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ARTICLE

Chemistry teaching: Impact of educational research on the practices of chemistry teachers in Singapore

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This paper reports the findings of a study which investigated the role that educational research plays in influencing 29 Singapore pre-university (Grades 11-12) and secondary (Grades 9-10) chemistry teachers' curricular and instructional decision making process. Twenty five teachers were interviewed while four preferred to submit written responses to questions in the interview protocol. The findings indicated that factors which had an impact on the use of educational research by the teachers included those related to the teacher, school, research literature and time. This study can inform the chemistry education research community of the issues that are important to teachers in their teaching of chemistry and use of educational research, and ways of working with teachers to address these issues.

Introduction

Understanding what research is and how, when and why it is used (or not used) by practitioners and policy makers are important to determine the interaction between research, practice and policy, as well as to increase the utilisation and impact of research (Tseng, 2010, 2012). Walter, Nutley, Percy-Smith, McNeish and Frost (2004) state that research "comprise the results from systematic inquiry based on planned research strategies" (p. xii), which may be primary (based on observations or experiment) or secondary (inquiry into primary studies). Research-based knowledge refers to the findings, evidence (findings used to support a position), and theoretical and empirical insights derived from research (Davies and Nutley, 2008). This may form part of the practitioner's or policy maker's knowledge base which also includes other important and competing sources of knowledge such as personal experience and situational knowledge, experience and knowledge of other people, organisational knowledge and policies, media reports, public feedback and student data (Walter *et al.*, 2004; Davies and Nutley, 2008; Nelson *et al.*, 2009; Levin, 2013).

Ratcliffe *et al.* (2004) argue that much of the professional knowledge that teachers have about curriculum and teaching are "seldom formally codified and some of it may be tacit" (p. 2), so it may difficult to articulate the bases of classroom practice to guide or justify the actions of teachers. This tacit knowledge is valuable but not all of it may be correct or appropriate (Levin, 2011). There is also increasing demand on schools and teachers in many countries, for example, in the UK and US (Ratcliffe *et al.*, 2004; Nelson *et al.*, 2009) to show

evidence that their programmes are sound and are able to help students to achieve the required educational standards. As in other professions such as the medical and engineering professions where research plays an important part in informing practice, educational research can supply evidence to support, question or challenge assumptions, policies, programmes and practices, as well as generating new knowledge to guide present and future educational initiatives and endeavours (British Educational Research Association, 2013).

Davies and Nutley (2008) categorise research use into tactical, instrumental, conceptual, and process uses. They describe tactical use as the use of research to provide backing for political agendas and positions, or to win arguments or support for proposed courses of action. The use of research to solve a particular problem or make a particular decision is an instrumental use of research while conceptual use of research focusses on the indirect influences of research such as changing ways of thinking and doing, or creating new awareness and understandings. When a person engages in the process of research, he or she may gain new perspectives and understandings which can influence his or her thinking, behaviour and action (Ratcliffe *et al.*, 2004); this process use of research has conceptual elements in it, as well as instrumental or tactical element if the research involves addressing specific problems or provides evidence to support a particular position or policy, respectively. Thus, different research uses can overlap.

Singapore has a centralised educational system with a national curriculum and national examinations at the end of Grades 6, 10 and 12. However, teachers have the freedom to choose the instructional material and approaches to teach the

learning objectives listed in the subject syllabuses; they are encouraged to consider the interest and ability of their students as well as use a variety of teaching approaches rather than to follow the syllabus too strictly (Ministry of Education, 2012a). Instructional approaches suggested to teachers include case study, concept cartoon and mapping, demonstrations, games, field trip, problem solving and model building (Ministry of Education, 2012a). Teachers are also encouraged to collaborate in lesson study or action research to improve teaching and learning in schools (Ministry of Education, 2012b), and research findings are an important resource for teachers in the planning and implementation of their lesson study or action research.

Impact of research on practice and policy

In general, researchers want their work to have significant impact on educational practice and policy (Millar *et al.*, 2006; Nelson *et al.*, 2009), and one of the aims of science education research is to produce insights into improving the teaching and learning of science in schools (Treagust, 1995). Research can challenge ineffective practices and suggest ways of addressing them, support effective instructional efforts and evaluate innovations to be implemented in the classroom (Millar *et al.*, 2006). Unfortunately, research seems to have little influence on practice and policy (Gilbert *et al.*, 2002; Nutley *et al.*, 2002; Davies and Nutley, 2008; Nelson *et al.*, 2009; Levin, 2013); researchers have lamented that teachers continue to teach in the science classroom as if no research has been done into the teaching and learning of their subjects (Taber, 2001) but they acknowledge that teachers are generally unaware of relevant work available and that few researchers are willing to translate research findings into resources which teachers can easily understand and use in class (Liu, 2001; Taber, 2001; Millar and Hames, 2003).

However, teachers and policy makers have pointed out that they had difficulty finding research that is relevant and practical for their immediate needs/areas of concern, reading, interpreting and applying educational research (Nutley *et al.*, 2002; Edwards *et al.*, 2007; Tseng, 2008; Nelson *et al.*, 2009; Levin, 2013). The use of diverse approaches, the gaps in the research literature and/or the ambiguous findings are also disconcerting to them (Nutley *et al.*, 2002; Levin, 2013). Still, it has to be noted that it is often difficult to determine the influence of research on policy and practice (Levin, 2013), especially the conceptual use of research which impacts one's thinking and beliefs, and if research use is embedded in policy documents, curricular material and instructional approaches without explicit reference to the research which informed them (Walter *et al.*, 2004); there may be little awareness that research is actually used in these cases.

Changing current practices in response to research

The classical perspective of conceptual change (Posner *et al.*, 1982) can be adapted and used to describe the conditions under which research may have an impact on practice (Tan and Kim, 2012). Posner and colleagues proposed that a person is more willing to change his/her conceptions if he/she dissatisfied with his/her current conceptions and finds that the new knowledge is intelligible, plausible and fruitful. In Table 1, we draw correlations between the conditions necessary for conceptual change and conditions that may affect the impact of research on

practice. We propose the modification of 'dissatisfaction' to 'impetus to change' to include making changes in response to the external environment in addition to the practitioner or policy maker being dissatisfied with the current situation. Accessibility includes physical access to research addition to being able to read and understand research (cognitive access/intelligibility), so the term 'accessibility' is preferred to 'intelligibility'. The term, 'feasibility' replaces 'fruitfulness' because teachers need to assess if the suggestions or findings from research are worth implementing before they proceed with them.

Table 1 Adaptation of the conditions for conceptual change to describe the conditions under which research may have an impact on practice

Conditions for conceptual change (Posner <i>et al.</i> , 1982)	Adaptations to to describe the conditions under which research may have an impact on practice
<i>Dissatisfaction</i> Personal dissatisfaction with existing conceptions	<i>Impetus to change</i> Includes personal dissatisfaction with current situations and practices as well as external demands (e.g. societal changes, educational policy changes) to change
<i>Intelligibility</i> Ability to understand new conceptions	<i>Accessibility</i> Includes physical access to research (ability to retrieve research reports) and cognitive access to research (intelligibility of the reports to teachers and policy makers)
<i>Plausibility</i> Belief that the new conceptions are consistent with other knowledge and are capable of solving problems	<i>Plausibility</i> Belief that the research environment and the local context are similar, that the research is credible as well as relevant to the cultures, experiences, concerns and priorities of teachers or policy maker, and that the research can be applied to solve problems
<i>Fruitfulness</i> Potential of the new conception to be extended to other situations	<i>Feasibility</i> Whether research can be incorporated into current practices/situations with the available resources and expertise, and whether it is worth the time and effort in doing so

Impetus to change. One of the conditions necessary to initiate conceptual change is the dissatisfaction with the current situations, ways of doing things, ideas or understandings (Posner *et al.*, 1982). If current policies or practices are deemed to be effective, for example, if teachers find that students are still achieving good examination results and/or lessons are still engaging to them, then there will be very little motivation for teachers to make any change based on research (St.Clair, 2004). Apart from dissatisfaction with the current situation and practices, changes and innovations in society can also create an impetus for teachers to adopt new practices. For example, economic restructuring, increasing globalisation or rapid developments in technology can create new demands, cultures, behaviours and/or knowledge; in education, these give rise to changes in the profiles of students and teachers, expectations of education, classroom environments, and roles and functions of schools (Duze, 2012). Duze argues that to meet the changing needs of students and the demands of parents, school administrators and other stakeholders, teachers need to be involved in continuous professional development to

acquire the necessary competencies to fulfil their evolving roles. Involvement in research or reading and applying research findings can be part of this professional development for teachers to gain new insights and knowledge to update or rejuvenate their classroom practices, as well as expand their capabilities.

Accessibility. Before a user can read a research report, he or she must be able to obtain the report. Accessibility includes being able to retrieve research papers, in addition to being able to read and understand them. Studies (e.g. Ratcliffe *et al.*, 2004; Walter *et al.*, 2004; Nelson *et al.*, 2009) have shown that research reports are difficult for practitioners and policy makers to locate and retrieve because they may not be aware of the existence of relevant reports, lack the skills and confidence in searching for them, and may not have access to journals and other repository of research. Even if the reports have been retrieved, Nelson and colleagues (2009) reported that the teachers and policy makers in their study complained that research reports were too long and written in a manner difficult to comprehend. Thus, the accessibility of research, physical and cognitive, does affect the exposure of teachers and policy makers to research, and hence, the impact of research on practice and policy making.

Plausibility. The perceived differences between the research environment and the local context, and the relevance of the research to the cultures, experiences, concerns and priorities of practitioner or policy maker are important factors which determine whether the research findings will be considered by the practitioner or policy maker (Ratcliffe *et al.*, 2004; St.Clair, 2004; Davies *et al.*, 2008; Nelson *et al.*, 2009). As judgement on what can work is “largely provisional and highly context dependent” (Nutley *et al.*, 2002, p. 3), the lack of contextual information, as well as knowledge claims which are too general, will create difficulties for the practitioner or policy maker to judge if the research is relevant to his/her situation (Ratcliffe *et al.*, 2004). Research has also been criticised for identifying problems but doing little to develop and evaluate solutions to these problems (Gilbert *et al.*, 2002; Ratcliffe *et al.*, 2004; Millar *et al.*, 2006; Millar and Osborne, 2009). Conflicting research findings create additional problems and may lead to the perception that research is not trustworthy and of little use (Nelson *et al.*, 2009); St.Clair (2004) reported that the instructors and administrators in his study rated credibility of the research highest in assessing the value of the research that they read, the second and third ranking factors being relevance of the research and similarity of context of the research to their local contexts.

Feasibility. If the practitioner or policy maker is convinced that the research findings are valuable, sound and may apply to his/her local context, he/she still needs to figure out how to incorporate the research findings into his/her current practices and whether it is worth the time and effort in doing so (Ratcliffe *et al.*, 2004). Ratcliffe and colleagues argue that “there is a significant gulf between being aware of, or knowledgeable about research and acting on its implications” (p. 37); to increase the likelihood of research use, the practitioner or policy maker needs to be given the resources, guidelines and training to enable him/her to apply the research findings to his/her context. They also believe that “research will only lead to a change in practice when the new practice can be readily

assimilated into existing practice rather than demanding substantial change” (p. 53).

The worlds of research and practice/policy making. To the policymaker and practitioner, educational research may seem to be “preoccupied with arcane theoretical debates than making a difference in the classroom or decision-making forums” (Baker *et al.*, 2007, p. 794). However, it has to be noted that researchers and policy makers/practitioners have “different priorities, use different languages, operate to different time-scales and are subjected to very different reward systems” (Nutley, 2003, p. 12), so there is a need to bridge the gap between the two different worlds such that researchers can be guided to produce useful work which can inform policy and practice, as well as to disseminate findings effectively, and policy makers/practitioners can be educated to understand research processes and make better use of research findings (Walter *et al.*, 2004; Baker *et al.*, 2007; Edwards *et al.*, 2007; Tseng, 2010).

Purpose of the study

The aim of this study is to investigate the impact of educational research on the practices of chemistry teachers in Singapore. The research question which guided the study is:

- What are the factors influencing chemistry teachers’ use of educational research in their curricular and instructional decision-making?

Method

A survey study (Gall *et al.*, 2007) was utilised to obtain information on the impact of educational research on Singapore chemistry teachers’ curricular and instructional decisions in the teaching and learning of the subject. Semi-structured interviews were employed because they allowed the first-named researcher to collect specific data in response to the questions in the interview protocol, and yet provided him the leeway to clarify his understanding of the interviewee’s responses or probe the interviewee’s ideas in as much detail as desired (Taber, 1998) through the use of additional questions. In cases where the teacher had consented to participate in the study but did not wish to be interviewed, he/she would answer the questions in the interview protocol as if he/she were answering an open-ended survey questionnaire and email his/her responses to the researcher. If the researcher did not understand the teacher’s written responses or had queries about them, he would email his questions to the teacher and an iterative communication process, similar to that in the interviews, would begin and continue until the researcher had no further question for the teacher. The data collected were coded, collated under various themes and the frequencies of occurrences were tallied.

Sample selection

A combination of criterion-based, convenience and network sampling (Merriam, 2009) was used to select the teachers for the study. The researchers wanted in the sample, teachers with different years of teaching experience, and only one teacher per school to ensure that teachers with different school experiences were involved. With the criteria in mind, the first-named researcher approached a number of teachers who had attended courses in his institution to invite them to participate in the

study; it was difficult to get consent from teachers to participate in the study if they did not know the researcher personally. As the first-named researcher had difficulty locating more senior and experienced teachers, he sought the help of the teachers whom he had contacted earlier to recommend relevant teachers for him to contact. By the end of this phase of the research, a total of 29 teachers (Teachers T6 to T34) had agreed to participate in the study and they comprised 18 (62%) female teachers and 11 male teachers (38%) (see Appendix). These percentages are similar to that of the secondary and pre-university female (65%) and male teachers (35%) in the national school system (Ministry of Education, 2013a). At the point of data collection, except three participants, all were teaching in secondary (Grades 7 to 10), pre-university (Grades 11 and 12) or integrated programme (Grades 7 to 12) schools. Two teachers were attached to the Ministry of Education and one was attached to a teacher education institution.

Collecting data through interviews

The interview protocols were developed in two phases. The questions in the first interview protocol were adapted mainly from the interview guides used by Ratcliffe *et al.*, (2004) and Nelson *et al.*, (2009). Five teachers were approached in April to May 2011 to participate in a pilot study; four agreed to be interviewed while one preferred to send his responses through email. The interview questions were revised based on the data collected to produce the final version of the interview protocol. Examples of the questions relevant to this paper can be found in Figure 1. In the second phase, 25 teachers were interviewed and four teachers preferred to submit written responses to the researcher through email.

1. What are the factors that encouraged you to change your chemistry curriculum or scheme of work, or the way you teach chemistry?
2. What do you consider educational research?
3. Do you use educational research to decide on the science curriculum or how you would teach a particular topic in science?
4. What could be done to make research information more useful to you in decision making? Why?

Fig. 1 Questions in the finalised interview protocol which are relevant to this paper.

Data analysis

All interviews were audio-recorded with the permission of the teachers and transcribed verbatim. The interview and written data were analysed to identify recurring “themes supported by the data from which they were derived” (Merriam, 2009, p. 23). Findings from previous studies (e.g., Ratcliffe *et al.*, 2004; Nelson *et al.*, 2009) suggested several useful themes to code and interpret the data. Other themes were derived through open coding in the pilot and main studies. As the analysis of the interview transcripts and written responses progressed, analytical coding was utilized to combine similar codes while others were further subdivided or elaborated where necessary. Previously analysed data were revisited and recoded where applicable. Finally, inferences on the influence of educational research on the chemistry teachers’ instructional and curricular practices were made based on the analysis of the data. Member checks (Merriam, 2009) were conducted at the end of the study to obtain feedback from the teachers on the first-named researcher’s interpretation of their responses to the interview

questions. Clarification that the researcher required of the teachers was also included in the documents. In general, the teachers would respond to the researcher’s requests for clarification but very few commented on the inferences that the researcher made on their responses to each question other than to indicate that they agreed with the researcher’s interpretation of their responses for the whole document.

Results

As the number of teachers involved in the study was small, the responses of the teachers to the interview questions were collated and analysed as a whole group. Excerpts of the interviews used to illustrate the findings were lightly edited, where necessary, to improve their readability. Only factors mentioned by 3 (10%) or more teachers are highlighted.

Factors influencing chemistry teachers’ use of educational research in their curricular and instructional decision-making

The teachers were asked what educational research was to obtain their views on it, as well as for the researcher to clarify the teachers’ understanding, if necessary, so that they could answer the subsequent questions on the impact of research on their practice with the appropriate understanding of research. Teachers also were asked if they used educational research to make curricular or instructional decisions. If they did not use educational research, then they were asked to give their reasons for not doing so. Twenty seven teachers indicated that they had used educational research to some extent while two mentioned that they did not use educational research in their practice.

What is educational research? The majority of the teachers mentioned that educational research comprised studies on teaching and learning, and on educational leadership (see Table 2).

Table 2 What is educational research?

	Studies on teaching and learning	Studies on educational leadership	Description of research
No of teachers	20	3	8

Teacher T6 considered educational research to be “(t)hose that explore the affordances and/or integration of new pedagogies”, “(t)hose of which the findings sheds light on how people learn/process information” and “help to improve on assessments”. Several teachers, however, described the process of research when asked what educational research meant to them. Teacher T24 wrote that education research was “any form of investigation that requires teacher or teachers to read up literature, formulating a series of actions, carrying out the plan, collecting and analyzing data, interpreting data and reflection to find out if the plan works”.

Impetus to change and the use of educational research. Important impetuses for teachers to change their existing practices and possibly to use educational research to guide the process of change include their concern over students’ understanding of concepts taught, responding to school

directions, and implementing initiatives by Ministry of Education (see Table 3).

Table 3 Impetus to change			
	Student understanding of concepts	School directions	Ministry initiatives
No of teachers	14	10	11

Students understanding of concepts. Teachers will tend to explore alternative ways of teaching if they are concerned over their students understanding of the concepts taught. Teacher T21 stated that he regularly reflected on his teaching and how he could deepen his students understanding of the concepts by using different pedagogy:

T21 ...after my lessons I go back to my office and reflect, is there a better way to teach it, is there a better pedagogy, a better way or a better method through which I can teach that concept better so that they will understand better...so we also think about knowledge retention, so...which kind of...learning will actually have a higher knowledge retention at the end of the day...is it inquiry based learning, guided inquiry, ICT method, or just normal textbook teaching, so all these factors are actually very important to actually cause me to come out of my comfort zone to change.

School directions. The directions or goals of the school also influence changes in curriculum and instruction as teachers have respond to or work with these directions or goals in mind as explained by Teacher T22:

T22 Perhaps the direction from the management...like...what they want to emphasize on...then you will tend to...gear...not really geared but you tend to put in things or activities that...will allow students to move in that direction, like for example... inquiry learning is one... here...in the lower levels...the school wants the students go through the inquiry process...then subconsciously when you plan your activities, you will think in terms of that direction...so it's...also a direction set by the school...

Ministry initiatives. Similar to school directions, teachers also need to heed the directions of the Ministry of Education. One of the recent initiatives of the Ministry of Education is to enhance students' "life-ready competencies like creativity, innovation, cross-cultural understanding and resilience" (Ministry of Education, 2010). Thus, Teacher T12 explained that teachers "need to move...with the direction that the MOE has set".

T12 I think...it would be like trying to make learning meaningful for the students...or teach them skills that will help them...what do you call...take them into the twenty-first century...and I find that as a teacher, I need to move...with the direction that the MOE has set ...and I also see that... we...are past a stage where we...are textbook bound...we must go beyond that...so I feel that in a lot of ways, I need to change the way I teach...although there is a need to do a lot of content for the exam but it would also be nice to be able to enrich the students...so that they are able to connect what they have learnt and find meaning and a bigger purpose in the world they are living in.

The use of ICT is also strongly encouraged by the Ministry of Education (Ministry of Education, 2008) and this is reflected in the response of Teacher T13.

T13 ...we have to think of ways to incorporate ICT into our lessons...like I think for chemistry... common ones will be like using data loggers...but then again data loggers can only be used for certain topics and things...so how does it affect my way of teaching...to me it does affect, because of these initiative, right, that means I have to put in more effort to...as in not putting in more effort but I'd have to find out what are the suitable ICT tools or some structures that I can use to...incorporate into my lesson.

Thus, students' understanding of concepts taught, directions of the school and ministry initiatives provide the impetuses to change and research can be used to guide the change. As discussed in an earlier section, the use of research can be tactical (to win arguments or support), instrumental (to solve specific problems), conceptual (to gain new understandings and ways of thinking), and involvement in research can help a person to gain new perspectives and understandings of research and its processes. As the focus of the study was on the impact of research of teachers' practice, the teachers were asked whether they used educational research to inform their teaching and curricular decisions, and if so, to elaborate on its use, the responses of teachers indicated that the conceptual use of research was more prevalent than its instrumental or process use (see Table 4). However, it has to be admitted that it is not easy at times to differentiate between the instrumental and conceptual uses of research, and the process use of research will very likely have conceptual as well as instrumental elements.

Table 4 Use of education research				
	Instrumental	Conceptual	Process	Tactical
No of teachers	18	16	10	3

Instrumental use. The instrumental use of research is illustrated by the excerpt of interview with Teacher T25 who had to read up on inquiry-based learning to identify frameworks and tools which could be used to facilitate inquiry in class:

T25 ...usually we try to see whether something has been done first...for example we try embark on a science inquiry curriculum because there was the belief that...inquiry will help students to become more independent learners and it will also...it's also more in line with the spirit of science, so before we embark on this curriculum, we actually had to do a lot of reading up on what is inquiry, what are the frameworks or models of inquiry that are available, which is the one that best suits our needs, and then...what are the...some of the tools, that you can use to try and facilitate inquiry.

Conceptual use. The conceptual impact of research is illustrated by Teacher T7 who mentioned that he consulted "educational research for alternative conceptions, common issues, different modes/ways of teaching that topic", Teacher T8 who wrote that exposure to educational research enabled him to be more aware of "the various factors that would promote learning" and Teacher T16 who said that his postgraduate studies gave "a different perspective of how we sometimes teach students, and a better understanding of why misconceptions arise".

Process use. Participation in research projects, be they action research, lesson study or collaboration with university researchers expose teachers to educational research and its impact on teaching and learning. When one participates in research, one will most likely use some material/instructional strategy or ideas associated with the research to address issues in teaching and learning, and the experience may change one's way of thinking about teaching and learning; this leads to instrumental and conceptual use of research. Thus, all three uses, process, instrumental and conceptual, can come into play. This is illustrated in the excerpt of interview with Teacher T13:

T13 ...so I think two years ago we are having this action research on using cooperative learning...so, at that point of time, my students are actually one of the experimental group...so I need to carry out cooperative learning on my students... and through this process I realized that my students actually enjoy it and they're more engaged...so through this research I realized that cooperative learning is actually quite useful...in a way, to get things done faster and to allow my students to actually interact with each other and learn from each other, and they're more engaged as well.

Tactical use. The tactical use of research was evident in the statement given by Teacher T14 that she carried out action research on "POE (predict-observe-explain) and mind maps to enhance the learning of science concepts" and the "the data collected, from achievement test, student survey and reflection" helped her "to convince other science teachers in the department to change their approach towards teaching and learning".

Why educational research is not used. As mentioned in an earlier section, two teachers stated that they did not use educational research to inform their practice. In addition, several teachers who mentioned that they had used educational research to some extent indicated that there are many occasions when they did not use educational research to guide them in their work. The responses that the teachers gave for not using educational research could be categorised into factors related to research literature and time. Factors related to research literature included the lack of access to, awareness and understanding of research in addition to the difference between the context of the research and that of their schools (see Table 5).

Table 5 Factors related to the research literature used to explain why education research is not used

	Access to research	Awareness of research	Understanding of research	Different contexts
No of teachers	3	4	3	5

Research literature. Teachers T6 and T12 mentioned that they and their schools did not subscribe to education journals, hence they did not have physical access to the journal papers. Awareness of relevant research literature is also a problem as well as understanding research reports because of the way they are written. These are illustrated by the following excerpts of interviews.

T6 ...it's more the awareness...implementation issue is of course another important factor...but awareness of such thing...are available...are out there...is very important

because teachers...I mean the thing is that no time...no time to go...and browse journals or even read those reports...

T15 I suppose, like for most laymen they won't understand the research jargon, and...even though it's like, you know when I was doing my assignment last time when I was a masters student, I had to read like three four times to really comprehend certain articles, so it's really not easy.

T30 ...the language and terminologies used were not easy to understand, so it was hard to process the information and use it accordingly...

Different contexts. The relevance of the research context to the teachers' contexts is also an important factor in determining if teachers will implement suggestions from research as they need to assess if these suggestions will have any impact on their classes. This was mentioned by Teachers T6 and T20:

T6 ...we still have to...qualify...all these...most of these studies...are done overseas...so the kind of environment can be quite different from ours so...something may work out over there...may not have that much impact over here...

T20 ...and what work for others may not work for your students, so...you really have to know your students well and see what you can do to help them, and if it...serves them, then, that's good...whatever the research says may or may not work for your students...I think we have to...take it...in a way where we can evaluate whether it would be meaningful to our students or not...there's no point looking at a research paper and just...you know copy it and adopt it and...transfer it completely to your context but... because it may not work...

Time. In addition to the physical and cognitive accessibility, and the plausibility of research, the teachers also indicated that they had little time to read educational research or implement suggestions from research in their classes (see Table 6).

Table 6 Factors related to time used to explain why education research is not used

	Time to read	Time to translate research
No of teachers	4	4

Teacher T6 said that "the most important thing about research is that people no time to read, teachers...really have no time in school to read" while Teacher T10 stated that time should be allocated for teachers to work on and make use of suggestions from research as she believed "there is some value" in research:

T10 ...I think if there is some time allocated...for teachers to actually spend time working on it...we are better able to make use of what has been researched and try to use it in our school...actually I...I believe that it can be...used in the school, adapted for school use...it's just that although a lot of us may think that what is done as research is research, what we do in real life is not the case, but I do believe that there is some value in the...research that is...whatever that is found actually we can try out in our classes...and if we

are given that kind of leeway to try out and it's part of our professional development, I think this is really good...

Research topics valued by teachers

There is a need to know what research topics are valued by teachers and how to make research information useful to teachers in order to encourage them to refer to it to inform their practice. Twenty-six teachers mentioned that they were attracted to research on how to teach more effectively and how to help students learn more meaningfully. For example, Teacher T21 stated that knowledge of student alternative conceptions helped teachers to improve their teaching by being aware of what to highlight and what to avoid so that alternative conceptions did not arise. Research on the use of information and communication technology (ICT) and on formative assessment were also highlighted as useful for facilitating student learning; these are also initiatives by the Ministry of Education to improve teaching and learning in schools (Ministry of Education, 2008; 2013b).

What could be done to make research information useful to teachers

The teachers' responses to the question of how to make research information more useful to them can be categorised into making research more accessible and assessing the feasibility of research.

Making research more accessible to teachers. To make research more accessible, the teachers suggested that (a) more intelligible language should be used; (b) less statistics should be employed; (c) research summaries should be produced; (d) awareness of research should be raised; (e) physical access to research should be improved (see Table 7).

More intelligible language. Five teachers complained that the language used in educational research papers was difficult to read and understand. Teacher T6 stated that "most of the research paper is for academic consumption" so teachers find research papers difficult to understand and Teacher T23 mentioned that she lost interest and gave up reading after a while:

T23 Sometimes it's trying to...to interpret...the interpretation part I think tires you out...you know...along the way, so you just give up.

Less statistics. The statistics present in educational research papers poses problems to teachers as they generally do not understand them. Teacher T6 commented that most teachers would not be able to make sense of the statistics and analyses given in the papers. Teacher T10 gave a similar response:

T10 "statistical analysis I think I can do away without it...because it... because it doesn't make a lot of sense to me unless...you know you're really into the...research then I think...maybe that's important"

Research summaries. As mentioned earlier, teachers generally found research papers difficult to read and understand because of the language and statistics used in the papers.

Teacher T12 argued that the gap between researchers and teachers needed to be bridged in order to make research useful to teachers:

T12 ...I think one of the big gaps between researchers and teachers is that...teachers are more interested in...ok when I read this how do I apply to my classroom...so the researcher has to learn how to bridge the gap by being able to simplify their papers...or put themselves in the position of teachers...if I am a teacher reading this, how do I make sense of what you're doing and how do I then be able to use it in my classroom.

Producing research summaries which were shorter and more relevant to teachers would be helpful as Teacher T25 explained:

T25 ...I think having summaries, which are more to the point, which actually...because I think journal articles, for...the benefit of people who really want to find out more, it will give more of the introduction to the topic, what...research has been done previously and so on, which is good...but for teachers, they...will tend to gloss over all these parts, so just go straight to the point...what does this study aim to address...what...very briefly how it was conducted, what are the results and what's the conclusion...I think it's more to the point, so teachers can actually read through in a shorter period of time...

Teacher T9 liked the idea of research summaries because "it's something that can be used very quickly" and "it also means it's something that I can understand without having to...spend hours deciphering what's being written".

Raising awareness. Teachers need to be aware of available research which is relevant to their needs in order for research to be of use to them; Teacher T21 lamented that teachers "don't know the kind of...information that's out there in the first place" and Teacher T30 stated that it was not in the culture of teachers to look for readings and research papers unless they were doing action research or postgraduate studies. Teacher T12 admitted that she was ignorant on where she could find the relevant research and required guidance in this aspect. Teacher T19 suggested that the availability of research papers on issues of interest to teachers should be communicated to all teachers through circulars or emails from the Ministry of Education. She also recommended that "a channel of communication be established where feedback can be given by more experienced teachers or those who have implemented the ideas/resources" to "facilitate the cycle of conception of ideas, implementation, feedback and so forth".

Physical access. Teacher T13 wished that research information would be more easily available to teachers. Teacher T11 said that when teachers searched on the internet for resources for teaching, "we actually come up with a lot of journal articles, but whether we have access to that or not, that's another problem". Teacher T21 mentioned that after his studies in a teacher education institution, he no longer had access to the institution's online journal service, so research literature "is hardly accessible". Teacher T16 and T20 also complained about the high cost of subscription to journals and purchasing papers online.

Table 7 Making research more accessible to teachers

	More intelligible language	Less statistics	Produce research summaries	Awareness of research	Physical access to research
No of teachers	5	8	10	11	11

Making research more plausible and feasible. Teachers need to assess the plausibility and feasibility of research in order to decide if it is useful to them and worth implementing in their classes. Thus they need to know the context of the research and practical details as well as discuss these with colleagues before making decisions on its plausibility and feasibility (see Table 8).

Table 8 Assessing the plausibility and feasibility of research

	Context of the research	Need for practical details	Discussions with colleagues
No of teachers	10	6	6

Context of the research. The importance of the describing the context of the research is highlighted by the excerpt of the interview with Teacher T28 below:

T28 I think when...when the, research is quite close to the scenario in the classroom... like for example difficulties of students understanding mole concept...so when I see that kind of parallels...then I guess probably I should do it...if I see similarities between the research and my own practice.

Teacher T32 believed that research done in the local context would create more buy-in from teachers than research done overseas because the contexts of research done in Singapore and their school contexts would be quite similar.

Practical details. Several teachers highlighted that researchers did not explicitly describe what was done during the research and Teacher T6 stated that because of the lack of information, “you have no idea how to carry out yourself, unless you go and clarify with the researcher”. Teacher 26 stated that researchers should translate the implications of the research into activities that the teacher could carry out in class without too much difficulty. Teacher T21 wished that research papers could include lesson plans which took into account the time allocated for a normal lesson so that the activities suggested could be realistically implemented in the classroom.

Discussion with colleagues. Having colleagues to discuss research and its implementation in class is important for teachers. This is illustrated by the excerpts of interviews with Teachers T10 and T20.

T10 ...maybe there should be a group of teachers to help and work this out...and how to bring something like...high level to be used in school...because many times I hear people telling me...oh that is a very ideal situation, it may not be the case in a real situation...but now with PLC [Professional Learning Communities] I realise that there are opportunities to explore...and I think it's quite interesting...to explore all these...

T20 ...another one is...it's good to have a group of...people with similar interests together, so they can talk about it, because I think at the moment or so...you don't have this culture of, you know, professional discourse, talk

about...whether you talk about differentiated learning in chemistry, how you can do it, you talk about misconceptions in chemistry, what can be done to help students learn...it's very much lacking...many reasons why it is lacking...but...it is good I think if we have this...platforms to discuss...

Discussion

The data showed that many of the teachers considered educational research to be studies on teaching and learning, and they also indicated that such research was useful to them. Such research can address the impetus to change – their concerns over students' understanding of the concepts and the demands of the school and ministry initiatives, for example, to use ICT and formative assessment to facilitate student learning. The teachers' use of research in response to the various impetuses were mainly instrumental and conceptual, with research providing them with tools to use in classroom teaching or greater awareness and better understanding of the processes involved in teaching and learning. However, there was one explicit instance of the tactical use of research where Teacher T14 used the data from her action research to convince her colleagues to change their practices.

Educational research has to be accessible to teachers in terms of awareness of relevant research, access to papers and comprehensibility of the papers. As mentioned by Nelson and colleagues (2009), the lack of awareness of the existence of relevant papers prevents teachers from using education research. In addition, very few schools and teachers, if any, subscribe to science education journals, and both schools and teachers balk at the cost of purchasing papers online. Therefore, teachers' physical access to educational research is limited even if they manage to identify relevant research papers. Another hurdle for them when they manage to obtain research papers is the difficulty in understanding the papers because of the language used and the prevalence of technical terms and statistics. Ratcliffe *et al.* (2004) also found that teachers do not read research papers because of the lack of practical access to the papers and the difficulties in reading the papers. Teacher T12 wants researchers to put “themselves in the position of teachers” so that they can see the need to simplify their papers and consider how teachers can make sense of and apply the research in their classrooms. Putting research summaries or “distilled accounts of up to date research outcomes to be disseminated to schools, in a form that is quick to digest” (Ratcliffe *et al.*, 2004, p. 32) can help make research “more available, relevant, and useful” (Nelson *et al.*, 2009, p. 1) for teachers.

In Singapore, one way to make research summaries more easily accessible to teachers working in national schools is to upload them on an internet portal such as OPAL, the learning and content management system of the Ministry of Education, which is designed to promote the professional development of teachers (Academic of Singapore Teachers, 2012a); all teachers in national schools have free access to the portal and its

contents, and some form of tracking is possible to guide the administrators on teachers' preferences for research material and social interaction. As previously mentioned, research summaries would be easier to read and understand, so teachers should take less time to extract relevant information or judge if the research is plausible and feasible to implement. The research summaries can also act as a filter or the first step for teachers to select relevant full papers if they want to know more details about the research (Bell *et al.*, 2004). However, Ratcliffe *et al.* (2004) and Millar *et al.* (2006) caution that awareness of research does not necessarily lead to significant changes in practices as the challenge is in adapting and using research findings "in a practical and effective manner in the classroom" (Ratcliffe *et al.*, 2004, p. 24).

One of the things that a teacher will scrutinise in a research paper is the context of the research to determine its plausibility to his/her situation, so authors need to supply the relevant information pertaining to the educational systems, schools, teachers and students involved in order to extend the reach of the research to other educational situations. Ratcliffe *et al.* (2004) also stated that without adequate description of the research context, "many potential users are unlikely to be persuaded of the relevance of the findings to their own contexts" (p. 51). In addition, there is a need for researchers to explicitly describe what they do during the research, and the resources and time required so that teachers can have a sense of how the research or the intervention is implemented in order to evaluate its feasibility in their schools; they need to work within the constraints of the resources they have in school, the curriculum time given for a particular subject or topic and the duration of a normal teaching period. This means that the clear translation of research into practical actions by researchers is important (Bell *et al.*, 2004; Millar *et al.*, 2006) and such details should be made available to readers upon request if they are not given in the reports. The teachers indicated that they would most likely have to modify the suggestions from research because of the different local situations and needs, so "fidelity and faithful replication of the evidence-based programme or tool in the process of implementation" (Nutley *et al.*, 2009, p. 553) outside the research site is going to be an issue. In this respect, design experiment research would be very useful for teachers as the details of classroom context, the instructional material and strategies used and the recommended interactions during lessons would be described in the research paper. Such research would also explain why the "designs work and suggest how they may be adapted to new circumstances" (Cobb *et al.*, 2003).

The Ministry of Education places great importance in the profession development of teachers as they are the "heart of quality education" and encourages the development of Professional Learning Communities (PLCs) within schools and across schools to help them hone their professional practices (Ministry of Education, 2009). These PLCs provide teachers the platforms to engage in lesson studies or action research, inquiring together, learning from, and supporting, each other to improve teaching and learning in their classrooms (Ministry of Education, 2012b). The impact of PLCs was evident when six teachers stated that working in groups and having colleagues to discuss the implications of research and share ideas was important for them to decide on the feasibility of implementing research suggestions in the school. This also highlights the value of that teachers place on the opinions of, and endorsement by, colleagues (Ratcliffe *et al.*, 2004; Tseng,

2010) as well as the importance of social processes in influencing research interpretation and use (Tseng, 2008).

All chemistry teachers in national schools are members of the Chemistry Subject Chapter of the Academy of Singapore Teachers. The subject chapter is helmed by Chemistry Master Teachers from the academy, senior school teachers and teacher educators. Subject chapters have been set up by the MOE to grow communities of practice across schools to learn the best practices of schools throughout Singapore to raise the standards of teaching and learning of the subject (Academy of Singapore Teachers, 2012b). The Master Teachers, senior teachers and teacher educators involved are respected for their professional expertise, so they can be important intermediaries in recommending relevant research, facilitating "productive discussion of research evidence" (Ratcliffe *et al.*, 2004, p. 36), and working with teachers to translate research for use in the local context (Nelson *et al.*, 2009). Practice can also inform research as the teacher educators and researchers can take up issues raised during discussions and encountered in implementing research ideas in different schools (Tseng, 2012) and address these issues in their current or future research endeavours.

Limitations

The small sample size of the teachers involved in the study and the non-random sampling of teachers are limitations to the study. Thus, the data obtained are not representative of the chemistry teachers in Singapore schools. The findings of the study are also limited by the nature of the data collected as there was no substantiation of the information given by the teachers, for example, through document analysis and direct observations (Nelson *et al.*, 2009).

Conclusions

The views of Singapore chemistry teachers of research informing their practice have been described in the paper. In general, teachers will not change their practices unless there are compelling impetuses to do so. The accessibility, plausibility and feasibility of research are factors which influence teachers' use of research. Research summaries which are short and easy to read, as well as contain details of the context and how the research or intervention is implemented is a way of putting research into the teacher's hand and decreasing the barrier to research use. Design experiment research reports, especially those focussing on the teaching and learning of chemistry, can be recommended to teachers as they are very relevant to teachers and can facilitate their use of research. In addition, researchers can provide support for or work with teachers who wish to develop and implement research-informed materials and strategies for their own classes and assess their efficacy (Woolf, 2008). In this way, there will be a two-way flow of research use as new knowledge and practices will be co-created by the teachers and researchers in a "dynamic and interactive process" (Walter *et al.*, 2004, p. 35) benefitting both practice and research.

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Appendix

Distribution of teachers over years of teaching

Years of teaching	<6	6-10	11-15	16-20	21-25	>25
Female	3	1	3	2	5	4
Male	3	3	3	0	1	1
Total	6	4	6	2	6	5

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