“Feeling like a Scientist”: Factors Affecting Students’ Selections of Technology Tools in the Science Classroom

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Abstract

This research looked at the choices that children make in the classroom when offered manual and technological options to measure scientific variables. Over 170 school children were involved in science lessons designed in collaboration with school teachers and the research team as part of the planned curriculum. We found that approximately 25% of the students chose the manual measuring options, compared with 75% who chose the technological options. During the focus group interviews ($n = 62$) carried out immediately after the class, we found that some children who had selected the technological option had done so due to perceptions of the tool’s novelty and “accuracy.” Some later regretted their choice, reasoning that “real” scientists did not use technology, that it would have been more challenging to measure manually, and therefore that they would have “felt more like scientists” had they selected the manual option. Perceptions of ease of use sometimes lowered children’s intent to use the technology option. Similarly, students who chose the manual option alluded to the inauthenticity of the technology option: this is not “what scientists do.” Consequently, students who had selected the manual option were also more likely to describe feeling “like a scientist” when carrying out the measurements. The possible implications of the findings, in terms of a possible inversion of the technology acceptance model for students in the science classroom, are explored.

Keywords Technology acceptance · Science · Choices · Perceptions · Data-loggers · Probeware

Introduction

A key educational priority for the United Arab Emirates (UAE), the setting for this study, is to “encourage a society that is driven by science, technology and innovation.”¹ This aspiration is supported at the policy level, where educational targets are focused on improving the UAE’s performance in international large-scale assessments, improving teaching and school leadership, and increasing the number of students enrolling in higher education. These educational reforms are aligned with the UAE’s National Vision 2030² and the plan to develop a predominantly knowledge-based economy. Consequently, the development of a highly skilled workforce is an important prerequisite to reaching the UAE’s goal of economic diversification, sustainability, and stability.

The technology choices offered to the students in this study consisted of data-loggers (digital probes connected to a display device capable of automatically plotting the data acquired) and the manual options consisted of analogue measuring instruments. The views of primary school aged students in the Abu Dhabi school system regarding their relationship with these technologies and their science identities are particularly salient when considering the region’s economic focus on science and technology. The perceptions of these children, in the technologically advanced and multi-cultural city of Abu Dhabi, are also relevant to the wider educational community to help educators provide authentic, motivational, and pedagogically sound uses of technology in the twenty-first century science classroom.

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¹ <https://www.moe.gov.ae/En/AboutTheMinistry/Pages/MinistryStrategy.aspx>

² <https://www.ecouncil.ae/PublicationsEn/economic-vision-2030-full-versionEn.pdf>

Literature Review

The Partnership Between Science and Technology in the Classroom

Wang et al. (2014) studied school students' technology experiences to explore barriers to students' and teachers' use of technology. As the use of technology is becoming more commonplace in schools, research is beginning to emerge about the ways in which technology impacts on students' identity as being both "techy types" and as scientists. The way in which technology impacts on one's identity is important to explore and understand, since technology and science education are intrinsically linked. Studies from almost two decades ago, when Internet technology was beginning to emerge in schools, showed the transformative power of such tools, and the ways in which it could expose the students to other worlds, "allowing them to view themselves as capable participants in this new learning situation" (Mistler-Jackson & Songer, 2000, p. 459). As one of the students in that study remarked, she liked using the computers and the internet because she "got to go to places that not the whole class was doing" (p. 459). The authors concluded that these activities reaped benefits in the motivational, self-efficacy, and learning dimensions, that they attributed at least in part to "students' ability to find a learning environment in which their voices, and those of their peers, were valued and respected" (p. 460).

Increasingly, the integration of educational technology into science classrooms is considered to be critical. However, some research also points to possible negative consequences. For example, a lack of confidence or training on the teachers' part when integrating technology with the curriculum can lead to variation in the quality of lesson delivery (Eastwood & Sadler, 2013; Wang et al., 2014) and frustration on students' part when equipment does not work, or where they are unable to problem-solve independently (see for example, Sung et al., 2016). Others have written of a supposed disconnect between the "digital immigrant" teachers, with their "digital native" students (Prensky, 2001) in what was termed an educational "singularity" predicated by the ubiquitous use of digital technology by young people from the late twentieth century onwards. However, the existence of such a clear dichotomy (between "old" teachers and their students) has been called into question by a number of researchers (see for example, Bennett & Maton, 2010; Kirschner & De Bruyckere, 2017; Selwyn, 2009).

The term "digital native" arose from a series of articles (see for example, Prensky, 2005) in which, people born from 1980 onward were perceived as "immersed" in technology rather than being intermittent users, as characterized

by previous generations. This suggests that students in this digital era should embrace the use of digital technology in the science classroom, even if teachers do not. The concept of "digital natives" is underpinned by the assumption that young people have some form of innate ability with digital technologies (such as the existence of "homo-zappiens"; Veen & Vrakking, 2006) and the reports of neuroscientists claiming that young people's frequent interactions with technologies can increase their working memory and strengthen perceptual learning (Small & Vorgan, 2009). However, the *nature* of these interactions is likely to be socially, economically, and culturally complex, and rather narrower and less emancipatory than the "digital native" rhetoric suggests (Selwyn, 2009). Rather than being a virtual space for creative collaboration, as envisaged by educators, many young people (and likely adults) currently use technology passively and without interacting meaningfully with others (Livingstone, 2009). As such, it seems unlikely that students would then instinctively associate technology use with authentic learning in the classroom. For example, in an ethnographic study of liberal arts college students' use of technology in both academic and non-academic settings, Lohnes and Kinzer (2007) reported an almost universal theme of resistance to using laptops in the classroom, but not during leisure time. As such, the role of the adult should not be considered to be that of a powerless bystander, but rather a sophisticated learner who can stimulate and guide young people towards meaningful engagement with technologies in the classroom and therefore promote genuine digital scholarship (Rosenblum, 2008).

Technology Acceptance

The technology acceptance model (TAM) was developed by market researchers who wanted to understand the adoption of new information systems by potential users (Davis et al., 1989). The TAM is considered to be largely successful in its ability to explain end-user technology usage (see, Scherer et al., 2019; Wu et al., 2007) but research relating to the application of the TAM to technology usage by children and young adults is limited. Studies that have applied the TAM when evaluating new technology use by these "digital natives" (see, Barteit et al., 2019; Drehlich et al., 2020; Moyo, 2015) have found that, much like with adults, perceived usefulness and ease of use are primary drivers for increased intention of use and ultimately uptake of the technology. As such, in the present study, we expect that elementary school children will readily use the digital measuring technologies on offer due to their perceived ease of use and usefulness when collecting data during classroom experiments.

Table 1 Examples of scientific variables and associated measuring tool

Science topic	Scientific variable example	Measuring tool	
		Analogue	Digital
Matter: solids, liquids, gases and change of state	Temperature	Glass thermometer	Temperature measurement probe/data sensor and display device
Acids and alkalis	pH	Universal indicator paper	pH measurement probe/data sensor and display device
Using forces in motion	Force	Newton meter	Force measurement probe/data sensor and display device

The Benefits of Data-Loggers in the Science Classroom

The uses of technology in science education discussed above, in a broad sense, focus on scientific reasoning and supporting empirical science activities such as researching a concept prior to experimentation or the interpretation of a set of results (McFarlane & Sakellariou, 2002). In the present study, the technology choices consisted of whether to use digital sensors or their analogue counterparts (see Table 1). As such, the empirical science use, in this case, was specifically for observing and measuring variables (McFarlane & Sakellariou, 2002). Although there were some early reports of drawbacks from using digital sensors and graphing equipment (Coleman, 1996) in the science classroom, there is a more recent body of evidence suggesting that using technology in this way improves conceptual knowledge relating to an experiment. For example, students are more easily able to make inferences when the gathering of data and the generation of graphs are automated (Linn & Hsi, 2000; Metcalf & Tinker, 2004). Another reported benefit is the increased independence of students during experimental work, allowing for more meaningful interactions with the teacher. In a study drawing from evidence gathered from teachers' evaluations of over 300 lessons taught using ICT, teachers reported that when using data-loggers, they were able to move beyond conversations about the correct use of manual measuring equipment to a greater focus on the interpreting of the results using conceptual understanding (Rogers & Finlayson, 2004).

According to cognitive load theory, the often negative outcomes observed for inquiry-learning approaches (Areepattamannil, 2012; Lavonen & Laaksonen, 2009; OECD, 2016) are likely due to the excessive use of cognitive resources in the working memory (Pillay, 1994), leading to students not grasping the key learning points of an inquiry-based science lesson. Thus, a teacher employing this pedagogic strategy should scaffold student learning that does not relate directly to the learning intentions of the lesson (Furtak et al., 2012; Hmelo-Silver et al., 2007). The use of data-loggers and the accompanying graph generation software is considered an effective means of scaffolding student learning in inquiry learning environments, particularly if the learning intentions of the lesson are not related to, say, reading analogue scales or manually plotting a graph (Salamon et al.,

1991; Sandoval & Reiser, 2004). Furthermore, the use of data-loggers also provides benefits to teachers' professional knowledge and practice and can result in better understandings of pedagogies such as inquiry-learning. In workshop-based professional development programs about the use of data-loggers offered in Japan and the USA, teachers reported deeper understanding of inquiry approaches through their own deepened conceptual understanding attributed to the hands-on nature of the activities and the intuitive graphical representations of the data (Tosa & Martin, 2010).

We also note that many barriers to carrying out experimental work in science lessons exist (such as health and safety concerns, resource availability, curriculum time pressures and the uncertain pedagogical benefits) and the integration of experimental work into an inquiry-learning approach provides yet greater challenges for students and teachers alike. Some of these barriers can be overcome by using data-logging equipment. As discussed, data-loggers facilitate inquiry-learning methodologies when students are collecting and interpreting scientific data. In the previously mentioned professional development project (Tosa & Martin, 2010), the teachers could see the clear pedagogical benefits of data sensing equipment in enabling more authentic approaches to science in their classrooms. This attitudinal shift is highly likely to increase the frequency of planned inquiry-learning experiences that their students experience. These experiences are also more likely to result in "successful" experiments in so much as the results obtained support the conceptual learning intentions underpinning the experimental activity. For instance, observations of classes in which teachers employed data sensing equipment as part of a technology-enhanced inquiry-learning project in elementary and middle schools showed that almost every investigation was completed successfully (Metcalf & Tinker, 2004). In terms of curriculum time pressures, data sensing equipment allows for data to be collected, presented, and analyzed, automatically. As a result, learning time is recovered by reducing the time spent on activities such as carrying out repetitive measurements, recollecting data due to errors in handling or reading the values of manual instruments, carrying out complex calculations, and manually drawing results tables and graphs. Data-loggers even allow for very slow experiments to be left unattended while other learning takes place.

Students Perceptions of “Feeling like a Scientist”

Following on from Zhai et al.’s (2014) study on students’ perceptions of being a scientist in the classroom, we were interested to explore the concepts of technology integration within this conceptual framework. If doing “dangerous” work makes one a real scientist, could using, for example, data sensing equipment to gather data, make one feel more like a “real” scientist? Or are there ways in which, for some students, the act of interacting with technology creates barriers or resistance, which in turn impacts on their ability to both use technological tools, and also on their own science self-identity? In other words, are children who choose technological tools as a means to investigate a scientific concept, more likely to express strong science self-identity, enjoyment of science, and to report “feeling more like a scientist” as a result of using those tools, than students who self-selected to investigate the identical scientific concepts by using manual measurement and data collection tools?

In the aforementioned study, students reported that they felt like they are a scientist when they did experiments by carrying out tasks such as recording data. In one interview, the student in question recognized that inquiry elements such as making observations and generating hypotheses made her feel more like a scientist (Zhai et al., 2014). However, these inquiry elements do not necessarily require the use of technology such as data sensing equipment. No studies have been undertaken in the MENA region into students’ motivations and attitudes towards self-selecting to use technology to “learn” science in the classroom, and we are not aware of any qualitative work in the region on science identity in primary school students. This work intends to fill this gap in the STEM education literature on children’s perceptions of using technology in the science classroom and also to illuminate and explore possible barriers to embracing STEM that could be overcome with greater understanding. Reluctance to use technology (where useful and appropriate) may be connected to science identity, both of self and others, and may possibly impact on their future career aspirations. Therefore, an awareness of these issues is important in order to advocate possible strategies to overcome some of these where appropriate. The purpose of this study was to explore the ways in which students’ science identity impacts upon their self-selecting to perform science experiments using technological tools versus using manual tools to study identical science concepts. A further aim is to identify whether by using technological devices to “perform” science, children are more likely to “feel” like scientists, and whether this is in part a factor of having a strong identification with science in the first place. The study also aims to explore the converse of this idea, namely, whether those students who selected manual tools to carry out their science experiment identified this as doing science differently, and whether this was linked to their science identity.

The following research questions guided the study:

- Q1. What relative proportions of students select to perform science experiments using technological, versus manual, tools?
- Q2. What are the reasons for students choosing manual or technological tools to perform science experiments?
- Q3. How does a student’s decision to choose to “do” science manually or by using technology relate to their self-expressed science identity?

Methodology

The participants were selected via stratified, convenience sampling in terms of the site choice and were invited to participate in the study, due primarily to familiarity of willing administrators in those schools who were known to the researchers as having interest in involving their schools in educational research. For various reasons, including the desire to focus on upper primary/early middle school age school children, we requested the involvement of multiple classes in those grade levels. The science lessons were co-planned with the science teacher/s in the schools, in alignment with their planned curriculum, so as to ensure that the study did not impinge upon their regular teaching requirements. Rather, we worked with the teachers to identify, within their existing curriculum, opportunities for measuring scientific variables which could fit with the concept of providing students with choices of manual or technological means of measuring these variables. Parental approval (and child assent) was sought for focus group interviews which would take place in addition to the science lessons.

The students undertook their normal planned science lesson, in their usual classroom, adhering to the regular planned curriculum coverage. The teacher introduced the scientific concept of the lesson and explained that the measurement of a variable would take place during the lesson. The students were “coached” in the use of the tool by way of two short explanatory videos. The video presenter took care to monitor voice tone and time of explanation for consistency, so as not to introduce bias toward either choice of measuring instrument. An independent review of the videos by a panel of children associated with the research team (but not the video presenter) and of a similar age to the study participants, found no preferential bias for the choice of equipment based on the content of the videos. Furthermore, no participant responses received during the interview process (outlined below) referred to the video content as a basis for their choice.

Students were then asked to choose an instrument to measure the scientific variable relevant to their lesson (this was temperature, pH, or force depending on the grade level

and curriculum content) as shown in Table 1. For example, in one class, students were asked to choose a tool to measure the temperature of hot water in boiling tubes that were arranged to model the huddle behavior of penguins (one central boiling-tube surrounded by six outer boiling-tubes secured with a rubber band). Students were required to measure the temperature of the water over a period of 20 min (at 1-min intervals) for one outer boiling-tube and the central boiling-tube. To carry out this experiment, students were given the choice of a Pasco SPARK LXi Datalogger (consisting of a display device running the Pasco SPARK-View software connected to Pasco PASPORT Temperature Probe) or one-or-more analogue glass thermometers. Once students had chosen their measuring instrument, they were assigned to groups by the teacher, with students who had made the same choice.

The students' choices of measuring tool were then recorded in a simple checklist. The other data collection tool was a focus group interview (see Appendix for interview schedule). After completing the experiment, groups of students were interviewed to investigate why they made their choice of measuring instrument, among other effects. The data analysis for the interviews utilized thematic analysis, where themes of science identity, concepts of choice, etc., as per the research questions, were extracted and compared to their instrument choice. A process of coding and iterative sub-coding was used until the data codes reached saturation for a particular code.

When deciding upon the method of interview data collection, we debated the advantages and disadvantages of various possible approaches, such as individual versus focus group interviews. The key disadvantage to the latter interviewing strategy is of course that there is the potential for children's views to be "distorted if social pressure were placed on the individual" (Breen, 2006, p. 466), which might mean in the case of this study, one student influencing another on their motivations for a selection of a particular measuring tool. However, the participants in this study were young children who would likely feel uncomfortable and possibly intimidated in an interview situation, and we reasoned that we could employ strategies to attempt to ameliorate the potential effect of peer influence, such as pointedly asking individual students their opinions, reminding all participants that they should express their own view, and finally prefacing some questions relative to the previous group member's response where appropriate (such as "what do you think about that—would you agree or disagree with what X said?") to clearly indicate that both similar and different answers to their peers were of equal merit. Consequently, we employed the focus group discussion method in this study in which small groups of students could express their views relating to the research topic in a discussion led by an experienced moderator (Hennink et al., 2020). As classmates, the focus group participants were familiar to

each other, and discussions relating to the moderator's questions (and exploratory follow-up questions) were encouraged to gain greater breadth and depth from the responses. It was hoped that this non-threatening group environment encouraged authentic student answers, where students would feel they could express their views without fear of judgment. The focus groups took place immediately after the science lesson thus increasing the response validity. The location of the focus group discussions was the normal school setting to "minimize influence of an unrealistic research environment" (Newby, 2014, p. 105).

Findings

To answer research question 1, the total number of students choosing the manual and technology options was recorded. Of a total of 172 students, 42 chose to use the manual instrument and 130 chose the technological instrument. In other words, only 24% of children chose the manual option while 76% chose the technology option.

What Are the Reasons for Your Choice of Equipment?

In order to address research questions 2 and 3, the main themes that arose from the data collected from the focus group interviews are presented below. With regard to research question 2, student justifications for selecting the technology option fell into four main categories: fun, novelty, and perceptions of the tool being both easier, and more accurate than the manual option.

Key Themes

"It's fun!" (Technology Option)

The idea that the technology option would be more fun than the manual option arose in most focus groups, as these examples illustrate:

I chose that because I thought it would be more fun... we might discover something new that we didn't know about science, because it's cool.

I choose it because I thought it was more fun... Like it's kinda one of a once-in-a-lifetime thing. But like you can do it other times, but not at this age. So I was like 'oh my god, I wanna do this so bad.

"Novelty" (Technology Option)

Students frequently referred the novelty and "newness" of the technology option as a justification for their choice, for example:

I've never seen the digital one before, so I just wanted to try it.
I chose the probes because, um, I've never worked with that...and I wanted to challenge myself.
I wanted to learn something new, something I never used before, I never saw it before.
I used the iPad thing, because it looks cool and interesting to use. [Did you also think it would be easier?]
No.

Ease of Use (Technology Option)

Some students chose the technology option as they believed this would be the easier option, as these examples demonstrate:

I chose digital because like I didn't want to read the other one, it's easier to just look at it.
Because I thought it would be a great way to see the temperature and it would be more easier to see it instead of going to eye levels.

Perceptions of Accuracy (Technology Option)

Students also expressed opinions about the accuracy of the digital option as the basis of their choice, which they perceived to be greater:

I chose probes because I think that it will give us a more accurate result and give us more information.
Because like, when you measure it in the normal, like, it might not like be exact, but it would give you more facts about it with the probe one.
Yeah, 'cause it would give us the exact answer.

Some of the justifications that students gave for selecting to measure their variable using the manual option also included the theme of a perception of accuracy or due to a belief that it would be simpler and easier to use than the technology option. However, some students chose the manual option due to the apparent challenge it presented.

Perceptions of Accuracy (Manual Option)

Several comments regarding the reason for choosing the manual option were due to the potential for technology to fail, and therefore not give accurate readings, and because the manual option is more “genuine” and perhaps more established given the perception of its longevity:

I chose the glass because the other thermometer is much harder and if something goes wrong you might get a wrong answer when you're doing important work.
We can have some wrongs in the glass thermometer,

but in the other thermometer it's much more difficult to see what's going on inside, you're not there to see what's working.

I thought the glass thermometer was more accurate than the other one... because, sometimes technology is not very accurate at stuff, so I used glass.

I think the glass one was more accurate, and it was more genuine. It's what they used in the olden days.

Ease of Use (Manual Option)

Similarly, as with the technology choice, some students choose the manual option as they believed this would be easier, as these responses indicate:

Cause, like, it's easier to look at and just write it down quick, and you gonna finish faster.
So, like, I chose glass cause, like, the digital one it was complicated just to get it ready, so I chose the glass cause you can just like poke it in and it's ready.
It felt very confusing to use the electronic one. Because you have to go through a lot of settings just to get to the temperature.

Perception of Greater Challenge (Manual Option)

Alternatively, some students chose the manual option because it was perceived to offer a greater challenge:

In the glass thermometer you need a very long time to think, about what will happen, while the other one, it gives you the answer, and not allows you to think what will happen, what the temperature will be at.

Does Choice of Instrument Affect Likelihood of “Feeling like a Scientist”?

To address research question 3, we asked the students to reflect on how their choice interacted with their sense of self as a scientist. Specifically, if their choice affected how ‘like a scientist’ working with that particular piece of equipment made them feel. This was partly a comparative judgment, since we followed this up with a question of how they *may* have felt if they had selected the other option.

For the students who had selected the manual measuring option, the responses were mixed. Some students felt strongly that using the manual tool, which they perceived as being more challenging and requiring more effort, contributed to them feeling more like a scientist, for example:

[Yes] Because we were making things like the scientists do

Yep. It feels like you're doing the hard work, and the rest are different. [Because they're using an iPad to help, you mean?] Yep.

If I chose the digital one, I'd just like think I barely put any effort into it... it just says the number for me instead of me actually reading it and seeing what it is.

I feel more like a scientist because I get to read it, not just look at it.

Conversely, some of the students who made this manual choice reported *not* feeling like a scientist, mainly due to reflections comparing themselves to those students working close by who had chosen the technology option. This appeared to elevate the scientist nature of the others' work, and by comparison, deflate their own, as these statements show:

I did not feel it because scientists use other equipment, like lasers, and what do you call it? I've seen it before. It's connected to a computer and shows the temperature.

I didn't feel like one. I think because I wasn't using the technology, maybe if I had used technology it might have been more like a scientist.

One student described how they would have been more likely to feel like a scientist had they selected the technological option, referring to this as being more of a present-day method:

I think if you use the probe you'd feel more like a scientist, it's like what more scientists use these days

The students who chose the technological option with which to measure also had mixed responses about feeling like a scientist whilst measuring with their tool of choice. For those who did feel like scientists, this was often due to perceptions of their work being similar to what “real” scientists did in their work, for example:

Yes [I do feel like a scientist] ... because we try our best and investigate new things about the scientific, what they do.

The novelty previously expressed in justification of their technology choice also contributed to some students feeling more like a scientist. Another student described an ambiguity in their feelings, and explained that their feelings had changed between making their selection and actually using their choice, as this statement shows:

No, I felt like a scientist when I was using it, but not when I picked it, I didn't feel like one. But when I used it, yes, I felt like a scientist.

Some of the students who chose the technological option reflected that they wished they had measured using the manual option, and that they thought this would have helped them to feel more like scientists. This was justified for reasons such as perceptions of authenticity while measuring manually, which was not felt by them using the technological option, or that they perceived their work to be retrospectively lazier, for example:

Because ... the glass helps you to be scientific, so you would feel scientific.

Yes, because this is what scientists do and I want to be like them. (The glass one?) Yes.

[I felt] less like a scientist. But I think I would have felt like an olden day scientist. That would be fine, it would be historical.

I regret my decision because I want to use glass now.

Because it's so fun. It's more educational... we were saying how spoiled we are [using the probe].

Yeah, I want to [use the glass one], I regret it. I feel lazy, reading the digital one.

Discussion

Overall, students chose the technology option over the manual option by a ratio of approximately 3:1. The experiment and the accompanying digital equipment appears to have provided some initial appeal as will be discussed with respect to research questions 2 and 3. According to our interview data there is certainly an element of fun and novelty associated with the equipment. Children are likely to see digital probes with displays as more appealing, at least in terms of entertainment value—particularly considering the common uses of display technologies by young people (Selwyn, 2009; Wang et al., 2014). However, more encouraging justifications for this choice were related to the degree of accuracy obtainable using, for example a digital probe over a glass thermometer. Although there is no reason to believe analogue devices are less accurate than their digital counterparts, the children here have likely conflated accuracy with precision, which suggests some understanding of the limitations of analogue scales, in some situations. Student justifications for choosing the manual option included what appears to be anxiety about using the technology on offer. These views align with research regarding technology acceptance theory (Barteit et al., 2019; Drehlich et al., 2020; Moyo, 2015); it appears that these children had low perceptions regarding the ease of use and usefulness of the technology that, in turn, reduced their intentions to use the digital sensors.

The opposite views were also shared, and it is worth noting that opposing views were very often observed within the same focus group, indicating that the steps implemented to alleviate possible concerns (mentioned earlier in the methodology section) with regard to students influencing one another's reasoning for their choice of measuring instruments, were effective. Our transcripts also revealed frequent use of discursive, dissentient language such as “I don't agree with that at all,” “I don't think so,” “I thought the opposite,” etc. This vindicated the choice of the focus group interview methodology and, to some extent, reassured us as researchers that we had minimized the potential influence of more dominant group members impressing their views on others, and implied that the data was likely to be trustworthy and authentic in representing the children's views. Some students chose the manual option because they *wanted* to be challenged in terms of effort. They stated that using a digital probe would have been too easy and that it is “lazy” to just read numbers from a digital display. Other views were related to the authenticity of the analogue device. Such tools were seen as more genuine than their digital counterparts and, for this reason, more “accurate.” These tools (perceived positively as from the “olden days”) were also chosen for their uniqueness; some students wished to differentiate themselves from the majority who were selecting the more attractive technology option. This combination of authenticity and challenge emerged as a theme and, according to these children, aligned the work they were carrying out in the classroom with the work of practicing scientists. The importance of these views held by a relative minority of students is worth noting as they appear to be a direct inversion of technology acceptance theory. Higher levels of perceptions of ease of use and usefulness *reduced* the children's intention of use. They claimed that using technology would make the work too easy. In other words, the technology was *too useful*.

This perception of the apparent seriousness of manual equipment is consistent with a leisure-dominant relationship with digital technology that overshadows more productive forms of technology usage (Livingstone, 2009; Wang et al., 2014). There is also a general sense, from a number of students, that they are not familiar with data-logging equipment and its uses in the science classroom. As there is evidence of the pedagogical, time-related and conceptual benefits of using these devices (McFarlane & Sakellariou, 2002; Metcalf & Tinker, 2004; Tosa & Martin, 2010), it is not encouraging for students to talk of their novelty value and, by making claims regarding the greater degree of authenticity of manual equipment, the students are indicating that they have naïve conceptions of how professional scientists work. Regular, authentic use of data-loggers allows teachers to address unsophisticated views of science and scientists that, in turn, may improve students' dispositions to learning science.

In terms of science identity, students explained how their choices made them feel during and after the experiment and whether they felt like scientists. Students across our sample repeatedly expressed feelings of authenticity when the work had increased levels of challenge and required higher levels of effort. For instance, students who selected the manual option expressed the views that simply reading a digital display required very little effort and, as the perceived work of a scientist requires both exertion and high levels of reasoning, this would not have made them feel like a scientist. This sentiment was expressed by one student who replied, “Yep. It feels like you're doing the hard work, and the rest are different. [Because they're using an iPad to help, you mean?] Yep.” Some students did not feel this way and felt that, if they had made the technology choice, they would have felt more like scientists. This perception likely arose from observing other students using technology in a productive and “scientific” way—a type of engagement with technology that they may not have experienced before or may have only experienced infrequently. This suggests that students' understanding of the use of technology as a learning tool was, at least partially, developed by experiencing (even vicariously) the use of data-loggers and graphical displays. Further evidence for this developmental process was articulated by a student who started off *not* feeling like a scientist but chose the data-logger for its novelty value alone. This student later expressed that, whilst using the data-logger to collect data, they started to feel like a scientist.

Some students were not convinced of the authenticity of the technological measuring tools. They verbalized concerns such as using the equipment made them feel lazy, the equipment was too modern, they were not learning as much as they should be (presumably, not learning how to read an analogue scale) and, ultimately, they were concerned that they were “spoiled”. These views again speak to the inversion of technology acceptance theory where the students appear to be linking the concept of working efficiently with being lazy. A concept that appears to be associated with the perception that “olden day” methods are more serious, and therefore genuine. These attitudes also speak to the perception that technology is associated with leisure and a lack of rigor. The student that implied that “they” are spoiled was a particularly interesting comment that provides further evidence for the perception of an academic golden age where, without the distractions and trivialities of modern (digital) life, people and therefore scientists, engaged in “real” science using authentic manual equipment.

Implications in the Classroom

The results of this study indicate that students would benefit from greater levels of exposure to meaningful learning using technology in their science lessons, both in terms

of improving student confidence and developing students' perceptions regarding the importance of technology in the field of science. Schools and regional educational authorities should budget for and purchase data-logging equipment in sufficient quantities to enable this to take place. Teachers also require training, not only in the technical skills required to use the equipment, but in the effective pedagogical approaches to using the equipment. Teachers should then plan for the regular and effective use of this equipment in ways that enhance conceptual understanding and develop students' conceptions of how scientists work.

Practicing Scientists

Students should also experience more examples of practicing scientists in the workplace. This could take place using digital media, invited speakers or educational visits. In terms of digital media, video upload sites such as YouTube have a wide range of resources for teachers with a plethora of videos showing working scientists using technology in their everyday work. These videos range in topic from using technology to preserve wildlife, improve farming, uncover Mayan ruins and combat global warming. Using these as teaching resources simply requires an internet connection and a screen on which to display the videos. While also useful to support learning during related units of work, many videos are short enough to be played at any time, and on a regular basis, for example during 'clean-up time', allowing for the normalization of active technology use in science. YouTube also provides access to science-based television series such as Blue Peter³ and Bill Nye the Science Guy,⁴ which are aimed specifically at children.

Activities to improve student familiarity with technology use in science could also involve fieldwork that involves the integration of science and technology when carrying out authentic tasks in their local environment (Dillon et al., 2006). The student perceptions of science in this study suggest that they have a limited understanding of how scientists work and *why* technology is used in laboratories. Students (and teachers) would benefit from visits to working laboratories in which technology use is embedded in the process of "doing" science. This would develop children's perception of technology use as a serious, authentic aspect of scientific work. A further benefit of this form of exposure is the opportunity for teachers and scientific communicators to involve students in constructive discourse as to the reasons why particular digital tools are used in laboratories and their technical advantages, in many cases, over their analogue counterparts.

Finally, professional development should focus on the empowerment of teachers as critical guides in the use of technology, by ensuring that young people are informed regarding their choices. In professional teaching terms, not using technology effectively should be seen as a pedagogical limitation of the science educator, to be addressed by training and support.

Further Research

The current study was limited to students aged between 10 and 13 in international private schools in the UAE. Although the students in these schools represent a range of countries and cultures we would like to expand this work to other countries and nationalities, different age ranges, and also study gender differences in technology choices. Another extension of this work could involve the study of students with and without STEM career aspirations and investigate how this influences their choices of equipment. The application of a technology acceptance instrument (that possibly measures social influence and intrinsic motivation variables) could also provide useful evidence regarding the factors that affect students' intentions to use digital technologies and allow for the triangulation of these measures with the accompanying interview data. Lastly, bearing in mind the likely pedagogical advantages of using data-loggers, further studies in this area could involve the development of instructional approaches that embed this technology in science units of study to investigate the benefits and drawbacks of their use, in terms of changes in students' and teachers' conceptual and epistemological understandings of science and science education.

Appendix. Student Interview Questions (Focus Group Interview)

1. What kind of work do you think scientists do? Can you describe this?
2. Do you think there is a difference between the work a scientist would do as a job, and the kinds of science you do in the classroom?
3. Do you like science? (if yes, *, if not, "why not"?) Would you like to have a job where you would use science in the future?
4. * What is your favourite thing about science?
5. Why did you choose to use the (appropriate device) in today's experiment?
6. How did you feel when you used the (appropriate device)? Did it make you feel more or less like a scientist?
7. Do you think you would have felt differently when you did the experiment if you had chosen the (opposite device)?

³ <https://www.youtube.com/watch?v=cwfXK8jNzbc>

⁴ <https://www.youtube.com/watch?v=2TyM1uXIsFY>

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Declarations

Ethics Approval Ethical approval was obtained from the Emirates College for Advanced Education Institutional Review Board.

Ethical Statement All procedures performed in this study involving human participants were in accordance with the ethical standards of the Department of Health Standards on Human Research (DOH/QD/SD/HSR/0.9) and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Consent Statement Informed consent was obtained from all individual participants involved in the study.

Conflict of Interest The authors declare no competing interests.

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