BARRIERS TO THE EFFECTIVE TEACHING OF PRIMARY SCIENCE AND TECHNOLOGY

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UTS
UNIVERSITY OF TECHNOLOGY SYDNEY

This study was commissioned by

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EXECUTIVE SUMMARY

This report presents findings of a study that examined barriers to the effective teaching of primary science and technology in independent schools in NSW. Utilising best-worst scaling (BWS) methodology, the study aimed to identify which barriers existed, and which ones were more significant to teachers in relative terms, with respect to how each barrier impacts effective teaching.

This study is the third component of a larger research project guided by the broad research question: *What characterises quality learning and teaching in primary science and technology?*

The other two components of this project which have been completed include:

- Quality learning and teaching in primary science and technology literature review (Aubusson, Schuck, Ng, Burke, Pressick-Kilborn, & Palmer, 2015)
- Case study report: Quality learning and teaching in primary science and technology (Aubusson, Schuck, Ng, Burke, Pressick-Kilborn, & Palmer, 2016)

In order to identify the list of barriers for the current study, several rounds of consultation with key stakeholders and a review of the existing literature were undertaken. A list of 42 barriers was then produced. Following this, participating teachers completed a BWS task that was embedded in a survey link sent to them. The BWS task asked teachers to consider small subsets of 42 barriers over several iterations. Teachers ranked the presented barriers in order of their impact on effective teaching of primary science and technology. From the data obtained, a predictive model was developed to quantify the probability of statistical significance of each barrier, relative to other potential barriers examined in the study.

The results indicate that time to prepare is a major factor inhibiting effective teaching of primary science and technology. Other time-related barriers that also appear relevant for teachers include prioritising the teaching of science and technology against other subjects, having significant blocks of time to enable effective delivery, and having time to collaborate with colleagues. Space — to maintain students' work in progress, store materials and keep track of resources — was another relevant barrier that was more likely to be nominated by teachers than other factors.

Participating teachers appeared to be extremely knowledgeable about science and technology but less concerned about navigating the syllabus, while gaining ideas for Working Scientifically or Working Technologically was more of a concern. A minority of teachers (15 to 25%) appeared to lack some elements of confidence, knowledge and/or interest which impacted their teaching of science and technology. Very few teachers nominated issues of noise and control as barriers compared to other areas of concern. Messiness, particularly cleaning up after activities, also appeared to be a concern, but less relevant for most of these teachers.

A cluster analysis revealed that there were differences among individual teachers with respect to concerns about space, resources and confidence in teaching science and technology. There was a general agreement about the significant impact of time to prepare and time to spend in the classroom on effective teaching, as well as the need to come up with ideas in teaching.

Concerns around the negative impact of timetabling and scheduling seemed to be more pronounced at larger, metropolitan schools, but less so in co-educational settings. Concerns about confidence in teaching science and technology appeared to be mitigated by professional learning activities or tertiary education in this subject area. Females, younger teachers, or those with less experience in this subject area, were more likely to be affected by these concerns.

INTRODUCTION

The quality of science and technology education in primary schools varies widely based on numerous factors, both teacher and school derived. This study identified and quantified the relative impact of factors nominated by primary teachers in NSW independent schools as being instrumental in influencing their effective teaching in this subject area.

This study is part of a larger, comprehensive project guided by the following overarching research question: *What characterises quality learning and teaching in primary science and technology?*

A number of research components have been designed and conducted to address this overarching question, including:

1. Quality learning and teaching in primary science and technology literature review (Aubusson et al., 2015): identifies the factors that influence and characterise quality learning and teaching in primary science and technology.
2. Case study report: Quality learning and teaching in primary science and technology (Aubusson et al., 2016): illustrates exemplary practices of six teachers working in NSW independent schools and identifies barriers to quality learning and teaching in primary science and technology.
3. Barriers to the effective teaching of primary science and technology: the current study.
4. Supporting the effective teaching of primary science and technology: A discrete choice experiment approach: available soon.

This study utilised best-worst scaling methodology — a quantitative technique employed to reveal which barriers matter more to NSW independent primary teachers in terms of inhibiting their effective teaching.

Ethics approval for all components of the larger project was granted by the University of Technology Sydney (UTS)'s Human Research Ethics Committee, reference number UTS HREC 2015000220.

IDENTIFYING POTENTIAL BARRIERS TO EFFECTIVE SCIENCE AND TECHNOLOGY TEACHING

For the current study, it was important to determine what made it harder for teachers to teach science and technology well. **Well** is broadly defined as referring to various approaches to teaching, including those where:

- science and technology activities are embedded in contexts that are relevant and important to students
- students engage in collaborative inquiry and solve problems
- students conduct hands-on investigations to gather evidence to test ideas
- students design and produce things
- students develop capabilities, knowledge and positive science and technology dispositions.

Before the BWS task was implemented to rank the barriers, a comprehensive list of potential factors was generated. This list was initially informed by results of a literature review, discussion with AISNSW staff, and expertise of the UTS research team. The list was then supplemented with factors generated from several rounds of discussions with teachers at all levels, school executive, academics, and AISNSW consultants.

STAKEHOLDER DISCUSSIONS

Several rounds of stakeholder discussions were organised to develop the list of potential barriers to effective teaching that would be utilised in the BWS task. These included:

- the first expert panel: involved teachers who were recognised by UTS education academics and representatives from the AISNSW for their expertise in teaching primary science and technology. The panel met for two hours and discussed the enablers and barriers to effective science and technology teaching and what they considered effective teaching meant

- a second stage of panel discussions: involved teachers who attended the Inaugural AISNSW Education Research Symposium 2015. The discussions were made up of four groups of teachers with four to six teachers in each group. Some of these groups included specialist teachers in science and technology, and some were joined by AISNSW consultants. The participants reviewed the list of factors resulting from the first expert panel, discussed the wording of these, and whether they believed any factors were missing
- a third expert panel: involved four highly experienced teachers who were invited by the AISNSW to review the factors identified. They met for approximately an hour and closely reviewed the final list of factors. The panel helped ensure that the list was complete and the factors were expressed in a way that was meaningful to teachers
- canvassing advice from case study teachers who discussed exemplary effective teaching practices in primary science and technology, and reinforced the need to include many of the factors in the list.

At each stage, the list was reviewed by members of the AISNSW and UTS research team, and further developed based on reflections of discussions with the stakeholder groups.

DEVELOPING THE LIST

Initially, the list of factors included several themes, including space, control, time, resources, as well as teachers' beliefs about science and technology, pedagogical knowledge, and knowledge of the science and technology curriculum. Other factors were also included, and covered issues relating to programming, resourcing and timetable constraints. Similarly, the support of school executive and colleagues (including collaboration) was considered a particularly important factor, as it helped not only to stimulate effective teaching, but also reduce rates of attrition and switching among teachers (Burke, Aubusson, Schuck, Buchanan, & Prescott, 2015; Hudson, 2004; Schuck, Aubusson, Buchanan, Prescott, Louviere, & Burke, 2012). During the list generation process, the items in the list were developed with respect to creating factors that were clear and mutually exclusive. It was also important to ensure that some factors were broken down if it was felt that certain elements of the factor needed to be separated for greater insight.

Examples below illustrate how the factors were developed and refined.

- Many participating teachers mentioned science and technology activities to be messy, but this was not necessarily an issue during the running of a class. Instead, it was the efforts to clean up the mess after class that appeared to be more of a barrier. Similarly, whilst noise and messiness were thought to be interrelated, several teachers suggested that these factors were very different. Most felt that they were happy with the noise level, considering it an accepted component of teaching science and technology. Messiness, however, demanded more of their time to deal with, or was more difficult to tolerate.
- One factor was initially stated as "there are more important subjects to teach" (than science and technology). However, many teachers argued that it did not accurately capture the barrier — science and technology was an important and relevant subject to many of them. The statement was then reworded as "other subjects were being prioritised."
- Initially time was considered as one factor. Through discussions, it was broken down into two factors, including time for planning and time for undertaking activities with students.
- There was a suggestion to consider the difficulty arising from integrating science and technology with other subjects. Integration, however, is not a requirement of the curriculum. Some teachers chose to implement integration of their own accord. This factor thus acted more like a solution to other barriers, rather than being a barrier per se.

The final list of factors used in the study is presented in Table 1. The next stage of the research was to understand which of the listed factors were perceived by the participating teachers to be a greater barrier to their teaching than others. To do so, an instrument using best-worst scaling (BWS) technique was developed.

Table 1: Statements Teachers Were Asked to Consider in the BWS Study

LIST OF FACTORS INCLUDED IN STUDY
1 Space for students to do things is a problem.
2 Space to set up for lessons is a problem.
3 Space to store materials and equipment is a problem.
4 Space to put students' work in progress is a problem.
5 Students don't bring requested resources (for example, plant matter, yogurt containers).
6 I'm concerned about safety in running activities.
7 The activities are too messy.
8 It's difficult to clean up after a class or activity.
9 My classroom gets too noisy.
10 The activities make it difficult to control the class.
11 The activities take too long to complete in class.
12 I don’t have time to prepare (for example, get ready, locate supplies).
13 I don't have time to plan the unit of work.
14 I don't have time to plan hands-on activities.
15 I don't have time to collaborate with colleagues.
16 It's difficult to fit it in with everything else I have to teach.
17 The timetable is too fragmented (teaching blocks are too short).
18 There are other subjects that I have to prioritise.
19 It's difficult to maintain and keep track of resources.
20 The school doesn’t provide the materials and equipment I need.
21 I have to buy my own materials.
22 The process to purchase materials is too difficult.
23 School funds are prioritised for other areas.
24 The syllabus is difficult to navigate and use.
25 I don't understand what the syllabus requires me to teach.
26 I'm not confident in facilitating an inquiry process.
27 I don’t understand the content well enough.
28 I'm concerned I won't be able to answer the students' questions.
29 I'm not confident in doing scientific investigations with my students.
30 I'm not confident in doing designing and producing/making with my students.
31 I find it difficult to explain the concepts to students.
32 It's difficult to come up with ideas for Working Technologically (designing and producing).
33 It's difficult to come up with ideas for Working Scientifically.
34 I'm not sure how to effectively gauge what students are really learning.
35 I'm unsure how to develop lesson sequences that build students' understanding.
36 The school leadership doesn't support science and technology enough.
37 My colleagues are not really interested in science and technology.
38 I haven't had enough professional learning in this area.
39 The scope and sequence doesn't allow me to teach things when I would like.
40 I have to do the same thing that other classes do.
41 The risk assessment process is difficult/time consuming.
42 It's difficult to keep students interested and motivated.

THE BEST-WORST SCALING METHODOLOGY

Consultation with teachers and AISNSW consultants produced an extensive list of 42 factors that were considered potential barriers to effective teaching in primary science and technology. The overarching objective of the current study was to understand which barriers were relatively more significant in terms of their impact.

One useful approach to identify which barriers are more concerning than others would be to ask teachers to rate each barrier on an appropriate scale, such as one that ranges from 1 (not at all important) to 7 (very important). As each factor is considered one-at-a-time — or in isolation, this approach does not entice teachers to directly consider which factor is more important. There is no incentive or instruction to make any trade-offs between the barriers. In this way, a teacher could rate 7 for all barriers because they are all relevant, which may suggest that everything matters to them (Carson, Groves, & Machina, 2000). Knowing that everything matters, however, does not help to understand where strategic efforts and resources should be focused to develop appropriate solutions. What is more revealing is to place teachers in a situation that forces them to nominate which barrier is relatively more important than another. Best-worst scaling is an approach that would enable this.

Best-worst scaling (BWS) methodology was first developed and published by Louviere and his colleagues in the 1990s (Finn & Louviere, 1992; Louviere & Woodworth, 1990). It is a relatively straightforward method that asks people to choose two factors from a list that most and least match a given criterion. In the current study, a variation of BWS was adopted. Teachers were provided with six barriers at a time and asked to nominate the one they considered to be the biggest barrier to their teaching of science and technology. After the first factor was nominated, it was removed from the list, leaving just five factors. Teachers were then asked to nominate the next most relevant factor. This process continued until a complete ordering of factors in terms of their relevant impact was obtained.

The use of BWS is attractive as it forces respondents to determine the relative importance of a list of factors, or barriers as in this study (Louviere & Islam, 2008). Another key characteristic of BWS is that the response scale provided to respondents is a discrete outcome (choice) rather than continuous (for example, rating on a 1 to 7 scale). This helps avoid several response style biases that have been found in prior research using such scales (see Baumgartner & Steenkamp, 2001; Harzing, Köster, & Zhao, 2012; Van Vaerenebergh & Thomas, 2013). For example, some respondents have a tendency to avoid the extreme ends of rating scales, whilst others tend to remain neutral. BWS is also advantageous because it is cognitively easy for respondents. There is no allocating of points or percentages to factors, or a need to rank a lengthy list of factors simultaneously (Louviere & Islam, 2008). This makes it easier for respondents to complete the task and reduces overall response times. A growing body of evidence indicates that the use of such indicators in BWS does not compromise measurement reliability (for example, Dolnicar & Grun, 2007; Dolnicar, Grün, & Leisch, 2011; Grassi, Nucera, Zanolin, Omenaas, Anto, & Leynaert, 2007; Preston & Colman, 2000). It is worth noting that by its very nature, BWS purposely minimises inter-item correlation rather than maximising it. This helps maximise discrimination among factors and measures which barriers impact teachers more across the 42 listed factors.

BWS has been applied in various contexts, including research in marketing and consumer behaviour (for example, Auger, Devinney, & Louviere, 2007; Burke, Louviere, Wei, MacAulay, Quail, & Carson, 2013; Burke, Eckert, & Davis, 2014; Louviere & Islam, 2008; Massey, Wang, Waller & Lanasier, 2015), personality research (Lee, Soutar, & Louviere, 2007, 2008), health economics (Lancsar, Louviere, & Flynn, 2007), and to understand the public's views on climate change (Carson, Louviere & Wei, 2010). In education, BWS has seldom been used. The first study introducing the method to education was undertaken by Schuck and colleagues (2012), aiming to understand which factors had a stronger impact on the decision of early career teachers to stay in the profession. Results of the study showed, for example, that collaboration with colleagues appeared to be relatively stronger than class size or support of parents in shaping teachers' commitment to the profession. A more recent application of BWS in education involves a study examining the reasons used by school students to reject or undertake study of a subject (Palmer, 2015; Palmer, Burke & Aubusson, 2017).

THE SURVEY INSTRUMENT AND BWS TASK

In order to qualify for the survey, potential participants needed to respond to a series of questions about their knowledge and teaching experience in primary science and technology. Following this, they were provided with a description of the survey objectives and background information on science and technology. Those who qualified for the survey were then provided with an operational description of what teaching science and technology well is, as defined by the researchers. The information read as follows:

Background

This survey is about teaching science and technology in primary school.

In science humans are concerned with understanding phenomena through systematic inquiry and using this knowledge to improve the human condition and our world.

In technology humans are concerned with the design and creation of products to meet human needs or wants. It seeks solutions to problems and exploits opportunities.

In a moment you will be asked to rank barriers that may make it hard for you to teach science and technology well.

By "well", we mean that science and technology activities are embedded in contexts that are relevant and important to students. Students engage in collaborative inquiry and solve problems. They conduct hands-on investigations to gather evidence to test ideas. They design and produce things. They develop capabilities, knowledge and positive science and technology dispositions.

Remember, there is no right or wrong answer – we are interested in understanding your opinions to better inform ways to improve your experiences as a teacher.

In the BWS task, respondents worked with subsets of six barriers, one subset at a time. Within each subset, they were asked to nominate one barrier that made it hardest for them to teach science and technology well (see Figure 1). Once the first factor was nominated, it would disappear from the list — leaving behind only five factors. Respondents continued to nominate the next relevant factor in this way until all six statements in the subset were fully ranked from the most to the least important.

A "none of these are barriers" option was trialled, but found to disrupt the cognitive flow of the task. This was then taken account of via a Likert scale question about the importance of a subset of barriers.

After a practice set, each respondent completed eight subsets of six barriers. The selection of which statements to display in each subset was determined by a survey design that, over a large enough sample, would reveal which barriers were considered more relevant.

Figure 1: Example of task

0% 25% 50% 75% 100%

Set 1 of 8:

Which of the following makes it hardest for you to teach Science and Technology well?

Please indicate your answer by clicking on a statement. Once selected, each statement will disappear so you can rank the remaining statements.

- Space to set up for lessons is a problem
- I don't understand what the syllabus requires me to teach
- It's difficult to fit it in with everything else I have to teach
- It's difficult to keep students interested and motivated
- The scope and sequence doesn't allow me to teach things when I would like
- I find it difficult to explain the concepts to students

After the BWS task and Likert scale validation task, respondents completed a series of questions with respect to their attitudes, experiences, and perceived effectiveness in teaching primary science and technology, as well as perceived capabilities of their school. They also reported demographic information about themselves (for example, age, gender, qualifications), their school (for example, number of students, resources), and their classrooms (for example, number of students).

RESPONDENTS

To qualify for the survey, respondents had to have been teaching primary science and technology at a school located in New South Wales at any stage within the last five years. This allowed the survey to be inclusive of teachers who may have had relevant experience but moved to a different role, such as becoming a principal. This approach was also inclusive of teachers who were no longer in the profession or were currently on extended leave.

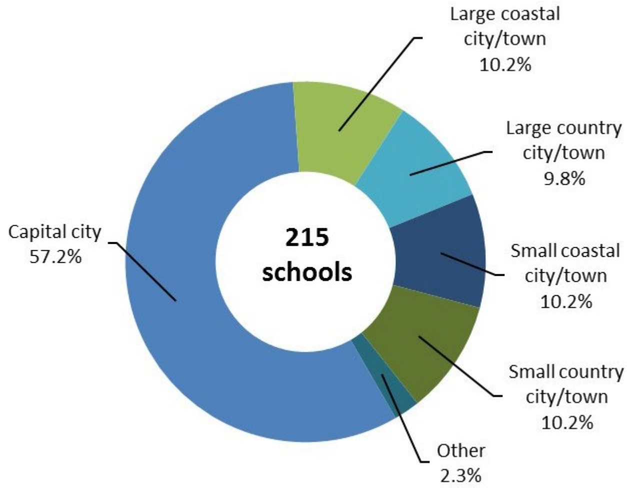
Recruitment of the respondents was undertaken primarily via email. An email invitation to participate in the survey was composed by the UTS researchers in collaboration with the AISNSW research team. The invitation was sent by AISNSW to school leaders who were asked to forward it onto primary teachers in their school. The invitation was also made available via the AISNSW Twitter account.

A total of 413 teachers commenced the survey, with 26% failing to qualify. Of the 304 teachers who qualified, 215 completed the survey in full, resulting in a 71% response rate. Demographic information about these teachers and their schools is briefly described below.

SCHOOL CHARACTERISTICS AND CAPABILITIES

The teachers were all working at NSW independent schools. Among these, 9% nominated that they were working at independent Catholic schools. The majority of teachers were working in the capital city (57%), with the remaining teachers evenly spread among schools located in a large coastal city/town, large country city/town, small coastal city/town, or small country city/town (see Figure 2).

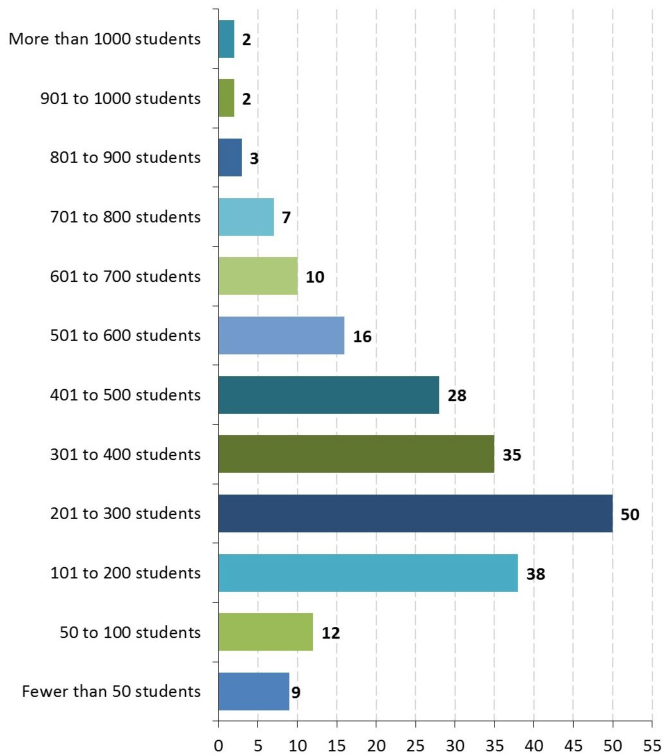
Figure 2: Location of School



On average, the participating schools each had approximately 330 students enrolled. About approximately 3 in 4 teachers worked at co-educational schools, with 17% working at schools with female students only, and 8% working at schools with male students only.

Figure 3: Number of Students at School

A small majority of teachers worked at schools where they agreed that other teachers had positive attitudes



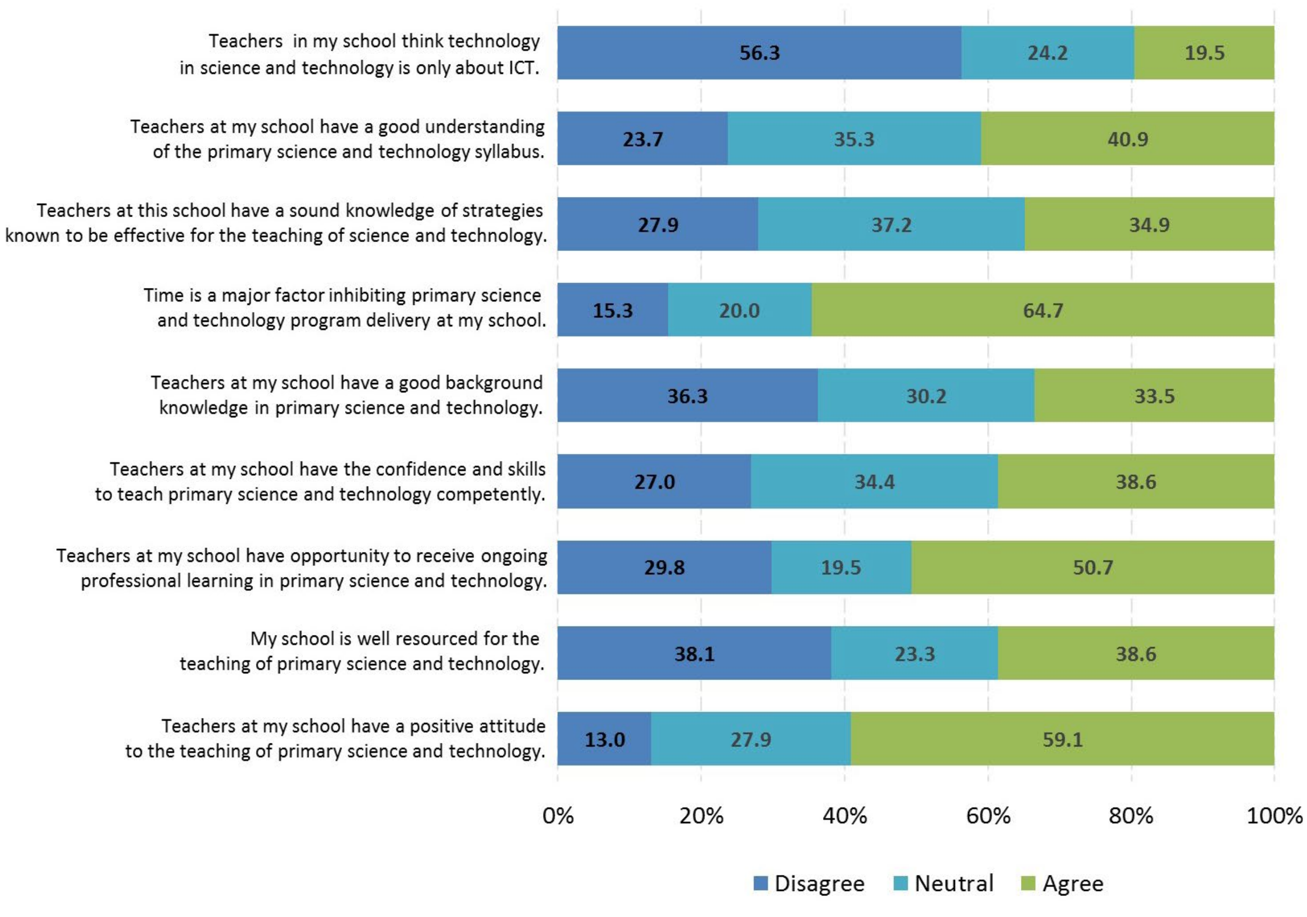
towards teaching science and technology (59%). This compares to 53% as reported by Aubusson and Griffin (2011) in another study focusing on teachers in NSW government schools.

In the current study, only 39% agreed that their colleagues had the confidence and skills to teach the subject competently, whilst 35% agreed that other teachers had sound knowledge of strategies for effective teaching in this area. Interestingly, 41% agreed that other teachers' understanding of the syllabus was good, whilst 24% of teachers disagreed with this. In Aubusson and Griffin (2011), the percentage of teachers agreeing that this was the level of understanding of the syllabus was slightly higher at 43%. This may be a reflection of changes to the curriculum that have been introduced since that time (for example, ACARA, 2014; BOSTES, 2012).

With respect to resources, 39% of teachers agreed that their school was well resourced for the teaching of primary science and technology, and 51% of teachers agreed that they worked at schools that provided opportunities for teachers to receive ongoing professional learning in this subject area.

It is worth noting that whilst fewer than 50% of teachers agreed with statements about their school or their colleagues in relation to the teaching and learning of science and technology capability (see Figure 4), many teachers chose to respond neutrally to questions about their school or their colleagues. Approximately 1 in 4 teachers suggested there appeared to be some concern with the capabilities of their school in teaching primary science and technology.

Figure 4: Perceived School Capabilities



CLASSROOM CHARACTERISTICS

In the current study, most primary science and technology classes were made up of 20 to 24 students (39%), or 25 to 29 students (37%). Of the remaining 24%, several teachers worked in rooms with fewer than 10 students (4.2% of the overall sample), or classes with 45 or more students (2.3% of the overall sample) (see Figure 5). On average, 89 minutes of school per week were devoted to the teaching of primary science and technology. Teachers indicated that the majority of their teaching experiences in this subject area in the last five years had occurred in Years 4 through to Year 6 (see Figure 6).

Figure 5: Number of Students in Typical Primary Science and Technology Class

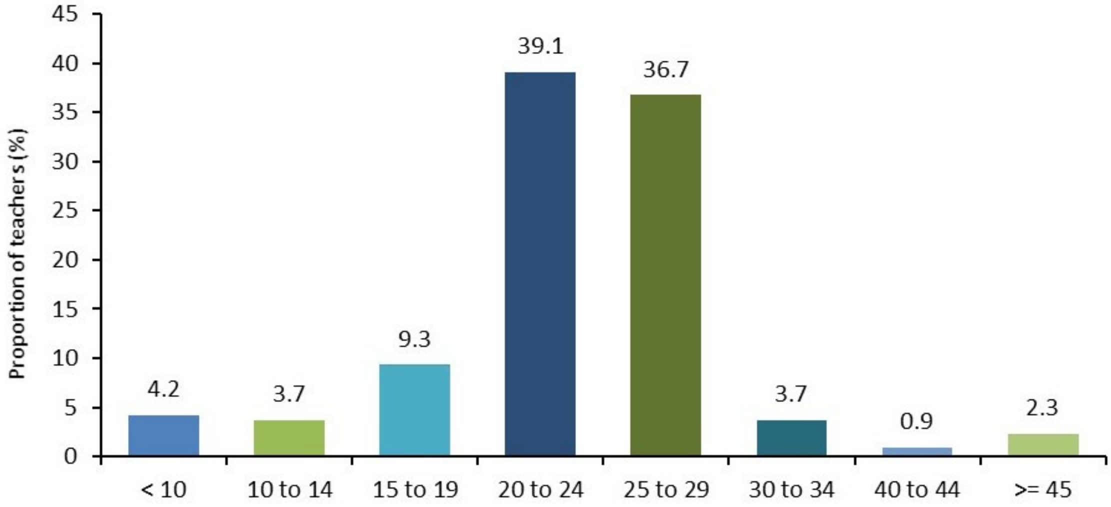
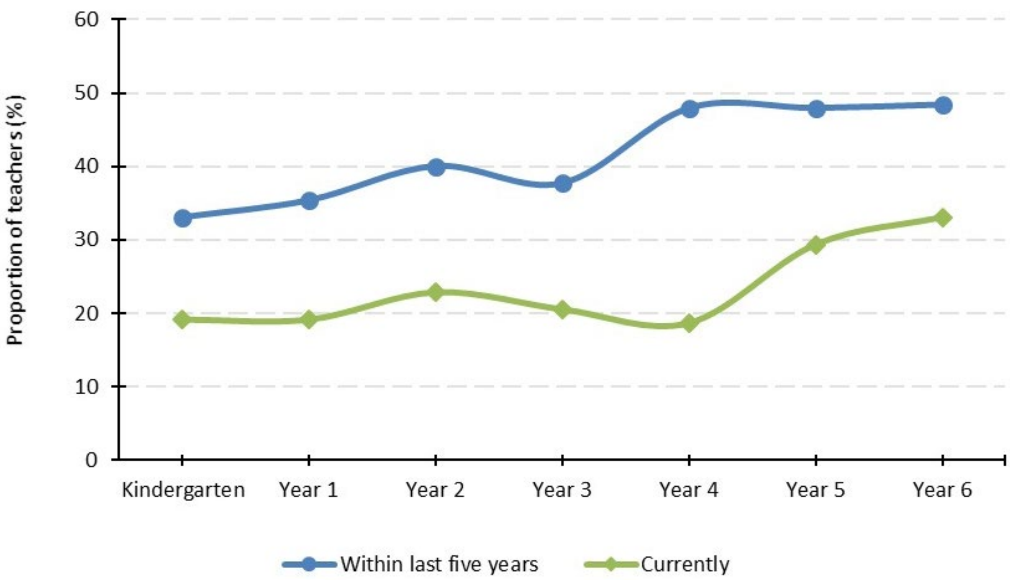


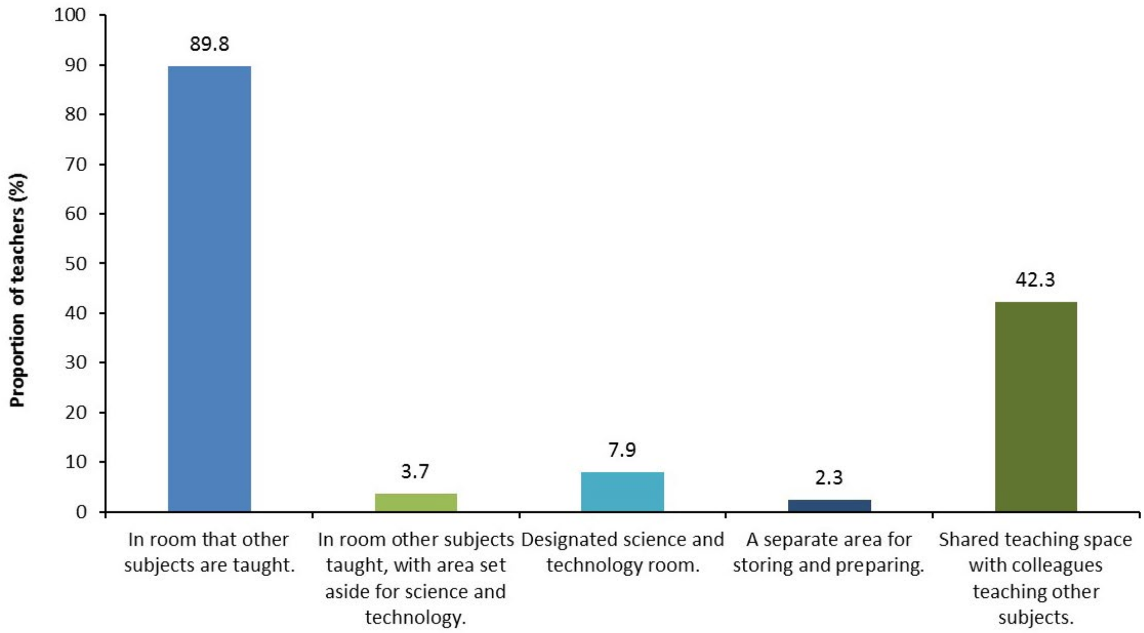
Figure 6: Level of Schooling Taught



Most teachers were delivering their classes in science and technology without the help of colleagues. Specifically, four out of five teachers taught the subject entirely by themselves, with 15% co-delivering with a primary teacher. The support of a teacher's aide was available to 7% of teachers in the sample and 4% worked with a specialist science and technology teacher.

Having shared classrooms and little storage space was common for most teachers. The vast majority of teachers (9 in 10) were teaching in a room where other subjects were taught. Less than 8% taught in a room that was dedicated to science and technology. Only 2% to 3% of teachers worked in a school in which they had a separate area for storing and preparing materials for the science and technology subject.

Figure 7: Teaching Spaces for Primary Science and Technology



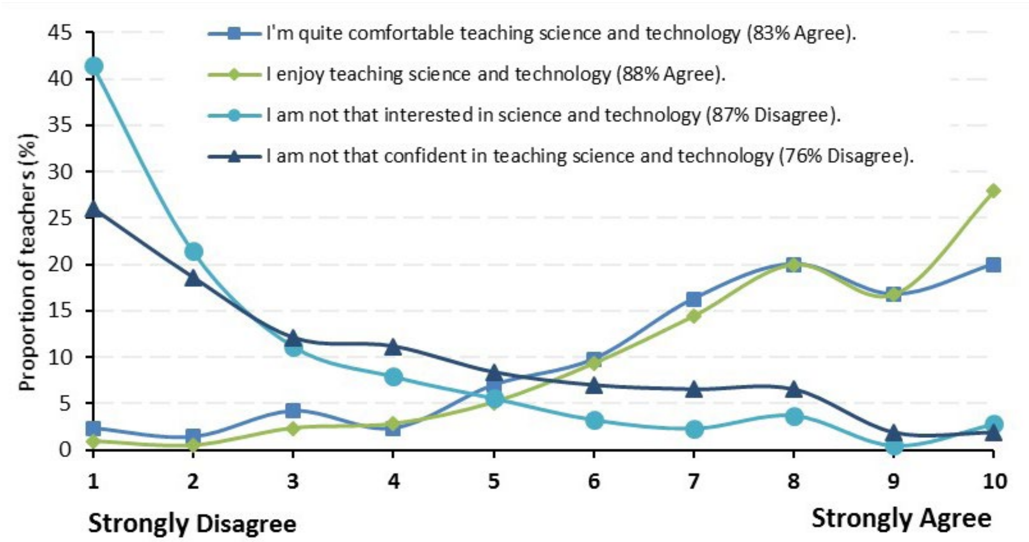
TEACHER CHARACTERISTICS

All participating teachers had taught in a primary setting within the last five years. Some had experience teaching at high school, with 13% having also taught students in Years 7 to Year 10, and 6% having taught students in Years 11 or Year 12. There was also a broad range of teaching experience with 50% of teachers having taught primary science and technology for 10 years or more. On average, the respondents had 12.9 years of teaching experience in this subject area. Approximately 87% of the teachers were female, and the average age of the sample was 42 years.

Most teachers were employed in a full-time capacity (87%), 11% part-time, and the remaining either on leave or in a non-teaching role. Less than 8% were specialist teachers of primary science and technology. Most were committed to the profession with 83% planning to remain in their current position for the next 12 months. About 7% of the teachers intended to stay in the profession but were looking for employment at a different school. The remaining 10% did not reveal specific reasons for leaving the profession — one teacher cited family reasons, and four cited professional reasons (such as stress, and income).

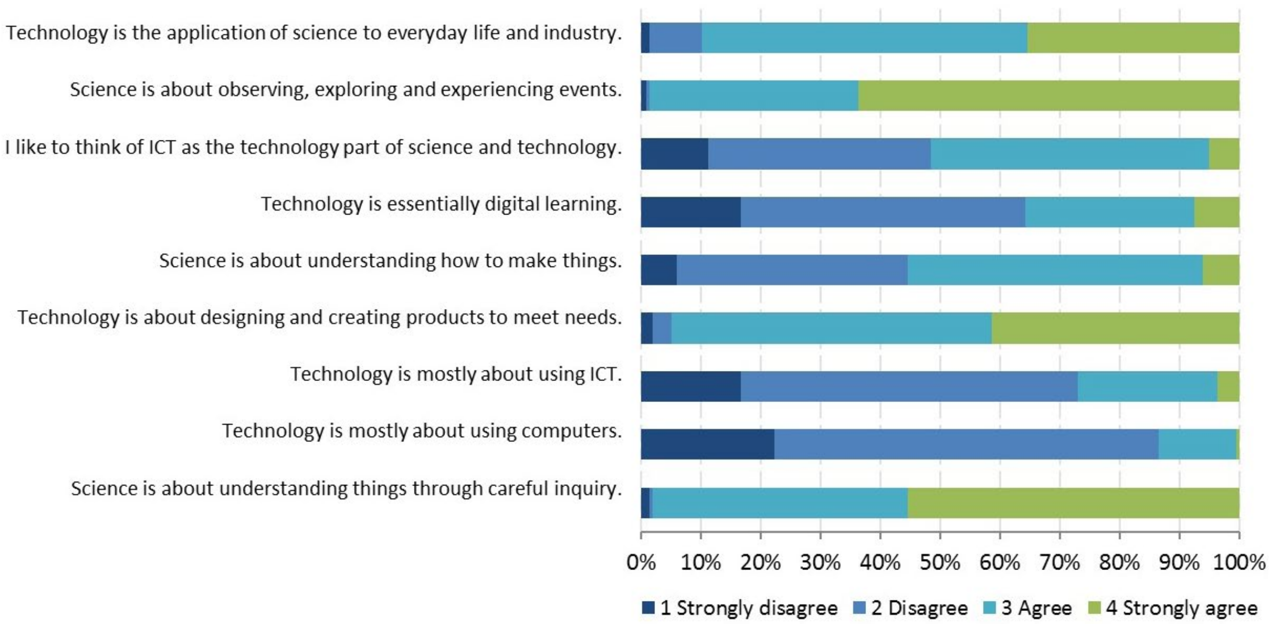
The confidence and interest in teaching primary science and technology was evident among the majority of teachers. About 94% of the teachers agreed that they did attempt to teach science and technology well, and around 9 out of 10 teachers suggested that their teaching approach resembled recommended practice. However, around 15% did not agree that they were effective science and technology teachers.

Figure 8: Confidence and Interest in Teaching Primary Science and Technology



Teachers' perspectives on what constitutes primary science and technology were largely consistent with the syllabus, where applicable, or varied as expected on factors where the syllabus is open to interpretation. For example, there was strong agreement on what science is about, with 99% of teachers agreeing that it is about observing, exploring and experiencing events (see Figure 9). Only 13% of teachers agreed that technology is mostly about using computers. About 89% agreed that technology is the application of science to everyday life and industry, which reflects a limited view of the relationship between science and technology. This is consistent with one aspect of the relationship identified in the syllabus.

Figure 9: Perspective among Teachers of What Constitutes Science and Technology



THE BEST-WORST SCALING RESULTS

The BWS approach allows a score to be determined for each of the 42 statements referring to barriers to teaching primary science and technology well as nominated by teachers. The score can be interpreted as an index describing whether a teacher will nominate a barrier as relatively more important than others, averaged across its co-occurrence with all other factors. The score is best interpreted as a relative, rather than absolute, measure of importance. Statements with scores that are higher in magnitude are reflective of those that teachers are more likely to nominate as barriers to their effective teaching of science and technology. Statements with lower scores are factors that teachers are less likely to nominate as barriers. To aid interpretation, each score has been standardised with respect to the least and most important barrier, scored 0 and 1 respectively. Factors scored closer to 1 are barriers that are more relevant in undermining effective teaching, whilst factors with scores closer to 0 are relatively less important in this regard.

The BWS scores are presented in Appendix 4. They have been arranged according to general areas of similarity, based on the work preceding the BWS study. Alternative relationships or similarities between factors are discussed later in this report.

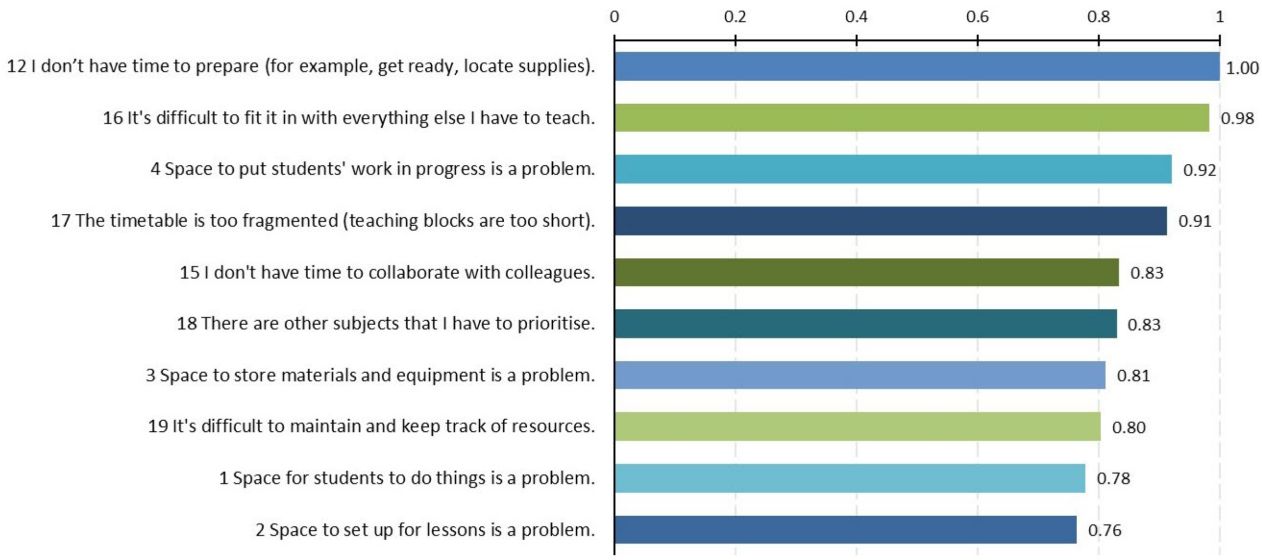
With this listing, review of the results can proceed by examining sets of factors focusing on a particular theme, and differences within the same theme. For example, the first four factors are largely to do with issues regarding space, and, as a group, appear to be greater barriers to effective primary science and technology teaching than others. Among this group of factors, space to put students' work in progress (statement 4 (S4)) is a more significant barrier relative to the storage of material and equipment (S3), followed by the space required to do things (S1), or to set up for lessons (S2).

At the other end of the scale, statements around confidence in undertaking activities are scored as being relatively less important in acting as barriers to effective teaching. In particular, confidence in doing scientific investigations with students (S29) and designing and making (S30), or facilitating an inquiry process (S26) are scored much lower than other factors. Instead, issues around coming up with ideas, Working Technologically (S32) or Working Scientifically (S33) are nominated by teachers as greater barriers.

The BWS scores can also be arranged with respect to their importance to teachers on average in being nominated as barriers to effective teaching. In Appendix 5, the statements are sorted by their corresponding BWS score. That is, out of all 42 factors, time to prepare (S12) is nominated as being the largest barrier, whilst difficulty motivating students (S42) is least likely to be nominated as a barrier to effective teaching.

THE MOST RELEVANT FACTORS (TOP 10)

Figure 10: BWS Scores for the Top 10 Barriers (Sorted by Importance)



Among the 42 statements examined, the one that is nominated as being the greatest barrier to effective primary science and technology teaching is:

- I don't have time to prepare (for example, get ready, locate supplies) (S12).

The associated choice model derived using the BWS data (McFadden, 1974) predicts that, on average, a teacher will nominate this factor as the most important barrier on 75% of occasions when compared to any other of the 41 barriers. The choice model predicts that, on average, 93% of teachers will nominate this top ranked factor as the most important barrier when offered the choice between the top ranked and bottom ranked factors.

The second and third most important barriers also relate to limited time. However, these speak more to an external second-order barrier resulting from approaches to timetabling. The two second highest ranked factors are:

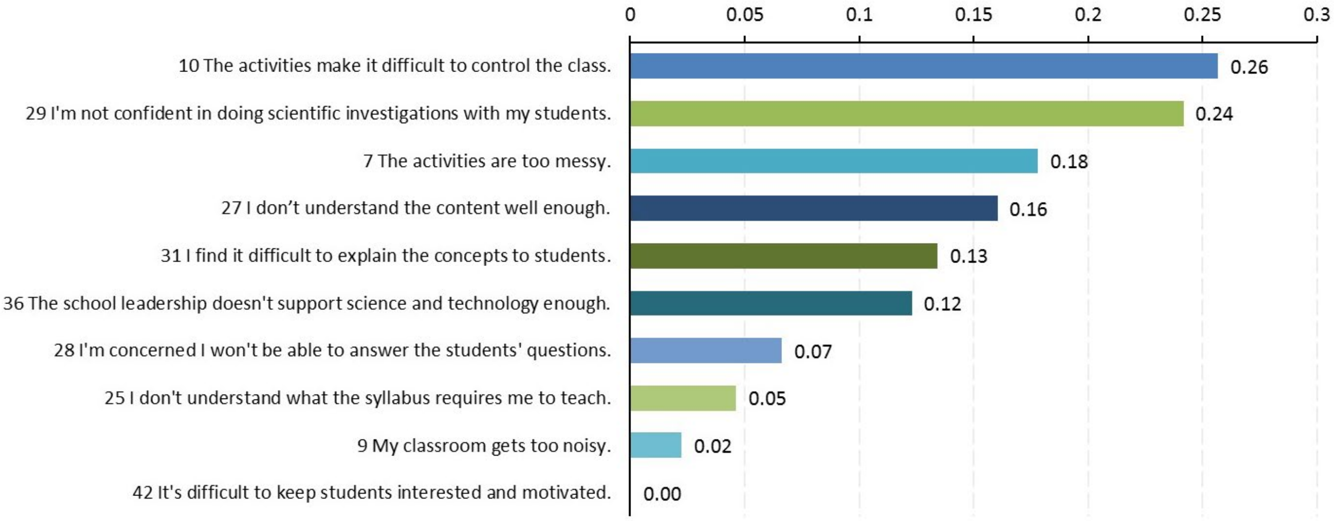
- It's difficult to fit it in with everything else I have to teach (S16).
- The timetable is too fragmented (teaching blocks are too short) (S17).

The theme of time also continues in the top 10 with time to collaborate with other colleagues (S15) ranked 5th, and priority given to other subjects (S18) ranked 6th. This is supported by the existing literature where time pressures are also identified as a significant contributor to stress and burnout among primary teachers (for example, Kokkinos, 2007).

The remaining factors in the top 10 show that space is also a particular issue that teachers nominate as a barrier to effective teaching. Among the space-related issues, space to store work in progress (S4) appears to be the most problematic (ranked 4th). This is followed by issues regarding inadequate spaces to store materials and equipment (S3, ranked 7th), inadequate space for doing things (S1, ranked 9th) and inadequate space for setting up lessons (S2, ranked 10th). Interestingly, issues of storage may be interrelated with maintaining and keeping track of resources (S19, ranked 8th) which also features in the top 10.

THE LESS RELEVANT FACTORS (BOTTOM 10)

Figure 11: BWS Scores for the Bottom 10 Barriers (Sorted by Importance)



The bottom 10 factors that are less likely to be nominated by teachers as barriers are shown in Figure 11. The interpretation must be preceded by the caveat that teachers may still believe that these are important barriers but less so relative to other factors such as space and time. In the BWS task, teachers were not given the option that none of the listed factors act as a barrier to their teaching. However, a second follow up Likert scale was used to normalise the results — factors at the lower end of the BWS score range were indeed much less important on an absolute measure of importance captured in the Likert Scale (albeit with less discrimination).

On average, the factors that appears to be the least significant barrier to effective primary science and technology as nominated by teachers is:

- It’s difficult to keep students interested and motivated (S42).

This is followed by concerns regarding noise in the classroom (S9, ranked 2nd last) or that activities are too messy (S7, ranked 7th last).

In general, teachers’ confidence in teaching science and technology, as captured by separate questions, is reflected in the lower BWS scores associated with concerns about answering students’ questions (S28, ranked 4th last) and dealing with concepts difficult to explain to students (S31, ranked 6th last). The strong knowledge of teachers with respect to what constitutes science and technology is also confirmed by their self-nomination that, relative to other factors, a lack of understanding of the syllabus is not a barrier (S25, 3rd last). The lack of understanding about content is also less of a barrier relative to other barriers examined (S2, ranked 8th last).

FACTOR ANALYSIS

Factor analysis is a useful technique to identify particular themes in the data, and to treat highly correlated items as a single construct, or factor, rather than view them as separate entities. For example, some teachers may perceive that space to do things is a problem (S1) in the same way that space to set up for lessons is a problem (S2), along with space to store (S3), or put work in progress (S4). If the general issue of space is a problem, these factors, on average, would all be scored higher by the individual teacher. Hence, this allows us to see whether teachers view the factors that refer to space in a similar way (as a construct), but differently to constructs measured by other factors, such as time to plan (S13, S14), materials provided by the school (S20, S21, S23), or confidence (S29, S30). Factor analysis tries to find those variables that can be grouped together and those which cannot. To illustrate this visually, Figure 12 represents a very early solution attempting to describe the data with just two factors (eventually several more were detected as discussed). This early analysis revealed some groupings in the data.

It is worth noting the appropriateness of utilising a factor analytical technique in the current context. The nature of the BWS task is that it maximises discrimination among factors. As a result, patterns of association are more difficult to detect as BWS aims to minimise rather than maximise inter-item correlations between any two factors, including those reflective of the same underlying construct. As such, forming reliable indicators of constructs will be more difficult. Nonetheless, patterns of inter-item correlation suggest several themes occur in the data.

TIME TO PREPARE VERSUS TIME TO TEACH

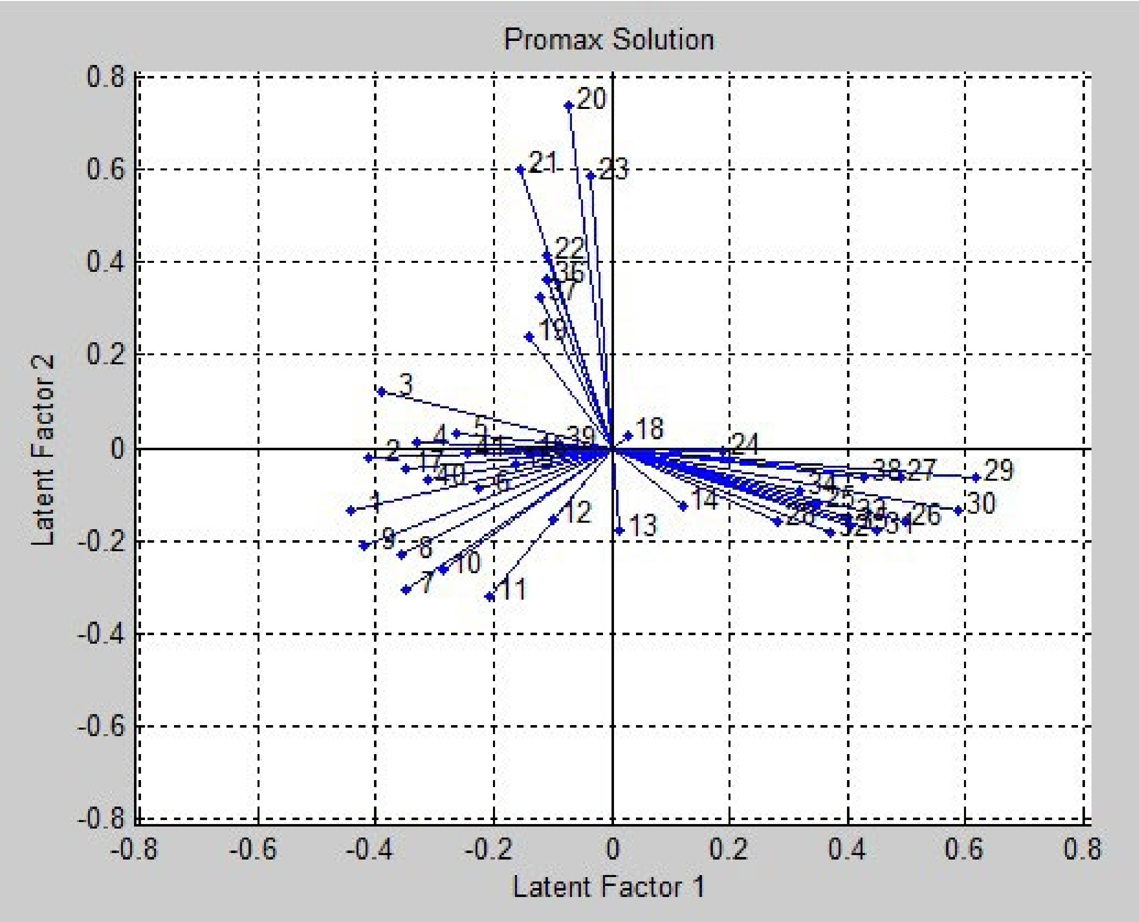
Time is nominated by teachers as a clear barrier to teaching science and technology well. However, factor analysis indicates that time can be broken up into several dimensions. First, the results suggest that teachers respond to the following factors in a similar way:

- I don't have time to prepare (for example, get ready, locate supplies) (S12).
- I don't have time to plan the unit of work (S13).
- I don't have time to plan hands-on activities (S14).

This suggests that time to plan is an overarching theme in the data. It appears distinct from other factors to do with time, with the results indicating distinctions between time before and time during the teaching of science and technology. In particular, the data suggest that this construct of time appears distinct from time to deliver, or time in the classroom:

- The timetable is too fragmented (teaching blocks are too short) (S17).
- It's difficult to fit it in with everything else I have to teach (S16).
- There are other subjects that I have to prioritise (S18).

Figure 12: Illustration of Initial Factor Analysis Solution (Two Factors)



SPACE

A major theme emerging from the data is to do with space. The following statements describe space as one of the overarching barriers:

- Space for students to do things is a problem (S1).
- Space to set up for lessons is a problem (S2).
- Space to put students' work in progress is a problem (S4).

There is less correlation with respondents who view the issue of space as measured by these factors, with the factor (S3) Space to store materials and equipment is a problem.

SUPPORT

The role of the school in supporting teachers in effective teaching practices appears to be captured by statements S20 to S22, and partially by S23 (School funds are prioritised for other areas). That is, school support (materials) is captured by teachers' responses to:

- The school doesn't provide the materials and equipment I need (S20).
- I have to buy my own materials (S21).
- The process to purchase materials is too difficult (S22).

The issue of support is also captured partially by statement S23 — School funds are prioritised for other areas. Results of data analysis further indicate these concerns are related to issues about space and resources, as captured by the following statements:

- Space to store materials and equipment is a problem (S3).
- It's difficult to maintain and keep track of resources (S19).

From the analysis, teachers appear to distinguish between various elements of support. In particular, results suggest that this type of material support is somewhat different from a culture supportive of science and technology as captured by the following factors:

- The school leadership doesn't support science and technology enough (S36).
- My colleagues are not really interested in science and technology (S37).
- School funds are prioritised for other areas (S23).

CLASSROOM CONTROL, NOISE AND MESSINESS

During the stakeholder discussion phase to identify the potential barriers, the participating teachers discussed issues relating to controlling students, the potential embarrassment of a noisy classroom for some teachers, and the messiness of activities taking place in effective science and technology classes. However, results of data analysis suggest some distinction among these elements. In particular, the factors relating to messiness appear to be interrelated and are captured by the following statements:

- The activities are too messy (S7).
- It's difficult to clean up after a class or activity (S8).

The issue of messiness appears to be distinct from those of noise and control, as captured by the statements below:

- My classroom gets too noisy (S9).
- The activities make it difficult to control the class (S10).

In general, the results suggest that both factors are less of an issue for teachers, but concerns about messiness feature more highly than concerns about noise and control.

CONFIDENCE AND IDEAS

Self-reflection of participating teachers suggests a high degree of confidence in teaching primary science and technology. However, they appear to be concerned about idea generation, as captured by the following factors:

- It's difficult to come up with ideas for Working Scientifically (S33).
- It's difficult to come up with ideas for Working Technologically (designing and producing) (S32).

These factors are also associated with confidence in doing, as measured by:

- I'm not confident in doing designing and producing/ making with my students (S30).
- I'm not confident in doing scientific investigations with my students (S29).
- I'm not confident in facilitating an inquiry process (S26).

These factors are, however, less correlated with concern related to confidence in explanations, as demonstrated by:

- I find it difficult to explain the concepts to students (S31).
- I'm concerned I won't be able to answer the students' questions (S28).

The concerns about confidence and knowledge appear to be separate from those about the impact of the syllabus as captured by:

- The syllabus is difficult to navigate and use (S24).
- I don't understand what the syllabus requires me to teach (S25).

Whilst S24 shares virtually no overlap with any other factors other than S25, S25 shares overlap with other elements of confidence, particularly:

- I'm not confident in facilitating an inquiry process (S26).
- I don't understand the content well enough (S27).
- I'm not confident in doing scientific investigations with my students (S29).

In general, concern regarding lesson ideas appears to be a dominating barrier for participating teachers. Concerns about the syllabus or knowledge about concepts seem to be less of an issue for these teachers in delivering effective science and technology teaching.

Overall, the themes that appear to emerge from the data, in order of relative importance, are:

1. adequate time in the classroom (S11, S16, S17, S18)
2. space to do and store (S1, S2, S4)
3. time to prepare (S12, S13, S14)
4. ideas for teaching (S32, S33)
5. material support (S20, S21, S22)
6. school culture (S36, S37, S23)
7. messiness (S7, S8)
8. confidence (S26, S27, S29)
9. control (S9, S10).

As noted, some factors are not highly correlated with others in the list of the 42 factors studied. However, some of these are still considered important by the teachers. For example, the fifth ranked factor with respect to the aggregate results is:

- I don't have time to collaborate with colleagues (S15).

It does not correlate with factors to do with time nor with those to do with culture. Nonetheless, its high BWS score constitutes collaboration as an important element on par with concerns about space. Indeed, the value of informal and formal interactions (for example, mentoring) among colleagues has been highlighted as an important factor in fostering teacher commitment to a school and the profession more broadly (Buchanan et al., 2013; Burke et al., 2013; Ewing & Manuel, 2005).

DIFFERENCES ACROSS TEACHERS (CLUSTER ANALYSIS)

Differences often exist across respondents. Sometimes completely different viewpoints may cancel each other out, reflecting neither viewpoint (Burke, 2013). One way to explore this heterogeneity in the results is to detect segments in the data and refer to each separately. Techniques that are useful in doing so include cluster analysis and latent segmentation. The full details of how this analysis was approached are presented in Appendix 1, along with statistical results that indicate which barriers are more significant in driving differences between the clusters.

The results indicate that two major factors driving the individual segment differences are oriented towards confidence in undertaking activities with students, and the perception of a school's resources. In contrast, there is considerable agreement among most teachers about the barriers relating to time to prepare and time that is allowable in activities. That messiness is less of a barrier is generally agreed upon, although it emerges as a driver of differences in both the two and three cluster solutions. Nonetheless, other differences relating to confidence and facilitation are dominant in determining the segments.

Figure 13: Importance of Barrier by Factors (Themes)

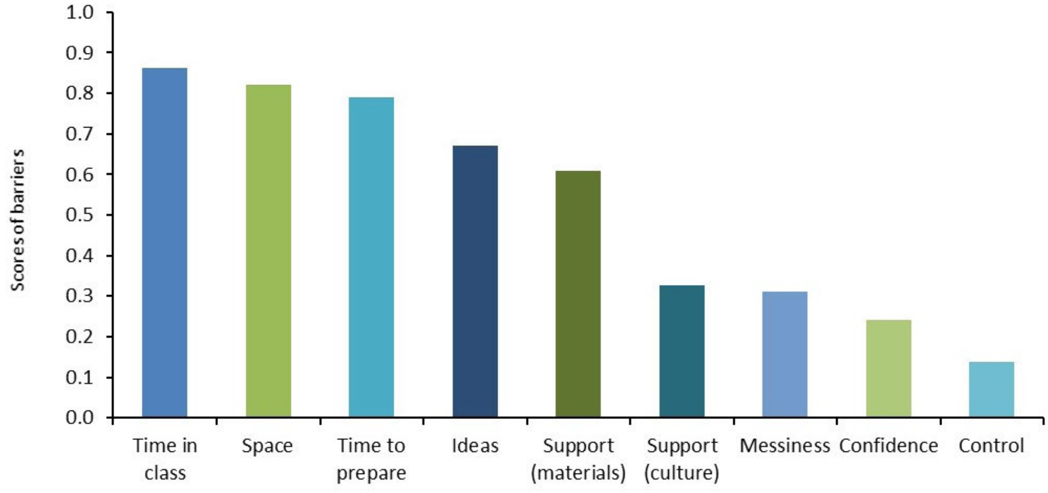


Table 2: Areas of Difference and Similarities across Latent Segments

STATEMENTS DRIVING LATENT SEGMENT DIFFERENCES
30 I'm not confident in doing designing and producing with my students.
26 I'm not confident in facilitating an inquiry process.
21 I have to buy my own materials.
20 The school doesn't provide the materials and equipment I need.
29 I'm not confident in doing scientific investigations with my students.
31 I find it difficult to explain the concepts to students.
23 School funds are prioritised for other areas.
33 It's difficult to come up with ideas for Working Scientifically.
3 Space to store materials and equipment is a problem.
27 I don't understand the content well enough.

STATEMENTS WHERE GREATER AGREEMENT EXISTS ACROSS SEGMENTS
12 I don't have time to prepare (for example, get ready, locate supplies).
18 There are other subjects that I have to prioritise.
11 The activities take too long to complete in class.
15 I don't have time to collaborate with colleagues.
7 The activities are too messy.
16 It's difficult to fit it in with everything else I have to teach.
10 The activities make it difficult to control the class.
39 The scope and sequence doesn't allow me to teach things when I would like.
8 It's difficult to clean up after a class or activity.

In the case of a two cluster solution, the two groups that emerge are approximately equal in size (54% for cluster 2). For cluster 1, concerns are more significant in terms of coming up with ideas for teaching, time to prepare and the priority of science and technology against other subjects. In contrast, cluster 2 is more concerned about space and resources provided by the school. Confidence and idea generation in teaching science and technology are perceived to be irrelevant as a barrier to the effective delivery of the subject.

In the three cluster solution, one group (cluster 1, making up 42% of the sample) appears to be adequately confident in teaching science and technology, but more concerned about time, space and resources.

Interestingly, a second group (cluster 2, accounting for 24% of the sample) nominates idea generation (S32, S33) and gauging student learning (S34, S35) as important barriers to their effective teaching, along with confidence in doing designing and producing activities (S29, S30). Elements of not understanding the syllabus, the content or being able to answer questions are not a feature of concern among this group. This result is largely consistent with the factor analysis suggesting that elements of confidence relate more to ideas and delivery than to content knowledge. The final cluster seems to sit amongst the two groups, but disagrees that the school leadership does not do enough to support science and technology teaching (S36).

Figure 14: Two-cluster Solution

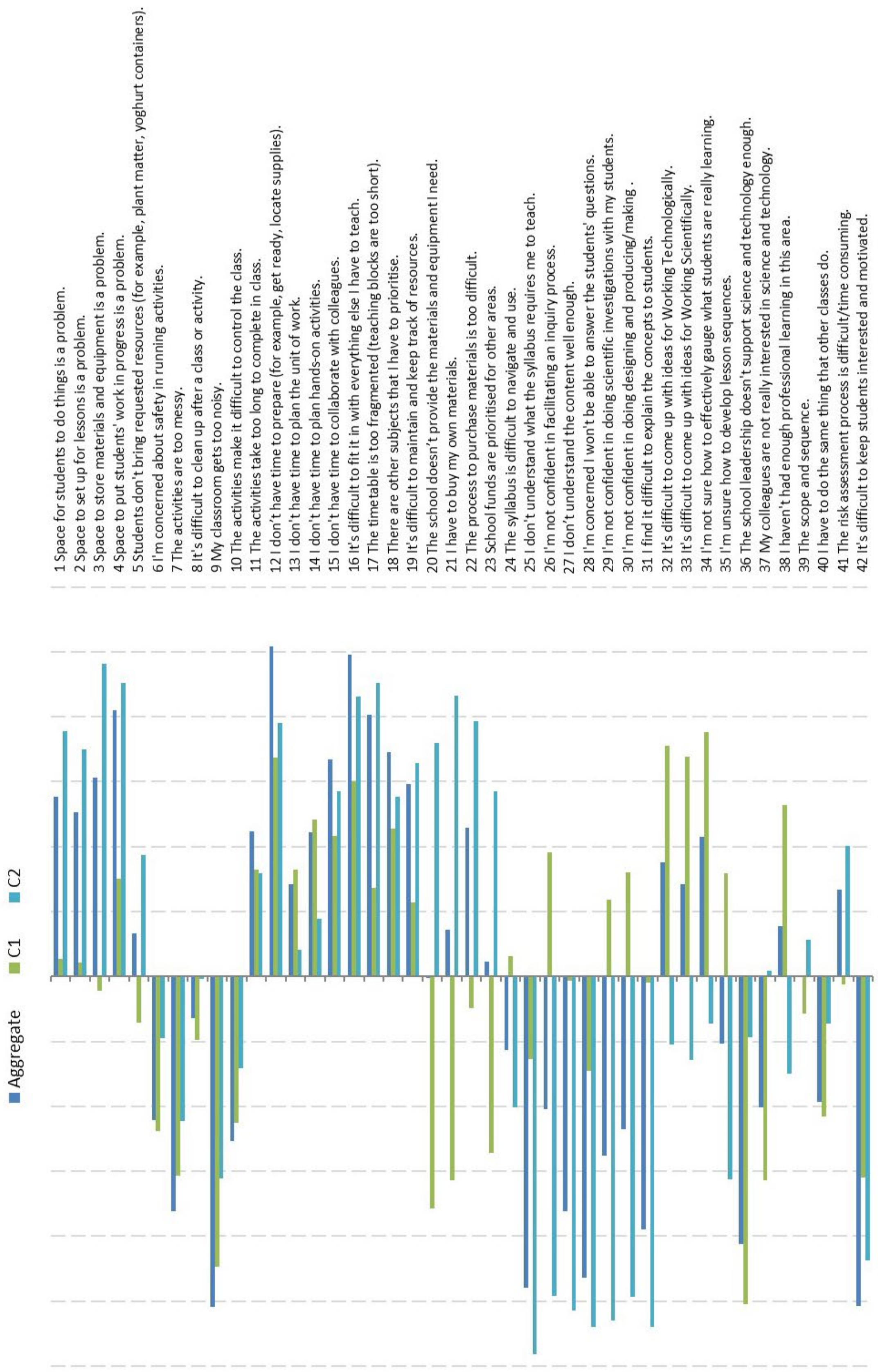
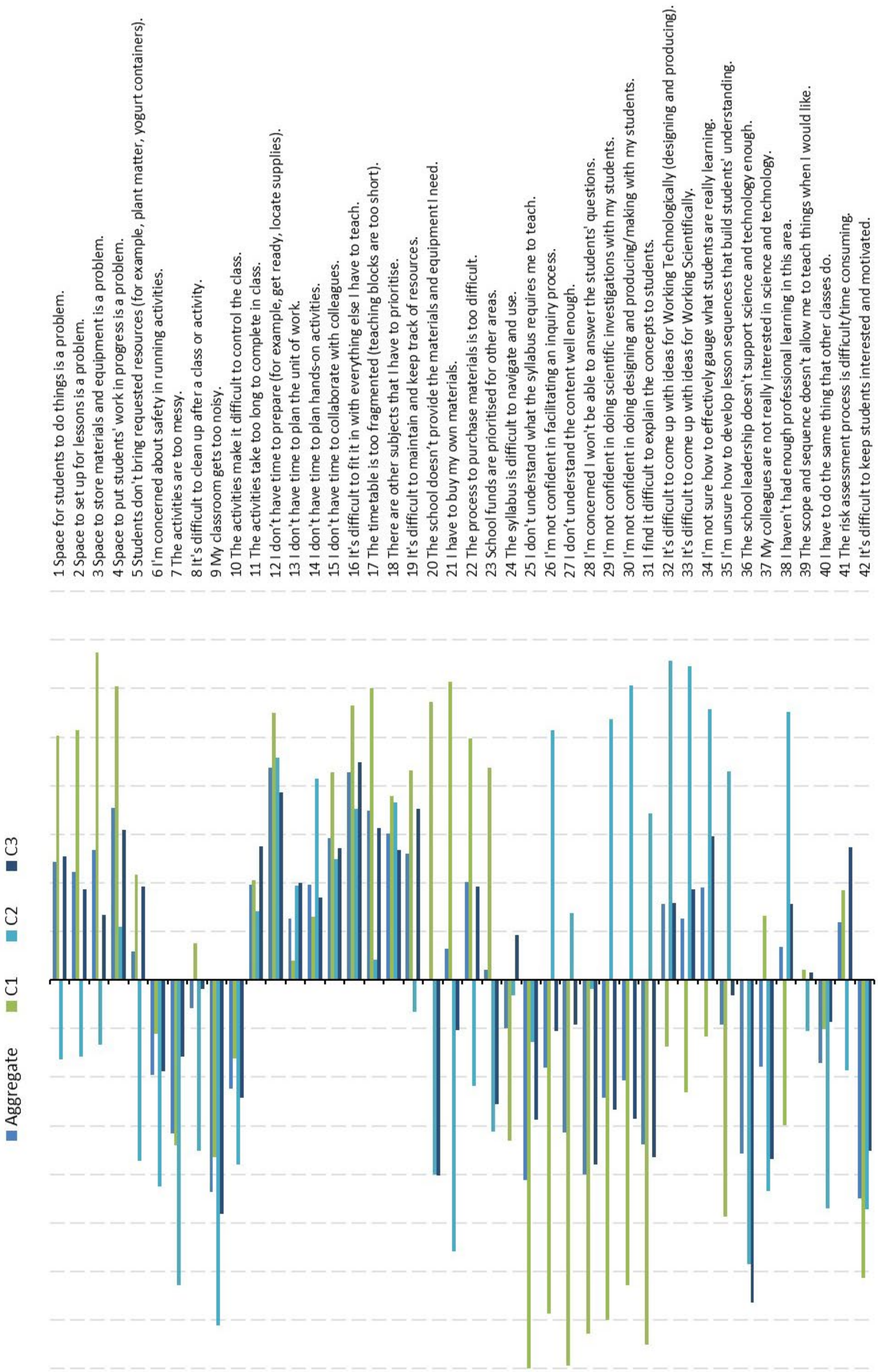


Figure 15: Three-cluster Solution



Overall the results suggest that differences do exist among teachers and these can vary in several ways. In particular, a segment of around 24% of teachers appears to have some concerns about their confidence in teaching, and about 25% agree with the statement that they are not confident in teaching science and technology on a 10-point Likert scale question. A larger segment of teachers (around 40%) appears to be more concerned about space, resources and time. Again, this is on par with the 38% of teachers who disagree with the statement that their school is well resourced for the teaching of primary science and technology. The results also reinforce the view of a majority of teachers, that time is a factor inhibiting effective science and technology teaching.

In general, whilst the results have identified what appears to be prominent barriers for effective teaching, it is important to realise that no two teachers nor schools are identical. The results of the cluster analysis indicate that those differences are largely based around the broad themes identified in the factor analysis. Subsequently, if improvements are to be made with respect to addressing barriers to effective science and technology teaching, some actions may be considered around resourcing, time and space more generally. Schools may employ initiatives that build the individual confidence of teachers, with a focus on idea generation.

DIFFERENCES ACROSS TEACHERS (COVARIATE ANALYSIS)

Whilst some differences across the teachers are related to latent segments in the data, often it is useful to interrogate the data to see if differences may be associated with particular teachers as described by certain characteristics. These may relate to their school setting, classroom context, their experiences as a teacher, their confidence with teaching primary science and technology, or their age and gender.

However, in some instances — and given the limited sample size — there are not enough data to interrogate further. For example, it would be interesting to know whether those who co-teach with a specialist would differ in their views about barriers relative to others. Only nine respondents (4.2% of the sample) are in such a situation. In some cases, there is often no detectable difference among teachers as related to a particular measure, such as whether a teacher has taught in Years 5 or Year 6 in the last five years or not. This may or may not be attributable to a low overall sample size — that is, the ability to detect significant differences becomes more likely when the sample size increases. Consequently, the following results focus only on those characteristics that offer something interesting to the interpretation of the aggregate results offered earlier.

For example, one question asks whether teachers agree with the statement that “time is a major factor inhibiting primary science and technology program delivery at my school” using a 5-point Likert scale of strongly agree/ disagree. Whilst 64.7% agree with this, 15% disagree. The results confirm that those who agree are more likely to be those nominating time related barriers as more significant to their effective teaching of primary science and technology (S12, S13, S16, S17, S18). Similarly, teachers who indicated that they teach at well-resourced schools nominate that school resources are less of a barrier to their teaching (as discussed below), whilst teachers at schools with colleagues that have a good background in science and technology are less likely to indicate that colleagues are not really interested in science and technology (S37).

FULL-TIME VERSUS PART-TIME

Respondents in part-time roles are significantly more likely to suggest that space for students to do things (S1) and setting up for lessons (S2) are barriers to effective teaching. This confirms some of the findings from the focus groups which indicate that, in some cases, part-time staff must prepare for lessons outside the room and this can be problematic. Similarly, part-time staff are significantly more likely to suggest that their school does not always provide the needed materials and equipment (S20) as a barrier for them relative to their full-time counterparts.

SIZE OF SCHOOL

With respect to school size, those teachers working at relatively large schools are significantly more likely to nominate that it is more difficult to fit teaching science and technology in with everything else (S16), and that there are issues regarding the fragmentation of the timetable (teaching blocks being too short) (S17). At smaller schools, teachers are significantly more likely to nominate spaces to set up for lessons as a problem (S2) along with the process of purchasing materials (S22).

CO-EDUCATIONAL SCHOOLS

Teachers in co-educational schools appear to show significant differences compared to those in schools, or classes, made up entirely of students of the same gender. Teachers of co-educational primary science and technology classes report significantly less concern both about the length of activities in class (S11) and about the timetable being too fragmented (S17), and that they have to do the same things that other classes do (S40). On the other hand, they suggest that having to buy their own materials (S21) features as more of a barrier relative to other factors.

NUMBER OF STUDENTS IN THE CLASSROOM

As discussed previously, 75% of teachers have between 20 and 29 students in their classroom. There is little detectable impact of the number of students in a given science and technology classroom on the perceived relevance of each barrier. Three exceptions are present. Space to store materials and equipment (S3) is nominated more as a barrier by teachers working with smaller classes, and teachers are more likely to nominate that they do not have time to prepare (for example, get ready, locate supplies) when teaching a greater number of students (S12). However, those teaching a larger number of students find that it is more difficult to maintain and keep track of resources (S19).

SHARED TEACHING SPACES AND SHARED TEACHING EXPERIENCES

Teachers who have to share their teaching spaces with other colleagues (42% of teachers) are significantly more likely to suggest that their barriers include fitting things in (S16), the timetable is fragmented (S17), and that they have to do what other classes are doing (S40). Interestingly, the same set of teachers is significantly more likely to indicate that an unsupportive school leadership for science and technology (S36) is a barrier for effective teaching. Overall, the results suggest that schools where teachers must share their classrooms with others should consider how teachers perceive flexibility in the teaching and learning of the curriculum, and the impediments on time that may be created by timetabling issues. The pressures to fit science and technology in with competing subjects is also a challenge.

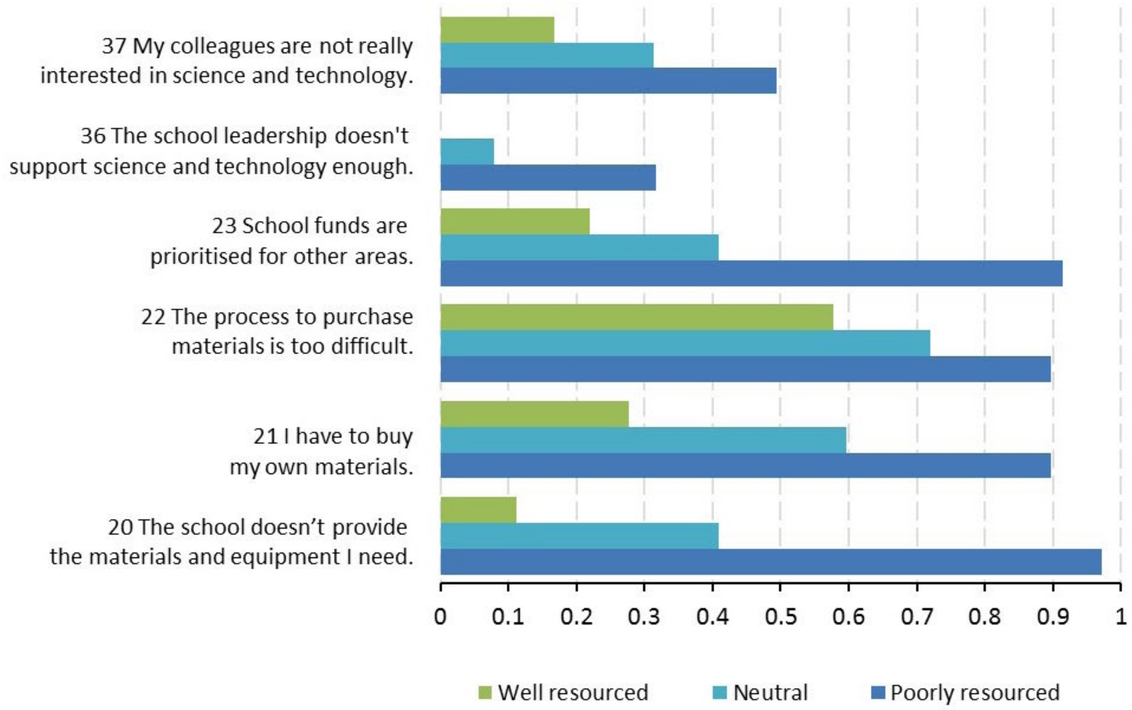
On average, teachers who have to teach by themselves appear to have different concerns from those who co-teach. Those teaching by themselves are significantly more likely to nominate issues of noise (S9) and control (S10) as barriers (80% of cases). Similarly, these teachers nominate effectively gauging student learning as being more problematic than others (S34). In contrast, those who co-teach with a primary teacher (15.3% of teachers) indicate that noise (S9) is significantly less of a barrier whereas a fragmented timetable (shorter teaching blocks) (S17) is significantly more concerning.

SCHOOL CULTURE AND RESOURCES

In a separate question, respondents are asked whether other teachers at their school have a positive attitude to the teaching of primary science and technology. Only 13% disagree with this statement, whilst 59% of teachers agree. Therefore, it is not surprising that the group with a relatively negative perception of the attitudes of colleagues is significantly more likely to nominate barriers relating to the interest of their colleagues in teaching science and technology (S37). However, they are also significantly more likely to nominate concerns about other aspects of support and school culture, including concerns about the priority of school funds for other areas (S23), and leadership (S36).

As expected, teachers who indicate that they work at well-resourced schools (38.6% of teachers) are very different in their nomination of school resources as a barrier compared to those who are neutral in their response about school capabilities (23%), and very different to those with resource issues (38.1% of teachers). The differences relate to issues pertaining to provision of materials (S20, S21), prioritising resources (S23) and prohibitive administration in resourcing (S22).

Figure 16: Significant Differences in Barriers by School Capabilities



EDUCATIONAL EXPERIENCE

A small number of teachers (16%) have completed studies in science and technology at university. These teachers indicate that factors relating to their levels of confidence, difficulty in answering questions, or coming up with ideas are significantly less likely to be barriers to their effective teaching. Instead, they are more likely to nominate concerns about time in preparation and working with others (S12, S15) as more relevant. They also suggest concerns about the school culture with respect to leadership (S36) and the levels of interest among colleagues (S37).

Around half of all teachers in the sample have undertaken professional learning to improve their science and technology pedagogical content knowledge. The results indicate that those with such experience are less likely to identify concerns about the syllabus (S24, S25), comprehension of the content (S26), and ability to undertake inquiry processes in teaching (S27) as barriers. Interestingly, there is no significant difference relating to coming up with ideas for teaching (S32, S33) or gauging learning outcomes (S34) amongst those who have and have not completed professional learning in this subject area.

Figure 17: Significant Differences in Barriers by University Study in Science and Technology

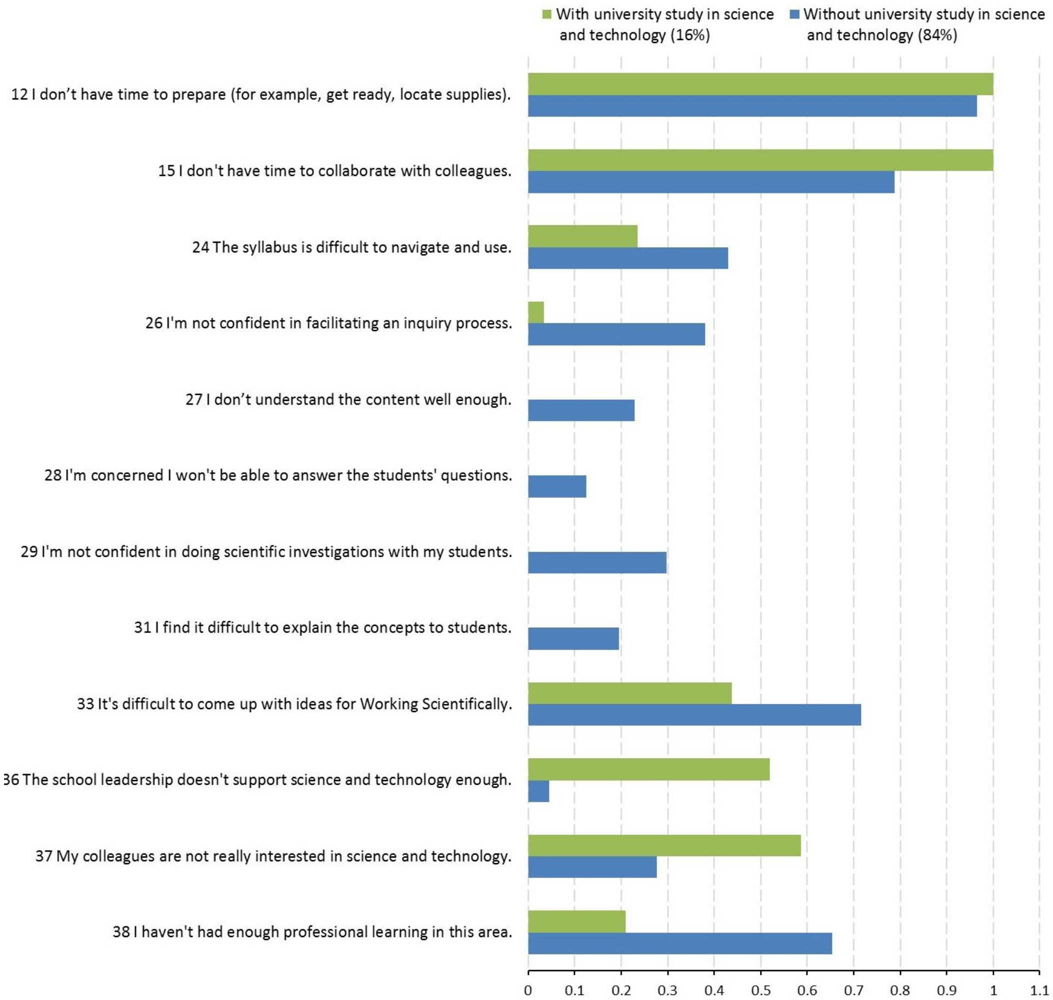
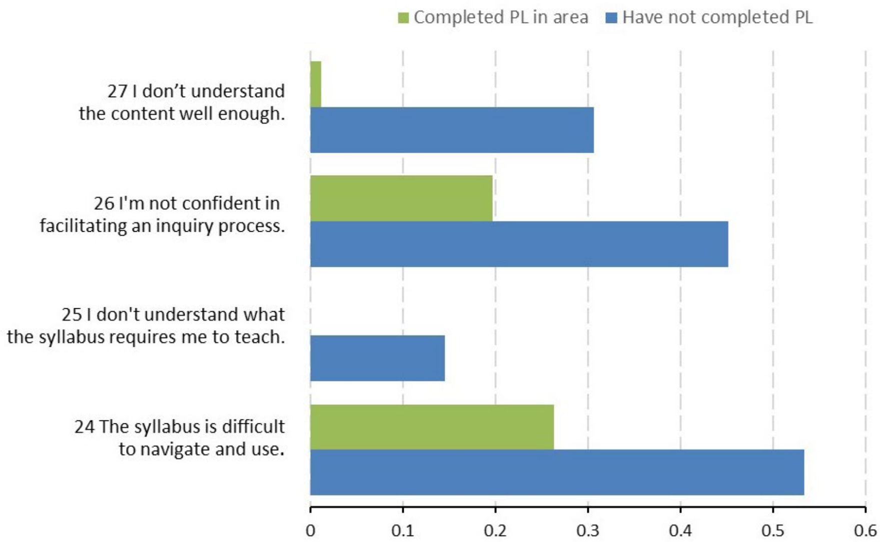


Figure 18: Significant Differences in Barriers by Professional Learning Activities



YEARS OF TEACHING AND AGE OF TEACHER

A regression analysis was used to understand the relationship between the age of a teacher and the likelihood that a particular barrier would be nominated as more relevant than others. The results indicate that younger teachers are more likely to nominate concerns about content knowledge (S27), confidence in undertaking scientific investigations (S29), and in providing explanations to students (S31). In contrast, older teachers appear more concerned by issues relating to space and resources.

Table 3: Barriers by Age of Teacher

FACTORS THAT ARE NOMINATED AS BARRIERS AMONG OLDER TEACHERS:	B	SE	t	Sig.	
1 Space for students to do things is a problem.	0.034	0.010	3.408	0.001	**
3 Space to store materials and equipment is a problem.	0.023	0.010	2.224	0.027	*
4 Space to put students' work in progress is a problem.	0.021	0.010	2.106	0.036	*
15 I don't have time to collaborate with colleagues.	0.026	0.009	2.819	0.005	**
20 The school doesn't provide the materials and equipment I need.	0.025	0.012	2.087	0.038	*

FACTORS THAT ARE NOMINATED AS BARRIERS AMONG YOUNGER TEACHERS:	B	SE	t	Sig.	
27 I don't understand the content well enough.	-0.040	0.010	-3.851	0.000	**
29 I'm not confident in doing scientific investigations with my students.	-0.024	0.011	-2.200	0.029	*
31 I find it difficult to explain the concepts to students.	-0.023	0.010	-2.290	0.023	*
11 The activities take too long to complete in class.	-0.023	0.010	-2.309	0.022	*

Note: **B**: unstandardised coefficient, **SE**: standard error, **t**: t-statistics, **Sig**.: significance level of t-statistics.

Teachers with less experience in teaching primary science and technology are significantly more likely to suggest that issues around control (S10), content knowledge (S27) and coming up with ideas for Working Scientifically (S33) are barriers compared to those with more years of experience. In contrast, teachers who have more experience in teaching primary science and technology are significantly more likely to suggest that space for doing activities and for storage are barriers compared to those with less experience.

Table 4: Barriers by Years of Teaching

NOMINATED AS BARRIER AMONG TEACHERS WHO HAD TAUGHT PRIMARY SCIENCE AND TECHNOLOGY FOR MORE YEARS:	B	SE	t	Sig.	
1 Space for students to do things is a problem.	0.006	0.002	2.597	0.010	*
3 Space to store materials and equipment is a problem.	0.005	0.002	1.988	0.048	*

NOMINATED AS BARRIER AMONG TEACHERS WHO HAD TAUGHT PRIMARY SCIENCE AND TECHNOLOGY FOR LESS YEARS:	B	SE	t	Sig.	
10 The activities make it difficult to control the class.	-0.006	0.002	-2.553	0.011	*
18 There are other subjects that I have to prioritise.	-0.006	0.002	-2.335	0.020	*
27 I don't understand the content well enough.	-0.007	0.002	-2.769	0.006	**
33 It's difficult to come up with ideas for Working Scientifically.	-0.005	0.002	-2.152	0.033	*

GENDER

Female teachers made up 87% of the survey sample, which is fairly consistent with their representation in primary schools. On average, both male and female teachers appear to agree about the barriers that are more likely to impact on their effective teaching of primary science and technology. There are, however, significant differences in factors relating to teachers' confidence (S28, S30, S31) and idea generation (S32). Relative to male teachers, females are significantly more likely to identify such concerns as barriers.

Table 5: Barriers More Likely to be Nominated by Female Teachers

28 I'm concerned I won't be able to answer the students' questions.
30 I'm not confident in doing designing and producing/making with my students.
31 I find it difficult to explain the concepts to students.
32 It's difficult to come up with ideas for Working Technologically (designing and producing).

EFFECTIVENESS OF TEACHING (SELF-ASSESSMENT)

Towards the end of the survey, teachers were reminded about what constitutes effective primary science and technology teaching. They were then asked to self-nominate their teaching effectiveness on a 6-point Likert scale (1 — strong disagree to 6 — strongly agree). The absence of a neutral factor forced respondents to evaluate themselves as being either positive or negative in terms of their effectiveness as a teacher. Most respondents (85%) nominated themselves as being effective although only 16% strongly agreed with the statement.

Results of a regression analysis indicate that teachers who assess themselves as less effective are more likely to nominate barriers relating to confidence, coming up with ideas, and the syllabus. They are also significantly more likely to nominate concerns about not receiving enough professional learning in teaching science and technology. Teachers who assess themselves as being more effective in teaching science and technology are more likely to nominate barriers relating to space and resources (S3, S1, S4, S21), safety and risk (S6, S41), and time (S17, S15).

Table 6: Differences in Barriers Relating to Perceived Effectiveness

FACTORS MORE RELEVANT AMONG TEACHERS NOMINATING THEMSELVES AS LESS EFFECTIVE:	B	SE	t	Sig.	
29 I'm not confident in doing scientific investigations with my students.	-0.100	0.019	-5.154	0.000	***
33 It's difficult to come up with ideas for Working Scientifically.	-0.065	0.020	-3.311	0.001	***
30 I'm not confident in doing designing and producing/making with my students.	-0.064	0.020	-3.208	0.002	***
26 I'm not confident in facilitating an inquiry process.	-0.066	0.021	-3.118	0.002	***
27 I don't understand the content well enough.	-0.054	0.020	-2.734	0.007	***
35 I'm unsure how to develop lesson sequences that build students' understanding.	-0.055	0.020	-2.673	0.008	***
25 I don't understand what the syllabus requires me to teach.	-0.047	0.018	-2.558	0.011	**
32 It's difficult to come up with ideas for Working Technologically.	-0.051	0.020	-2.519	0.012	**
38 I haven't had enough professional learning in this area.	-0.044	0.020	-2.159	0.032	**
24 The syllabus is difficult to navigate and use.	-0.040	0.020	-2.043	0.042	**

It is also interesting to examine those factors that teachers agree upon, irrespective of how they assess themselves with respect to teaching effectiveness. Time to prepare, time in the classroom and the priority of science and technology appear to be significant barriers all teachers agree upon. There is also agreement about those factors that are relatively less important in affecting teaching the subject well, including the ability to maintain student interest, ability to answer questions and an unsupportive leadership.

Table 7: Differences in Barriers Relating to Perceived Effectiveness

FACTORS MORE RELEVANT AMONG TEACHERS NOMINATING THEMSELVES AS MORE EFFECTIVE:	B	SE	t	Sig.	
3 Space to store materials and equipment is a problem.	0.087	0.019	4.660	0.000	***
6 I'm concerned about safety in running activities.	0.060	0.019	3.160	0.002	***
17 The timetable is too fragmented (teaching blocks are too short).	0.055	0.021	2.563	0.011	**
7 The activities are too messy.	0.045	0.018	2.480	0.014	**
41 The risk assessment process is difficult/time consuming.	0.048	0.020	2.362	0.019	**
37 My colleagues are not really interested in science and technology.	0.047	0.020	2.291	0.023	**
8 It's difficult to clean up after a class or activity.	0.040	0.019	2.061	0.041	**
1 Space for students to do things is a problem.	0.039	0.019	2.021	0.045	**
4 Space to put students' work in progress is a problem.	0.037	0.019	1.965	0.051	*
15 I don't have time to collaborate with colleagues.	0.034	0.018	1.896	0.059	*
9 My classroom gets too noisy.	0.034	0.018	1.887	0.061	*
21 I have to buy my own materials.	0.044	0.023	1.882	0.061	*

Table 8: Common Barriers across Differing Levels of Perceived Effectiveness

FACTORS THAT TEACHERS AGREE ON IRRESPECTIVE OF SELF-ASSESSED EFFECTIVENESS	RANK
12 I don’t have time to prepare (for example, get ready, locate supplies).	1
16 It's difficult to fit it in with everything else I have to teach.	2
18 There are other subjects that I have to prioritise.	6
19 It's difficult to maintain and keep track of resources.	8
2 Space to set up for lessons is a problem.	10
22 The process to purchase materials is too difficult.	11
11 The activities take too long to complete in class.	12
34 I'm not sure how to effectively gauge what students are really learning.	13
14 I don't have time to plan hands-on activities.	14
13 I don't have time to plan the unit of work.	17
5 Students don't bring requested resources (for example, plant matter, yogurt containers).	21
23 School funds are prioritised for other areas.	22
39 The scope and sequence doesn't allow me to teach things when I would like.	23
20 The school doesn’t provide the materials and equipment I need.	24
40 I have to do the same thing that other classes do.	28
10 The activities make it difficult to control the class.	33
31 I find it difficult to explain the concepts to students.	37
36 The school leadership doesn't support science and technology enough.	38
28 I'm concerned I won't be able to answer the students' questions.	39
42 It's difficult to keep students interested and motivated.	42

SUMMARY OF FINDINGS

The results show that this sample of teachers in independent schools in NSW are generally confident in their abilities to deliver science and technology effectively in primary schools. Not only this, these teachers generally suggest that they are interested in teaching the subject, and that a small majority of their co-teachers also share a positive attitude to the teaching of science and technology.

The major concerns nominated by almost two thirds of the sample as barriers to being effective largely pertain to the broad issue of time, not just for themselves, but also at the school level. However, the concept of time appears multi-faceted. The concerns about time with respect to preparing for class appear to be common across all teachers. Concerns about time in the classroom appear to be linked to competition for teaching time between other subjects and science and technology. These concerns may potentially be mitigated by how time is arranged in the school setting more generally, with reference to the disruption caused by timetabling and inadequate blocking. Removing such mitigating effects has the potential to address other concerns, particularly those arising with spaces to store work in progress in settings where classrooms must be shared. Like time, space appears to take various forms. Space — to store material and equipment and to store work in progress — is nominated as a relatively more important barrier to effective teaching. Furthermore, the results suggest that not all independent schools in NSW are well resourced for primary science and technology teaching — only two in five teachers agree that this is the case at their school.

The findings also highlight the need to be considerate of individual teachers and the differences in circumstances at a school level across the primary school sector. For example, one of the largest drivers in explaining variations in teachers' nomination of barriers is related to how they view the confidence with which they undertake designing and producing activities with students and their confidence in facilitating inquiry processes. Generally, primary teachers suggest that they are comfortable in navigating the syllabus and what they are required to teach. This does not appear to be a barrier to effective teaching relative to other concerns.

Some schools may have already put in place several strategies or allocated resources to address some of the barriers highlighted in this study, including those relating to space. However, other barriers may remain. For example, at least 50% of teachers suggest that they are employed at schools that offer adequate opportunities for professional learning in science and technology. Nonetheless, even at schools where professional learning is encouraged, concerns may still remain about how to put this learning into practice.

The findings of this report suggest that there may be significant opportunities for schools to engage in a variety of improvement efforts to best support primary teachers in the effective teaching of science and technology. Suggestions in this regard can be found in the Literature Review and Case Study as referenced earlier.

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APPENDICES

APPENDIX 1: CLUSTER ANALYSIS

There are several clustering techniques, such as hierarchical cluster analysis or k-means clustering. The analysis team used both in conjunction with each other and found that improvements in the agglomeration schedule and final predictive choice model results suggested that a two or a three cluster solution would be adequate in explaining underlying differences in the data. An Analysis of Variance (ANOVA) was used to examine how significant scores are across the three groups, with a higher F-statistic indicative of greater differences. These results appear in the table below.

STATEMENT	TWO-CLUSTER SOLUTION		THREE CLUSTERS		FOUR CLUSTERS	
	F-Statistic	Sig.	F-Statistic	Sig.	F-Statistic	Sig.
30 I'm not confident in doing designing and producing with my students.	96.105	.000	83.163	.000	52.504	.000
26 I'm not confident in facilitating an inquiry process.	82.559	.000	50.127	.000	31.021	.000
21 I have to buy my own materials.	82.370	.000	42.101	.000	42.848	.000
20 The school doesn't provide the materials and equipment I need.	80.174	.000	46.767	.000	75.065	.000
29 I'm not confident in doing scientific investigations with my students.	76.126	.000	62.524	.000	37.506	.000
31 I find it difficult to explain the concepts to students.	55.854	.000	52.123	.000	21.679	.000
23 School funds are prioritised for other areas.	54.617	.000	26.915	.000	46.538	.000
33 It's difficult to come up with ideas for Working Scientifically.	44.145	.000	26.754	.000	22.419	.000
3 Space to store materials and equipment is a problem.	43.423	.000	24.574	.000	10.148	.000
27 I don't understand the content well enough.	42.968	.000	40.308	.000	20.981	.000
35 I'm unsure how to develop lesson sequences that build understanding.	41.366	.000	31.661	.000	17.406	.000
32 It's difficult to come up with ideas for Working Technologically.	39.171	.000	20.083	.000	13.910	.000
22 The process to purchase materials is too difficult.	38.250	.000	15.369	.000	9.845	.000
25 I don't understand what the syllabus requires me to teach.	35.224	.000	18.723	.000	10.443	.000
34 I'm not sure how to effectively gauge what students are really learning.	34.004	.000	14.002	.000	10.082	.000
36 The school leadership doesn't support science and technology enough.	29.465	.000	21.618	.000	14.410	.000
38 I haven't had enough professional learning in this area.	28.780	.000	22.449	.000	20.967	.000
28 I'm concerned I won't be able to answer the students' questions.	23.142	.000	17.150	.000	9.479	.000
37 My colleagues are not really interested in science and technology.	20.763	.000	14.255	.000	8.907	.000
2 Space to set up for lessons is a problem.	20.280	.000	17.196	.000	8.613	.000
1 Space for students to do things is a problem.	19.726	.000	13.411	.000	13.854	.000
4 Space to put students' work in progress is a problem.	15.105	.000	9.958	.000	3.988	.009
17 The timetable is too fragmented (teaching blocks are too short).	13.801	.000	10.447	.000	10.369	.000
5 Students don't bring requested resources (for example, plant matter, containers).	10.217	.002	13.054	.000	11.904	.000
24 The syllabus is difficult to navigate and use.	8.899	.003	7.379	.001	2.295	.079
9 My classroom gets too noisy.	8.350	.004	6.653	.002	6.006	.001
19 It's difficult to maintain and keep track of resources.	7.208	.008	9.623	.000	6.909	.000
41 The risk assessment process is difficult/time consuming.	6.577	.011	6.260	.002	5.810	.001
14 I don't have time to plan hands-on activities.	5.402	.021	3.039	.050	3.277	.022
40 I have to do the same thing that other classes do.	5.013	.026	6.733	.001	8.498	.000
6 I'm concerned about safety in running activities.	3.109	.079	3.554	.030	3.840	.010
13 I don't have time to plan the unit of work.	3.054	.082	1.212	.300	5.455	.001
8 It's difficult to clean up after a class or activity.	2.334	.128	6.648	.002	9.299	.000
39 The scope and sequence doesn't allow me to teach things when I would like.	1.908	.169	.099	.905	3.251	.023
10 The activities make it difficult to control the class.	1.593	.208	1.452	.236	2.634	.051
16 It's difficult to fit it in with everything else I have to teach.	1.559	.213	2.091	.126	1.877	.134
7 The activities are too messy.	1.497	.222	7.335	.001	9.659	.000
15 I don't have time to collaborate with colleagues.	.460	.498	1.503	.225	2.056	.107
11 The activities take too long to complete in class.	.112	.738	.441	.644	13.650	.000
18 There are other subjects that I have to prioritise.	.037	.848	.088	.915	.609	.610
12 I don't have time to prepare (for example, get ready, locate supplies).	.002	.964	.403	.669	8.819	.000

Note: Statistics for factor 42 are not identifiable up to 4 decimal places, and therefore not reported.

APPENDIX 2: TWO-CLUSTER SOLUTION

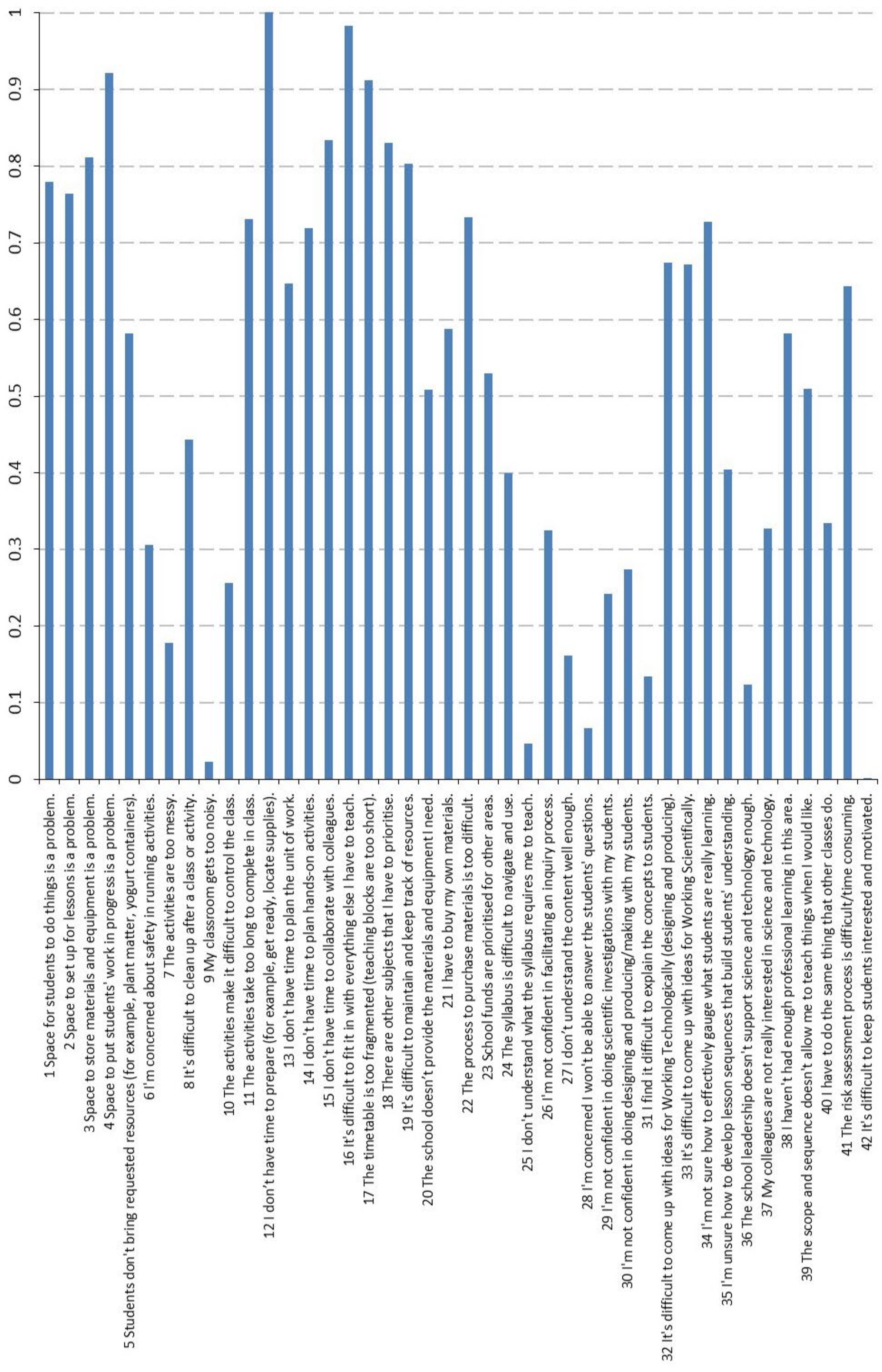
FACTOR	AGG	C1	C2	Sig. Diff.
1 Space for students to do things is a problem.	5.5473	0.5361	7.5482	***
2 Space to set up for lessons is a problem.	5.0616	0.4294	6.9965	***
3 Space to store materials and equipment is a problem.	6.124	-0.4393	9.639	***
4 Space to put students' work in progress is a problem.	8.2029	3.0227	9.0465	***
5 Students don't bring requested resources .	1.3355	-1.4161	3.7274	***
6 I'm concerned about safety in running activities.	-4.4203	-4.7532	-1.9025	***
7 The activities are too messy.	-7.2377	-6.1461	-4.46	**
8 It's difficult to clean up after a class or activity.	-1.2829	-1.9494	-0.0884	**
9 My classroom gets too noisy.	-10.172	-8.954	-6.2128	***
10 The activities make it difficult to control the class.	-5.0832	-4.5094	-2.8287	**
11 The activities take too long to complete in class.	4.4651	3.2926	3.1864	
12 I don't have time to prepare (for example, get ready, locate supplies).	10.1685	6.7522	7.819	
13 I don't have time to plan the unit of work.	2.8306	3.3037	0.8146	***
14 I don't have time to plan hands-on activities.	4.443	4.8337	1.766	***
15 I don't have time to collaborate with colleagues.	6.6843	4.3229	5.6903	
16 It's difficult to fit it in with everything else I have to teach.	9.9266	6.0171	8.6348	**
17 The timetable is too fragmented (teaching blocks are too short).	8.0647	2.7262	9.0449	***
18 There are other subjects that I have to prioritise.	6.9055	4.5595	5.5495	
19 It's difficult to maintain and keep track of resources.	5.9258	2.2711	6.5783	***
20 The school doesn't provide the materials and equipment I need.	-0.0502	-7.146	7.1818	***
21 I have to buy my own materials.	1.4461	-6.2657	8.6528	***
22 The process to purchase materials is too difficult.	4.5866	-0.9873	7.8759	***
23 School funds are prioritised for other areas.	0.4668	-5.4238	5.7037	***
24 The syllabus is difficult to navigate and use.	-2.2518	0.6127	-4.0293	***
25 I don't understand what the syllabus requires me to teach.	-9.5771	-2.5358	-11.6224	***
26 I'm not confident in facilitating an inquiry process.	-4.0998	3.8351	-9.8535	***
27 I don't understand the content well enough.	-7.2305	-0.1217	-10.2895	***
28 I'm concerned I won't be able to answer the students' questions.	-9.2755	-2.9129	-10.8076	***
29 I'm not confident in doing scientific investigations with my students.	-5.5276	2.3735	-10.6014	***
30 I'm not confident in doing designing and producing/making.	-4.6987	3.2201	-9.8601	***
31 I find it difficult to explain the concepts to students.	-7.7789	-0.1818	-10.8002	***
32 It's difficult to come up with ideas for Working Technologically .	3.5163	7.1123	-2.1022	***
33 It's difficult to come up with ideas for Working Scientifically.	2.8368	6.7725	-2.5779	***
34 I'm not sure how to effectively gauge what students are really learning.	4.298	7.5389	-1.4609	***
35 I'm unsure how to develop lesson sequences.	-2.0823	3.1862	-6.2467	***
36 The school leadership doesn't support science and technology enough.	-8.2412	-10.0974	-1.8658	***
37 My colleagues are not really interested in science and technology.	-4.0249	-6.2692	0.1758	***
38 I haven't had enough professional learning in this area.	1.5492	5.2803	-2.9804	***
39 The scope and sequence.	-0.0109	-1.1542	1.1316	***
40 I have to do the same thing that other classes do.	-3.8561	-4.3008	-1.44	***
41 The risk assessment process is difficult/time consuming.	2.6685	-0.2393	4.023	***
42 It's difficult to keep students interested and motivated.	-10.1521	-6.1954	-8.7557	**

APPENDIX 3: THREE-CLUSTER SOLUTION

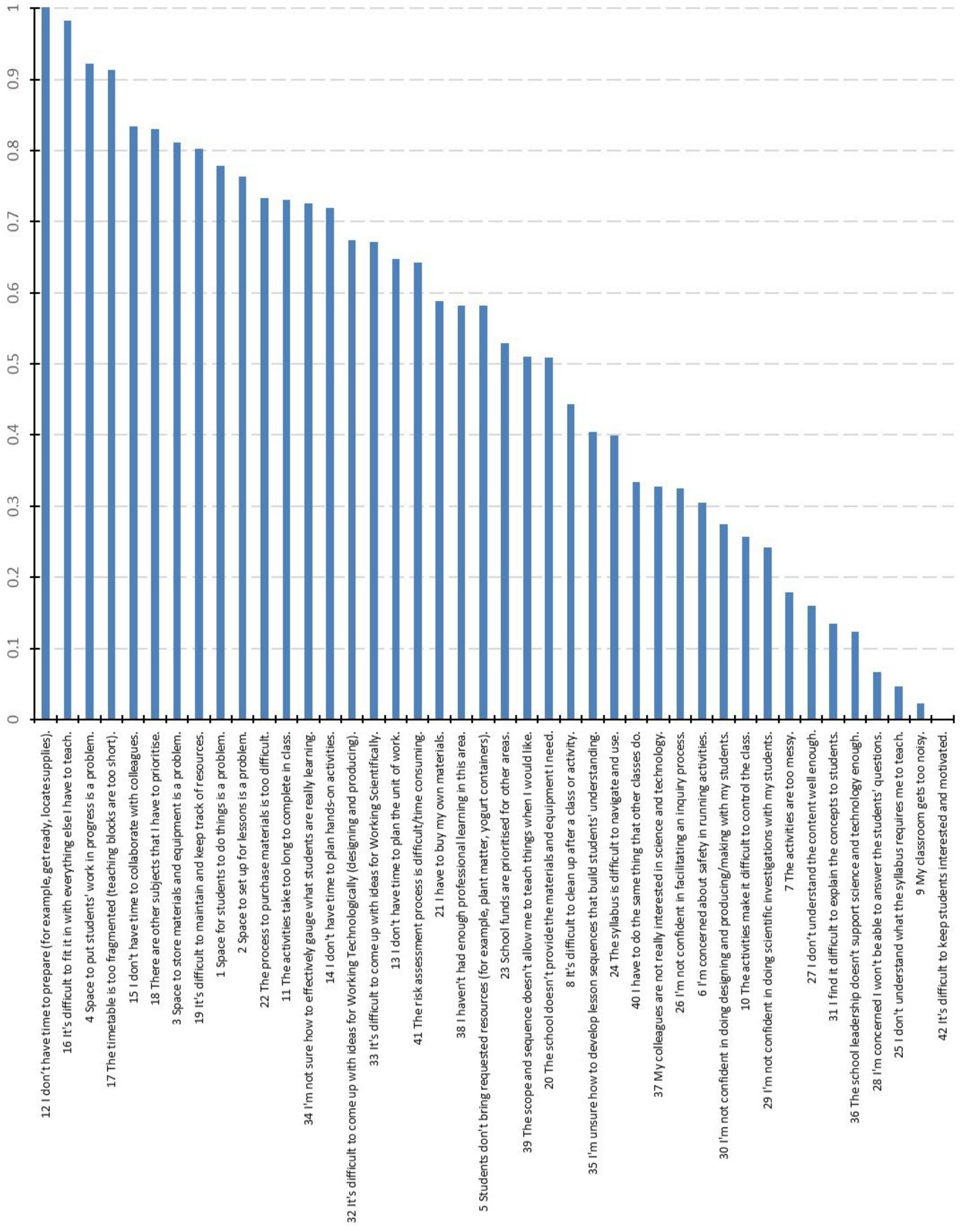
ITEM	AGG	C1	C2	C3	F-Statistics
1 Space for students to do things is a problem.	0.6082	1.255	-0.4064	0.6359	13.411
2 Space to set up for lessons is a problem.	0.5563	1.2859	-0.3924	0.4662	17.196
3 Space to store materials and equipment is a problem.	0.669	1.6872	-0.3341	0.3329	24.574
4 Space to put students' work in progress is a problem.	0.8871	1.5109	0.2731	0.7746	9.958
5 Students don't bring requested resources (for example, plant matter, yogurt containers).	0.1487	0.5443	-0.9328	0.4818	13.054
6 I'm concerned about safety in running activities.	-0.4896	-0.2779	-1.064	-0.4707	3.554
7 The activities are too messy.	-0.7896	-0.8512	-1.5725	-0.3934	7.335
8 It's difficult to clean up after a class or activity.	-0.1428	0.1888	-0.8771	-0.0447	6.648
9 My classroom gets too noisy.	-1.0921	-0.9115	-1.7776	-1.2055	6.653
10 The activities make it difficult to control the class.	-0.5579	-0.4029	-0.9507	-0.605	1.452
11 The activities take too long to complete in class.	0.4912	0.5121	0.3527	0.6886	.441
12 I don’t have time to prepare (for example, get ready, locate supplies).	1.0911	1.3745	1.1441	0.9662	.403
13 I don't have time to plan the unit of work.	0.3142	0.0997	0.4866	0.4994	1.212
14 I don't have time to plan hands-on activities.	0.4902	0.327	1.0375	0.4256	3.039
15 I don't have time to collaborate with colleagues.	0.7291	1.0709	0.6228	0.6807	1.503
16 It's difficult to fit it in with everything else I have to teach.	1.0679	1.4148	0.8793	1.1194	2.091
17 The timetable is too fragmented (teaching blocks are too short).	0.8732	1.5036	0.1027	0.7814	10.447
18 There are other subjects that I have to prioritise.	0.7535	0.947	0.9157	0.6684	0.088
19 It's difficult to maintain and keep track of resources.	0.6483	1.0786	-0.1651	0.8826	9.623
20 The school doesn’t provide the materials and equipment I need.	-0.0056	1.4308	-1.0011	-1.0051	46.767
21 I have to buy my own materials.	0.1609	1.5338	-1.3951	-0.2584	42.101
22 The process to purchase materials is too difficult.	0.5059	1.2439	-0.5427	0.4801	15.369
23 School funds are prioritised for other areas.	0.0521	1.0913	-0.7809	-0.6377	26.915
24 The syllabus is difficult to navigate and use.	-0.2505	-0.8254	-0.0776	0.231	7.379
25 I don't understand what the syllabus requires me to teach.	-1.0314	-1.9978	-0.3192	-0.7209	18.723
26 I'm not confident in facilitating an inquiry process.	-0.4528	-1.7155	1.2862	-0.2607	50.127
27 I don’t understand the content well enough.	-0.7862	-1.9829	0.3429	-0.2318	40.308
28 I'm concerned I won't be able to answer the students' questions.	-1.0006	-1.8212	-0.0481	-0.9476	17.150
29 I'm not confident in doing scientific investigations with my students.	-0.6076	-1.7511	1.3439	-0.6663	62.524
30 I'm not confident in doing designing and producing/making with my students.	-0.5172	-1.5688	1.5174	-0.7165	83.163
31 I find it difficult to explain the concepts to students.	-0.8444	-1.8786	0.8596	-0.9107	52.123
32 It's difficult to come up with ideas for Working Technologically (designing and producing).	0.3893	-0.3417	1.641	0.3949	20.083
33 It's difficult to come up with ideas for Working Scientifically.	0.3141	-0.5788	1.6167	0.4646	26.754
34 I'm not sure how to effectively gauge what students are really learning.	0.4746	-0.293	1.396	0.7394	14.002
35 I'm unsure how to develop lesson sequences that build students' understanding.	-0.2315	-1.216	1.0755	-0.0811	31.661
36 The school leadership doesn't support science and technology enough.	-0.8941	0.001	-1.4638	-1.6604	21.618
37 My colleagues are not really interested in science and technology.	-0.4453	0.3302	-1.0862	-0.9198	14.255
38 I haven't had enough professional learning in this area.	0.1727	-0.7463	1.3791	0.3917	22.449
39 The scope and sequence doesn't allow me to teach things when I would like.	-0.0012	0.0535	-0.2632	0.0366	0.099
40 I have to do the same thing that other classes do.	-0.4271	-0.2514	-1.1758	-0.2134	6.733
41 The risk assessment process is difficult/time consuming.	0.2958	0.4601	-0.4658	0.6852	6.260

Note: Statistics for factor 42 are not identifiable up to 4 decimal places, and therefore not reported.

APPENDIX 4: RANKING AND SCORES OF BARRIERS TO EFFECTIVE PRIMARY SCIENCE AND TECHNOLOGY TEACHING (UNSORTED)



APPENDIX 5: RANKING AND SCORES OF BARRIERS TO EFFECTIVE PRIMARY SCIENCE AND TECHNOLOGY TEACHING (SORTED BY IMPORTANCE)



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