report Findings. Retrieved from http://www.iteea.org/File.aspx?id=40498&v=3084cd04.

Bame, E., Dugger, W., De Vries, M., & McBee, J. (1993). Pupils' attitudes toward technology—PATT-USA. *Journal of Technology Studies, 19*(1), 40–48.

Becker, K. H., & Maunsaiyat, S. (2002). Thai students' attitudes and concepts of technology. *Journal of Technology Education, 13*(2), 6–19.

Boser, R. A., Palmer, J. D., & Daugherty, M. K. (1998). Students attitudes toward technology in selected technology education programmes. *Journal of Technology Education, 10*(1), 4–19.

De Klerk Wolters, F. (1988a). PATT research in 1987/88. In *PATT 3 conference proceedings* (pp. 39–46). Eindhoven, The Netherlands.

De Klerk Wolters, F. (1988b). Directions for use of the TAS in class. In *PATT 3 conference proceedings* (pp. 509–535). Eindhoven, The Netherlands.

De Klerk Wolters, F. (1989a). The PATT-project, an overview of an international project in technology education. In *PATT 4 conference proceedings* (pp. 290–308). Eindhoven, The Netherlands.

De Klerk Wolters, F. (1989b). A PATT study among 10 to 12-year-olds. In *PATT 4 conference proceedings* (pp. 324–330). Eindhoven, The Netherlands.

De Vries, M. (1988). Technology in physics education. In *PATT 3 conference proceedings* (pp. 182–188). Eindhoven, The Netherlands.

De Vries, M. (1991). What do students in Dutch technology teacher programmes think of their subject? *Research in Science & Technological Education, 9,* 173–179.

De Vries, M. J. (1992). Dutch technology education developments: A comment. *International Journal of Technology and Design Education, 2*(3), 58–60.

Dean, S., & Illowski, B. (2008). F distribution and ANOVA: Purpose and basic assumption of ANOVA. Available from http://cnx.org/content/m17068/1.5.

Doornekamp, B. G. (1991). Gender differences in the acquisition of technical knowledge, skills and attitudes in Dutch primary education: The need for technology education. *International Journal of Technology and Design Education, 2*(1), 37–47.

Dunlap, D. D., & Dugger, W. E. (1991). Comparing attitudes towards technology of third and forth grade students in Virginia relative to their exposure to technology. In *PATT 5 conference proceedings* (Vol. 2, pp. 194–201). Eindhoven, The Netherlands.

Fennema, E., & Sherman, J. A. (1976). Fennema-Sherman mathematics attitudes scales: Instruments designed to measure attitudes toward the learning of mathematics by males and females. *Journal for Research in Mathematics Education, 7,* 324–332.

Ferguson, E., & Cox, T. (1993). Exploratory factor analysis: A user's guide. *International Journal of Selection and Assessment, 1,* 84–94.

Fife-Schaw, C., Breakwell, G. M., Lee, T., & Spencer, J. (1987). Attitudes towards new technology in relation to scientific orientation at school: A preliminary study of undergraduates. *British Journal of Educational Psychology, 57,* 114–121.

Fleming, K. L. (2005). *An analysis of factors that influence community college students' attitudes toward technology*. Unpublished Ph.D. thesis, Texas A&M University.

Gaotlhobogwe, M. (2010). *Attitudes to and perceptions of design and technology students towards the subject: A case of five junior secondary schools in Botswana*. Unpublished Ph.D. thesis, University of Wales Institute, Cardiff.

Gaotlhobogwe, M. (2012). The impact of lack of resources on declining students' enrolments in Design and Technology in Botswana junior secondary schools. *Design and Technology Education: An International Journal, 17*(1), 10–17.

Güdel, K., Heitzmann, A., & Mueller, A. (2015). Affinity for technology—A potential instrument to measure PATT (pupils' attitude towards technology)? In *PATT 29 conference proceedings* (pp. 180–187). Marseille: Presses Universitaires de Provence.

Holter, C. A. (2016). *Assessing elementary pupils' attitudes toward technology*. Unpublished DEd thesis, Virginia Polytechnic Institute and State University. https://vtechworks.lib.vt.edu/bitstream/handle/10919/65148/Holter_CA_T_2016.pdf;sequence=1.

Householder, D. L., & Bolin, B. (1993). Technology: Its influence in the secondary school upon achievement in academic subjects and upon students' attitude toward technology. *International Journal of Technology and Design Education, 3*(2), 5–18.

Jack, B., & Clarke, A. (1998). The purpose and use of questionnaires in research. *Professional Nurse, 14,* 176–179.

Järvinen, E. M., & Rasinen, A. (2015). Implementing technology education in Finnish general education schools: Studying the cross-curricular theme 'Human being and technology'. *International Journal of Technology and Design Education, 25*(1), 67–84.

Jarvis, T., & Rennie, L. (1996a). Understanding technology: The development of a concept. *International Journal of Science Education, 18*(8), 977–992.

Jarvis, T., & Rennie, L. (1996b). Perceptions about technology held by primary teachers in England. *Research in Science and Technology Education, 14*(1), 43–54.

Jarvis, T., & Rennie, L. J. (1998). Factors that influence children's developing perceptions of technology. *International Journal of Technology and Design Education, 8*(3), 261–279.

Jeffrey, T. J. (1993). Validation of a technology attitude scale for use by American teachers at the middle school level. In *PATT 6 conference proceedings* (pp. 357–364). Breukelen, The Netherlands.

Jeffrey, T. J. (1995). Adaption and validation of a technology attitude scale for use by American teachers at the middle school level. In *PATT 7 conference proceedings* (pp. 53–58). Breukelen, The Netherlands.

Kent, D., & Towse, P. (1996). Pupil-centred aims and objectives for technology education in Botswana and Lesotho. In *PATT (South Africa) Conference proceedings* (pp. 184–189). Cape Town, South Africa.

Kőycű, Ü., & De Vries, M. J. (2016). What preconceptions and attitudes about engineering are prevalent amongst upper secondary school pupils? An international study. *International Journal of Technology and Design Education, 26*(2), 243–258.

Lou, S. J., Shih, R. C., Diez, C. R., & Tseng, K. H. (2011). The impact of problem-based learning strategies on STEM knowledge integration and attitudes: An exploratory study among female Taiwanese senior high school students. *International Journal of Technology and Design Education, 21*(2), 195–215.

Luckay, M. B., & Collier-Reed, B. I. (2014). An instrument to determine the technological literacy levels of upper secondary school students. *International Journal of Technology and Design Education, 24*(3), 261–273.

Mammes, I. (2004). Promoting girls' interest in technology through technology education: A research study. *International Journal of Technology and Design Education, 14*(2), 89–100.

Martins, A. (1991). Attitudes of middle secondary school pupils in Portugal towards technology. In *PATT 5 conference proceedings* (Vol. 2, pp. 155–171). Eindhoven, The Netherlands.

Mawson, B. (2010). Children's developing understanding of technology. *International Journal of Technology and Design Education, 20*(1), 1–13.

Meide, J. B. (1997). Pupils' attitudes towards technology: Botswana. In *PATT 8 conference proceedings* (pp. 208–213). Scheveningen, The Netherlands.

Metsärinne, M., & Kallio, M. (2015). How are students' attitudes related to learning outcomes? *International Journal of Technology and Design Education*. https://doi.org/10.1007/s10798-015-9317-0.

Mioduser, D., & Betzer, N. (2008). The contribution of project-based-learning to high-achievers' acquisition of technological knowledge and skills. *International Journal of Technology and Design Education, 18*(1), 59–77.

Moore, J. L., & Songun, R. (1991). The development of scales to measure the attitude to technology of vocational education students in Turkey. In *PATT 5 conference proceedings* (Vol. 2, pp. 182–193). Eindhoven, The Netherlands.

Mottier, I., Raat, J. H., & De Vries, M. J. (Eds.). (1991). Report on the PATT 5 conference. In *PATT 5 conference proceedings* (Vol. 1, pp. 29–36). Eindhoven, The Netherlands.

Otieno, F. O. (1988). Technology as a school subject: The Kenyan experience. In *PATT 3 conference proceedings* (pp. 189–196). Eindhoven, The Netherlands.

Prime, G. (1991). The attitudes and concepts of Trinidad and Tobago secondary school students toward technology. In *PATT 5 conference proceedings* (Vol. 2, pp. 172–181). Eindhoven, The Netherlands.

Raat, J. H., & De Vries, M. (1985). *What do 13-year old students think about technology? The conception of and the attitude towards technology of 13-year old girls and boys*. Eindhoven University of Technology, The Netherlands (ERIC Document Reproduction Service No. ED 262-998).

Raat, J. H., & De Vries, M. (Eds.). (1987). Technology in education: Research and development in the project "Physics and Technology". *International Journal of Science Education*, *9*, 159–168.

Rattray, J., & Jones, M. C. (2007). Issues in clinical nursing. Essential elements of questionnaire design and development. *Journal of Clinical Nursing, 16,* 234–243.

Rennie, L. J. (1988). How can we make technology interesting for girls?. In *PATT 3 conference proceedings* (pp. 397–414). Eindhoven, The Netherlands.

Rennie, L., & Jarvis, T. (1995a). Three approaches to measuring children's perceptions of technology'. *International Journal of Science Education, 17*(6), 755–774.

Rennie, L., & Jarvis, T. (1995b). English and Australian children's perceptions about technology. *Research in Science & Technological Education, 13*(1), 37–52.

Rennie, L. J., & Jarvis, T. (1995c). Children's choice of drawings to communicate their ideas about technology. *Research in Science Education, 25*(3), 239–252.

Rennie, L. J., & Treagust, D. F. (1989). Measuring students' attitudes and perceptions about technology: A multidimensional concept. *Research in Science Education, 19,* 221–230.

Rohaan, E. J., Taconis, R., & Jochems, W. M. (2010). Reviewing the relations between teachers' knowledge and pupils' attitude in the field of primary technology education. *International Journal of Technology and Design Education, 20*(1), 15–26.

Schendstok, C. (2009). Improving the attitude towards science and technology in Dutch primary education. In *PATT 22 conference proceedings* (pp. 383–389). Delft, The Netherlands.

Svenningsson, J., Hultén, M., & Hallström, J. (2016). Understanding attitude measurement: Exploring meaning and use of the PATT short questionnaire. *International Journal of Technology and Design Education*. https://doi.org/10.1007/s10798-016-9392-x.

Van Rensburg, S., Ankiewicz, P., & Myburgh, C. (1999). Assessing South Africa learners' attitudes towards technology by using the PATT (Pupils' Attitudes Towards Technology) questionnaire. *International Journal of Technology and Design Education, 9,* 137–151.

Volk, K. S., & Yip, W. M. (1999). Gender and technology in Hong Kong: A study of pupils' attitudes toward technology. *International Journal of Technology and Design Education, 9,* 57–71.

Volk, K., Yip, W. M., & Lo, T. K. (2003). Hong Kong pupils' attitudes toward technology: The impact of design and technology programs. *Journal of Technology Education, 15*(1), 48–63.

White, R. T. (1988). *Learning science*. New York: Basil Blackwell.

Williams, P. J. (2013). Research in technology education: Looking back to move forward. *International Journal of Technology and Design Education, 23*(1), 1–9.

Yu, K.-C., Lin, K.-Y., Han, F.-N., & Hsu, I. Y. (2012). A model of junior high school students' attitudes toward technology. *International Journal of Technology and Design Education, 22*(4), 423–436.

Yurdugül, H., & Aşkar, P. (2008). An investigation of the factorial structures of Pupils' Attitude towardsTechnology (PATT): A Turkish Sample. *İlköğretim/Elementary Education Online, 7*(2), 288–309.

Zuga, K. F. (1997). An analysis of technology education in the United States based upon an historical overview and review of contemporary curriculum research. *International Journal of Technology and Design Education, 7*(3), 203–217.