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# Barriers to the Successful Integration of ICT in Teaching and Learning Environments: A Review of the Literature

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The use of ICT in the classroom is very important for providing opportunities for students to learn to operate in an information age. Studying the obstacles to the use of ICT in education may assist educators to overcome these barriers and become successful technology adopters in the future. This paper provides a meta-analysis of the relevant literature that aims to present the perceived barriers to technology integration in science education. The findings indicate that teachers had a strong desire for to integrate ICT into education; but that, they encountered many barriers. The major barriers were lack of confidence, lack of competence, and lack of access to resources. Since confidence, competence and accessibility have been found to be the critical components of technology integration in schools, ICT resources including software and hardware, effective professional development, sufficient time, and technical support need to be provided to teachers. No one component in itself is sufficient to provide good teaching. However, the presence of all components increases the possibility of excellent integration of ICT in learning and teaching opportunities. Generally, this paper provides information and recommendation to those responsible for the integration of new technologies into science education.

*Keywords*: Science Teaching, ICT, Integration, Barriers, Professional Development, Review

## INTRODUCTION

Information and communication technology (ICT) has become an important part of most organisations and businesses these days (Zhang & Aikman, 2007). Computers began to be placed in schools in the early 1980s, and several researchers suggest that ICT will be an important part of education for the next generation too (Bransford, Brown, &Cocking, 2000; Grimus, 2000; Yelland, 2001). Modern technology offers many means of improving teaching and learning in the classroom (Lefebvre, Deaudelin & Loiselle, 2006). Dawes (2001) is of the view that new technologies have the potential to support education across the curriculum and provide opportunities for effective communication between teachers and students in ways that have not been possible before. ICT in education has the potential to be influential in bringing about changes in ways of teaching. However, this potential may not easily be realised, as Dawes (2001) underlined when he stated that "problems arise when teachers are expected to implement changes in what may well be adverse circumstances" (p. 61).

Due to ICT's importance in society and possibly in the future of education, identifying the possible obstacles to the integration of these technologies in schools would be an important step in improving the quality of teaching and learning. Balanskat, Blamire, and Kefala (2006) argue that although educators appear to acknowledge the value of ICT in schools, difficulties

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continue to be encountered during the processes of adopting these technologies.

Many studies have been conducted to investigate barriers to the integration of technology in education and in particular in science education (e. g. Al-Alwani, 2005; Gomes, 2005; Osborne & Hennessy, 2003; Özden, 2007). This paper provides a meta-analysis of this literature that aims to present the perceived barriers to technology integration in science education highlighted in these studies.

**The purpose of this paper**

This analysis aims to bring together the findings and key points from a review of a significant part of the available literature associated with teachers' integration of ICT into their teaching. Studying the obstacles to the use of ICT in learning and teaching environments is crucial because this knowledge could provide "guidance for ways to enhance technology integration" (Schoepp, 2005, p. 2) and encourage greater use of ICT. Identifying the fundamental barriers may assist teachers and educators to overcome these barriers and become successful technology adopters (Al-Alwani, 2005).

Based on this analysis, the paper provides recommendations on improving ICT integration in classrooms.

According to Becta (2004), although there is a reasonable amount of research literature on the barriers to ICT in general, there are few studies that look at barriers which exist in specific subject areas. Becta (2004) asserts that focusing on the barriers that particularly affect practitioners in specific roles may be helpful. In response to this suggestion, after briefly reviewing the literature on the place of ICT in education more generally, the paper then provides a general discussion of the relationship between ICT and science education.

**The importance of ICT in education in the future**

Several studies argue that the use of new technologies in the classroom is essential for providing opportunities for students to learn to operate in an information age. It is evident, as Yelland (2001) argued, that traditional educational environments do not seem to be suitable for preparing learners to function or be productive in the workplaces of today's society. She claimed that organisations that do not incorporate the use of new technologies in schools cannot seriously claim to prepare their students for life in the twenty-first century. This argument is supported by Grimus (2000), who pointed out that "by teaching ICT skills in primary schools the pupils are prepared to face future developments based on proper understanding" (p. 362). Similarly, Bransford et al. (2000) reported that "what is now known about learning provides important guidelines for uses of technology that can help students and teachers develop the competencies needed for the twenty-first century" (p. 206).

ICT can play various roles in learning and teaching processes. According to Bransford et al. (2000), several studies have reviewed the literature on ICT and learning and have concluded that it has great potential to enhance student achievement and teacher learning. Wong et al. (2006) point out that technology can play a part in supporting face-to-face teaching and learning in the classroom. Many researchers and theorists assert that the use of computers can help students to become knowledgeable, reduce the amount of direct instruction given to them, and give teachers an opportunity to help those students with particular needs (Iding, Crosby, & Speitel, 2002; Shamatha, Peressini, & Meymaris 2004; Romeo, 2006).

While new technologies can help teachers enhance their pedagogical practice, they can also assist students in their learning. According to Grabe and Grabe (2007), technologies can play a role in student skills, motivation, and knowledge. They claim that ICT can be used to present information to students and help them complete learning tasks.

According to Becta (2003, p. 10), five factors influence the likelihood that good ICT learning opportunities will develop in schools: ICT resourcing, ICT leadership, ICT teaching, school leadership, and general teaching. Becta (2003) also indicated that the success of the integration of new technology into education varies from curriculum to curriculum, place to place, and class to class, depending on the ways in which it is applied. In science education, there are some areas where ICT has been shown to have a positive impact. The next section discusses this in more detail.

**Science education and ICT**

In the past few decades, science curriculum has changed to match the new aims of science education and it will continue to change (Osborne & Hennessy, 2003). Osborne and Hennessy (2003) state that the latest move towards "teaching about science rather than teaching its content will require a significant change in its mode of teaching and an improved knowledge and understanding in teachers" (p. 4). They emphasise that along with the changes in views on the nature of science and the role of science education, the increase in the number of ICTs offers a challenge to science teaching and learning.

Potential benefits from the use of ICT for science learning have been reported in several research studies. One of these potential benefits is the encouragement of communication and collaboration in science research

activities. According to Gillespie (2006), new technologies can be used in primary science education to enable students to collect science information and interact with resources, such as images and videos, and to encourage communication and collaboration. Murphy (2006) reviewed the impact of ICT on the teaching and learning of science in primary schools. She indicated that "the Internet is used in primary science both as a reference source and as a means of communication" (p. 24). New technologies may also help to increase student motivation (Osborne & Collins, 2000), facilitate clearer thinking, and develop interpretation skills with data (Newton & Rogers, 2003).

Another benefit from using ICT in science education is that it expands the pedagogical resources available to science teachers (Al-Alwani, 2005). Pickersgill (2003) explored effective ways of utilising the Internet when teaching science. He found that the ease of Internet access allows teachers to help students to become experts in searching for information rather than receiving facts. He claimed it could "increase their [students'] awareness of the importance of the world around them, of citizenship and of a scientifically literate community" (p. 86). Kelleher (2000) reviewed recent developments in the use of ICT in science classrooms. While he wrote that ICT cannot replace normal classroom teaching, the review indicated that ICTs could be positive forces in science classrooms for a deeper understanding of the principles and concepts of science and could be used to provide new, authentic, interesting, motivating, and successful educational activities.

The new ICTs have other potential benefits as tools for enhancing science teaching and learning in schools (Skinner & Preece, 2003). These tools include those for data capture, multimedia software for simulation, publishing and presentation tools, digital recording equipment, computer projection technology, and computer-controlled microscopes (Osborne & Hennessy, 2003).

However, although the use of educational technologies in the classroom has many advantages, current research would suggest that it is not appropriate to simply assume that the use of ICT will necessarily transform science education (Osborne & Hennessy, 2003). As suggested above, there are several barriers that confront teachers when integrating ICT into education.

## BARRIERS TO INTEGRATION OF ICT INTO EDUCATION

The act of integrating ICT into teaching and learning is a complex process and one that may encounter a number of difficulties. These difficulties are known as "barriers" (Schoepp, 2005). A barrier is defined as "any condition that makes it difficult to make progress or to achieve an objective" (WordNet, 1997, as cited in Schoepp, 2005, p. 2). The objective being analysed in this paper is successful ICT integration in science education.

***Classification of the barriers.*** Different categories have been used by researchers and educators to classify barriers to teacher use of ICT in science classrooms.

Several studies have divided the barriers into two categories: extrinsic and intrinsic barriers. However, what they meant by extrinsic and intrinsic differed. In one study, Ertmer (1999) referred to extrinsic barriers as first-order and cited access, time, support, resources and training and intrinsic barriers as second-order and cited attitudes, beliefs, practices and resistance; whereas, Hendren (2000, as cited in Al-Alwani, 2005) saw extrinsic barriers as pertaining to organisations rather than individuals and intrinsic barriers as pertaining to teachers, administrators, and individuals.

Another classification found in the literature is teacher-level barriers versus school-level barriers. Becta (2004) grouped the barriers according to whether they relate to the individual (teacher-level barriers), such as lack of time, lack of confidence, and resistance to change, or to the institution (school-level barriers), such as lack of effective training in solving technical problems and lack of access to resources. Similarly, Balanskat et al. (2006) divided them into micro level barriers, including those related to teachers' attitudes and approach to ICT, and meso level barriers, including those related to the institutional context. The latter added a third category called macro level (system-level barriers), including those related to the wider educational framework.

Another perspective presents the obstacles as pertaining to two kinds of conditions: material and non-material (Pelgrum, 2001). The material conditions may be the insufficient number of computers or copies of software. The non-material obstacles include teachers' insufficient ICT knowledge and skills, the difficulty of integrating ICT in instruction, and insufficient teacher time.

Some of these studies look at the barriers at teacher, institution, or system level. However, since the purpose of this paper is to determine the present and future barriers that face science teachers in their schools, this analysis focuses on the teacher-level and school-level barriers only as discussed in the following sections.

### Teacher-level barriers

***Lack of teacher confidence.*** Several researchers indicate that one barrier that prevents teachers from using ICT in their teaching is lack of confidence. Dawes (2001) sees this as a contextual factor which can act as a barrier. According to Becta (2004), much of the research proposes that this is a major barrier to the uptake of

ICT by teachers in the classroom. In Becta's survey of practitioners (2004), the issue of lack of confidence was the area that attracted most responses from those that took part.

Some studies have investigated the reasons for teachers' lack of confidence with the use of ICT. For example, Beggs (2000) asserted that teachers' "fear of failure" caused a lack of confidence. On the other hand, Balanskat et al. (2006) found that limitations in teachers' ICT knowledge makes them feel anxious about using ICT in the classroom and thus not confident to use it in their teaching. Similarly, Becta (2004) concluded their study with the statement: "many teachers who do not consider themselves to be well skilled in using ICT feel anxious about using it in front of a class of children who perhaps know more than they do" (p. 7). In Becta's survey (2004), many of the teacher respondents who identified their lack of confidence as a barrier reported being particularly afraid of entering the classroom with limited knowledge in the area of ICT with their students knowing that this was the case. It was argued that lack of confidence and experience with technology influence teachers' motivation to use ICT in the classroom (Cox, Preston, and Cox, 1999b; Osborne & Hennessy, 2003; Balanskat et al., 2006).

On the other hand, teachers who confidently use technologies in their classrooms understand the usefulness of ICT. Cox, Preston, and Cox (1999a) found that teachers who have confidence in using ICT identify that technologies are helpful in their teaching and personal work and they need to extend their use further in the future.

***Lack of teacher competence.*** Another barrier, which is directly related to teacher confidence, is teachers' competence in integrating ICT into pedagogical practice (Becta, 2004). In Australian research, Newhouse (2002) found that many teachers lacked the knowledge and skills to use computers and were not enthusiastic about the changes and integration of supplementary learning associated with bringing computers into their teaching practices.

Current research has shown that the level of this barrier differs from country to country. In the developing countries, research reported that teachers' lack of technological competence is a main barrier to their acceptance and adoption of ICT (Pelgrum, 2001; Al-Oteawi, 2002). In Syria, for example, teachers' lack of technological competence has been cited as the main barrier (Albirini, 2006). Likewise, in Saudi Arabia, a lack of ICT skills is a serious obstacle to the integration of technologies into science education (Al-Alwani, 2005; Almohaissin, 2006). Empirica (2006) produced a report on the use of ICT in European schools. The data used for the report came from the Head Teachers and Classroom Teachers Survey carried out in 27 European countries. The findings show that teachers who do not use computers in classrooms claim that "lack of skills" are a constraining factor preventing teachers from using ICT for teaching. Another worldwide survey conducted by Pelgrum (2001), of nationally representative samples of schools from 26 countries, found that teachers' lack of knowledge and skills is a serious obstacle to using ICT in primary and secondary schools. The results of a study conducted by Balanskat et al. (2006) have shown that "in Denmark ... many teachers still chose not to use ICT and media in teaching situations because of their lack of ICT skills rather than for pedagogical/didactics reasons" while "in the Netherlands ... teachers' ICT knowledge and skills is [sic] not regarded any more as the main barrier to ICT use" (p. 50). Hence, lack of teacher competence may be one of the strong barriers to the integration of technologies into education. It may also be one of the factors involved in resistance to change.

***Resistance to change & negative attitudes.*** Much research into the barriers to the integration of ICT into education found that teachers' attitudes and an inherent resistance to change were a significant barrier (Cox et al., 1999a; Watson, 1999; Earle, 2002; Becta, 2004; Gomes, 2005; Schoepp, 2005). From his/her analysis of the questionnaires, Gomes (2005) found that science teachers' resistance to change concerning the use of new strategies is an obstacle to ICT integration in science teaching. At a broader level, Becta (2004) argued that resistance to change is an important barrier to teachers' use of new technologies in education.

Watson, an Australian researcher, (1999) argued that integrating the new technologies into educational settings requires change and different teachers will handle this change differently. According to him, considering different teachers' attitudes to change is important because teachers' beliefs influence what they do in classrooms. Becta (2004) claims that one key area of teachers' attitudes towards the use of technologies is their understanding of how these technologies will benefit their teaching and their students' learning. Schoepp's study (2005) found that, although teachers felt that there was more than enough technology available, they did not believe that they were being supported, guided, or rewarded in the integration of technology into their teaching. According to Empirica (2006), teachers who are not using new technology such as computers in the classroom are still of the opinion that the use of ICT has no benefits or unclear benefits.

Resistance to change seems not to be a barrier itself; instead, it is an indication that something is wrong. In other words, there are reasons why resistance to change occurs. According to Earle (2002), the change from a present level to a desired level of performance is facilitated by driving (encouraging) forces such as the power of new developments, rapid availability, creativity, Internet access, or ease of communication,

while it is delayed by resisting (discouraging) forces such as lack of technical support, teacher expertise, or time for planning. In their study, Cox et al. (1999a) found that teachers are unlikely to use new technologies in their teaching if they see no need to change their professional practice. They showed that teachers who resist change are not rejecting the need for change but lack the necessary education in accepting the changes and are given insufficient long-term opportunities to make sense of the new technologies for themselves.

Obviously, not all communities have this barrier. In Europe, for example, Korte and Hüsing (2007) state that only very few teachers can be regarded as fundamentally opposing the use of ICT in the classroom. Only a fifth of European teachers believe that using computers in class does not have significant learning benefits for pupils (Korte & Hüsing, 2007).

**School-level barriers**

***Lack of time.*** Several recent studies indicate that many teachers have competence and confidence in using computers in the classroom, but they still make little use of technologies because they do not have enough time. A significant number of researchers identified time limitations and the difficulty in scheduling enough computer time for classes as a barrier to teachers' use of ICT in their teaching (Al-Alwani, 2005; Becta, 2004; Beggs, 2000; Schoepp, 2005; Sicilia, 2005). According to Sicilia (2005), the most common challenge reported by all the teachers was the lack of time they had to plan technology lessons, explore the different Internet sites, or look at various aspects of educational software.

Becta's study (2004) found that the problem of lack of time exists for teachers in many aspects of their work as it affects their ability to complete tasks, with some of the participant teachers specifically stating which aspects of ICT require more time. These include the time needed to locate Internet advice, prepare lessons, explore and practise using the technology, deal with technical problems, and receive adequate training.

Recent studies show that lack of time is an important factor affecting the application of new technologies in science education (Al-Alwani, 2005). According to Al-Alwani (2005), lack of time is a barrier affecting the application of ICT in Saudi Arabia because of busy schedules. He indicated that because Saudi teachers work from about 7.00 a.m. until 2.00 p.m. and the average number of class sessions taught by science teachers is 18 per week, both teachers and students have a limited number of hours during the day to work on integrating ICT into science education. Similarly, in Canada, Sicilia (2005) concluded that teachers take much more time to design projects that include the use of new ICT than to prepare traditional lessons. Teachers interviewed by Sicilia (2005) commented that "the constraints of different class schedule [sic] contributed to the lack of time they spent together to work on planning classroom activities" (p. 41). Supporting this finding, the most significant constraint on use quoted by 86–88% of primary and secondary science teachers surveyed by Dillon, Osborne, Fairbrother, and Kurina (2000) was lack of time (as cited in Osborne & Hennessy, 2003, p. 37). Gomes (2005) concluded that one of the main reasons that science teachers do not use ICT in the classroom is lack of the time necessary to accomplish plans.

***Lack of effective training***. The barrier most frequently referred to in the literature is lack of effective training (Albirini, 2006; Balanskat et al., 2006; Beggs, 2000; Özden, 2007; Schoepp, 2005; Sicilia, 2005; Toprakci, 2006). One finding of Pelgrum's (2001) study was that there were not enough training opportunities for teachers in the use of ICTs in a classroom environment. Similarly, Beggs (2000) found that one of the top three barriers to teachers' use of ICT in teaching students was the lack of training. Recent research in Turkey found that the main problem with the implementation of new ICT in science was the insufficient amount of in-service training programs for science teachers (Özden, 2007), and Toprakci (2006) concluded that limited teacher training in the use of ICT in Turkish schools is an obstacle.

According to Becta (2004), the issue of training is certainly complex because it is important to consider several components to ensure the effectiveness of the training. These were time for training, pedagogical training, skills training, and an ICT use in initial teacher training. Correspondingly, recent research by Gomes (2005) relating to science education concluded that lack of training in digital literacy, lack of pedagogic and didactic training in how to use ICT in the classroom, and lack of training concerning the use of technologies in science specific areas were obstacles to using new technologies in classroom practice. Some of the Saudi Arabian studies reported similar reasons for failures in using educational technologies: the weakness of teacher training in the use of computers, the use of a "delivery" teaching style instead of investment in modern technology (Alhamd, Alotaibi, Motwaly, & Zyadah, 2004), as well as the shortage of teachers who are qualified to use the technology confidently (Sager, 2002).

Providing pedagogical training for teachers, rather than simply training them to use ICT tools, is an important issue (Becta, 2004). Cox et al. (1999a) argue that if teachers are to be convinced of the value of using ICT in their teaching, their training should focus on the pedagogical issues. The results of the research by Cox et al. (1999a) showed that after teachers had attended professional development courses in ICT they still did

not know how to use ICT in their classrooms; instead they just knew how to run a computer and set up a printer. They explained that this is because the courses only focused on teachers acquiring basic ICT skills and did not often teach teachers how to develop the pedagogical aspects of ICT. In line with the research by Cox et al. (1999a), Balanskat et al. (2006) indicated that inappropriate teacher training is not helping teachers to use ICT in their classrooms and in preparing lessons. They assert that this is because training programmes do not focus on teachers' pedagogical practices in relation to ICT but on the development of ICT skills.

However, beside the need for pedagogical training, according to Becta (2004), it is still necessary to train teachers in specific ICT skills. Schoepp (2005) claims that when new technologies need to be integrated in the classroom, teachers have to be trained in the use of these particular ICTs. According to Newhouse (2002), some initial training is needed for teachers to develop appropriate skills, knowledge, and attitudes regarding the effective use of computers to support learning by their students. He argued that this also requires continuing provision of professional development to maintain appropriate skills and knowledge.

Fundamentally, when there are new tools and approaches to teaching, teacher training is essential (Osborne & Hennessy, 2003) if they are to integrate these into their teaching. However, according to Balanskat et al. (2006), inadequate or inappropriate training leads to teachers being neither sufficiently prepared nor sufficiently confident to carry out full integration of ICT in the classroom. Newhouse (2002) states that "teachers need to not only be computer literate but they also need to develop skills in integrating computer use into their teaching/learning programmes" (p. 45).

According to Newhouse (2002), teachers need training in technology education (focusing on the study of technologies themselves) and educational technology (support for teaching in the classroom). Similarity, Sicilia (2005) found that teachers want to learn how to use new technologies in their classrooms but the lack of opportunities for professional development obstructed them from integrating technology in certain subjects such as science or maths. Other problematic issues related to professional development in ICT are that training courses are not differentiated to meet the specific learning needs of teachers and the sessions are not regularly updated (Balanskat et al. 2006).

Pre-service teacher education can also play a significant role in providing opportunities for experimentation with ICT before using it in classroom teaching (Albirini, 2006). Lack of on ICT focus in initial teacher education is a barrier to teachers' use of what is available in the classroom during teaching practice (Becta, 2004). Where training is ineffective, teachers may not be able access to ICT resources.

***Lack of accessibility.*** Several research studies indicate that lack of access to resources, including home access, is another complex barrier that discourages teachers from integrating new technologies into education and particularly into science education as the following discussion illustrates.

The various research studies indicated several reasons for the lack of access to technologies occurred. In Sicilia's study (2005), teachers complained about how difficult it was to always have access to computers. The author gave reasons like "computers had to be booked in advance and the teachers would forget to do so, or they could not book them for several periods in a row when they wanted to work on several projects with the students" (p. 50). In other words, a teacher would have no access to ICT materials because most of these were shared with other teachers. According to Becta (2004), the inaccessibility of ICT resources is not always merely due to the non-availability of the hardware and software or other ICT materials within the school. It may be the result of one of a number of factors such as poor organisation of resources, poor quality hardware, inappropriate software, or lack of personal access for teachers (Becta, 2004).

The barriers related to the accessibility of new technologies for teachers are widespread and differ from country to country. Empirica's (2006) European study found that lack of access is the largest barrier and that different barriers to using ICT in teaching were reported by teachers, for example a lack of computers and a lack of adequate material. Similarly, Korte and Hüsing (2007, p.4) found that in European schools there are some infrastructure barriers such as broadband access not yet being available. They concluded that one third of European schools still do not have broadband Internet access. Pelgrum (2001) explored practitioners' views from 26 countries on what were the main obstacles to the implementation of ICT in schools. He concluded that four of the top ten barriers were related to the accessibility of ICT. These barriers were insufficient numbers of computers, insufficient peripherals, insufficient numbers of copies of software, and insufficient simultaneous Internet access. Toprakci (2006) found that low numbers of computers, oldness or slowness of ICT systems, and scarcity of educational software in the school were barriers to the successful implementation of ICT into science education in Turkish schools. Similarly, Al-Alwani (2005) found that having no access to the Internet during the school day and lack of hardware were impeding technology integration in Saudi schools. Recent research on Syrian schools indicated that insufficient computer resources were one of the greatest impediments to technology integration in the classroom (Albirini, 2006).

Basically, there are several barriers associated with the lack of access to ICT. In his research, Gomes (2005) found a lack of appropriate infrastructure and a lack of appropriate material resources to be barriers. However, overcoming such hardware barriers does not, in itself, ensure ICT will be used successfully. According to Balanskat et al. (2006), the accessibility of ICT resources does not guarantee its successful implementation in teaching, and this is not merely because of the lack of ICT infrastructure but also because of other barriers such as lack of high quality hardware, suitable educational software, and access to ICT resources.

Newhouse (2002) asserts that poor choices of hardware and software and a lack of consideration of what is suitable for classroom teaching are problems facing many teachers. Similarly, Cox et al. (1999a) found that the majority of teachers agreed that insufficient ICT resources in the school and insufficient time to review software prevent teachers using ICT. According to Osborne and Hennessy (2003), the limitations on access to hardware and software resources influenced teachers' motivation to use ICT in the classroom.

***Lack of technical support.*** Without both good technical support in the classroom and whole-school resources, teachers cannot be expected to overcome the barriers preventing them from using ICT (Lewis, 2003). Pelgrum (2001) found that in the view of primary and secondary teachers, one of the top barriers to ICT use in education was lack of technical assistance.

In Sicilia's study (2005), technical problems were found to be a major barrier for teachers. These technical barriers included waiting for websites to open, failing to connect to the Internet, printers not printing, malfunctioning computers, and teachers having to work on old computers. "Technical barriers impeded the smooth delivery of the lesson or the natural flow of the classroom activity" (Sicilia, 2005, p. 43).

Korte and Hüsing (2007) argued that ICT support or maintenance contracts in schools help teachers to use ICT in teaching without losing time through having to fix software and hardware problems. The Becta (2004) report stated that "if there is a lack of technical support available in a school, then it is likely that technical maintenance will not be carried out regularly, resulting in a higher risk of technical breakdowns" (p. 16). Many of the respondents to Becta's survey (2004) indicated that technical faults might discourage them from using ICT in their teaching because of the fear of equipment breaking down during a lesson.

In science teaching, several studies indicated that lack of technical support is a main barrier to using technologies. According to Gomes (2005), ICT integration in science teaching needs a technician and if one is not available the lack of technical support can be an obstacle. In Turkey, Toprakci (2006) found that the lack of technical support was one of two significant barriers to the integration of ICT into science education in schools and might be considered "serious". In Saudi Arabia, science teachers would agree to introduce computers into science teaching, except that they believe they will encounter problems such as technical service or hardware problems (Almohaissin, 2006). Sicilia (2005) argued that whatever kind of technical support and access teaching staff have and whether they have twenty years of experience or are novices to the profession, technical problems generate barriers to the smooth delivery of science lessons by teachers.

Although lack of technical support can prevent teachers from successfully integrating ICT into education, recent research indicates that in some countries (such as the United Kingdom, the Netherlands, Latvia, Malta and the Czech Republic), schools have recognised the importance of technical support to assist teachers to use ICT in the classroom (Korte and Hüsing, 2007).

In general, several studies have identified a range of the following or similar factors as widespread barriers: lack of computers, lack of quality software, lack of time, technical problems, teachers' attitudes towards computers, poor funding, lack of teacher confidence, resistance to change, poor administrative support, lack of computer skills, poor fit with the curriculum, lack of incentives, scheduling difficulties, poor training opportunities, and lack of skills in how to integrate ICT in education. There are complicated relationships among these barriers as discussed in the following section.

## DISCUSSION

This section is divided into three parts. First, the relationship between the barriers will be discussed, then some implications for teachers and for schools will be suggested, followed by a discussion on the limitations of this study.

***The relationship between the barriers.*** As previously mentioned, there are multifaceted relationships between the barriers. Some barriers such as lack of teacher competence and lack of accessibility seem to be closely related to others. Some barriers such as lack of teacher confidence and resistance to change seem to be more significant than others. The following discussion focuses on the relationships between lack of accessibility and lack of competence and other factors such as time, training, and technical support.

The lack of accessibility to resources as a barrier is closely related to several other key issues which can themselves be considered barriers to teachers' use of ICT. Although the resources are available in schools, the lack of time does not allow teachers to access these resources. There may be technical equipment available but there is no time for the teacher to operate and

review those techniques. This may be because the number of lessons in one day is too many or because the time available during the class lesson is insufficient.

Another example related to the accessibility barrier, as found by previous studies, is that lack of teacher training reduces the integration of technology into education. Educational technological materials may be available in schools but teachers cannot use them because of a lack of pedagogical or skills-related (practical) training in how to use these ICT resources. On the other hand, it may be that the lack of access to resources leads to a reduction in training opportunities. It is important to remember that not only is access to resources used in the classroom for students' learning important, but also access at home will help with self-training.

Access to resources might be available, but teachers cannot use ICT in the classroom because it may be difficult for them to operate ICT tools. Thus teachers always need technical assistance because this assistance may provide them with up-to-date equipment in the new world of technology. Technical support helps in training and training takes time. Together they allow access to ICT resources and thus help the successful integration of technology in the teaching process.

Lack of competence is one of the most important obstacles to teachers' use of technology in education. It is linked to other issues such as training, time and technical support. The first problem linked to the competence barrier is the lack of effective training. Teacher training in the use of modern technology in the classroom helps to increase the teachers' efficiency in using ICT in education effectively. Training includes training in basic skills in using technology as well as training in the integration of those technologies into interactive and effective teaching. Self-training is also important to increase competence and improve ICT use. It can happen through providing teachers with opportunities to use resources such as user guides, CDs, and IT equipment for self-training at home.

The improvement of ICT skills also requires that teachers have time available. Teachers whose schools give them time to develop their skills can be more creative than teachers who do not have sufficient time. In order to achieve sufficient competence in using ICT effectively in education, a teacher also needs professional technical support.

As discussed above, the relationship between access to modern technological resources and the competence of teachers to use them is complicated. This relationship links those factors with other issues such as time, training, and technical support. Also, there is a relationship between the barriers of lack of accessibility and lack of competence. In other words, teachers may not be able to access ICT resources unless they have skills in the use of technology and can work with it efficiently in their teaching. On the other hand, access to ICT resources can help teachers increase their competence whether by self-training through the Internet or by communication with experts. The opportunities for development of teachers' skills and their access to ICT resources can be increased by providing them with technical support and sufficient time.

Another issue that has to be raised, according to previous studies, is the teachers' confidence in using ICT to help them teach effectively. The lack of confidence is a problem linked to the previous two issues: the lack of access to resources and the lack of teacher competence. Regarding the availability of ICT resources, perceived ability to use ICT and having the basic skills to operate it may increase teachers' satisfaction with modern technologies, which may motivate teachers to integrate ICT in education. However, we should not overlook the provision of training, enough time, and technical support.

In general, it is difficult to classify the barriers into groups and think about the barriers in entirely separate categories because, as mentioned above, there are complex relationships among the barriers. For example, lack of technical support, time, and training can lead to technical problems, which can in turn lead to a lack of access to ICT resources and a lack of teachers' competence. This can lead to teachers lacking confidence and influence their motivation.

Understanding the levels in this study at which these barriers prevent teachers from using ICT may help educators to decide how the barriers can be tackled. In other words, teachers should be convinced of the importance of using ICT in the classroom. Then, they should be provided with access to resources. After that, teachers need to be able to use these resources successfully. Access to ICT and the ability to use it cannot be possible without sufficient time, effective training, and technical support.

***Implementation.*** One can see that it is much easier to remove barriers by resolving and reducing the reasons for the occurrence of these barriers. Educators, teachers, and school principals need to collaborate to overcome any of the obstacles and break down the above mentioned barriers to the meaningful integration of ICT into teaching and learning.

There are some implications for teachers and schools for successful integration of ICT into education arising from this. Table 1 aims to illustrate these implications.

Schools need to provide training courses for teachers to gain experience in dealing with the new devices, modern technologies, and new pedagogical approaches. Technical support needs to be provided in schools. Additionally, schools must provide teachers with the necessary ICT resources including hardware and software. It is important for schools to cooperate with

**Table 1. Possible implications for schools and teachers for the integration of ICT into education**

| Barriers | Implementation | |
|---|---|---|
| | **For schools** | **For teachers** |
| **Lack of access** | - Providing ICT resources including hardware and software | - Taking advantage of resources offered at schools<br>- Access to ICT resources at home |
| **Resistance to change** | - Training in new pedagogical approaches | - Being open minded towards new ways of teaching |
| **Lack of time** | - Providing sufficient time: reducing the number of teacher lessons or increasing the daily lesson time | - Acquiring skills of self-organisation and time managements |
| **Lack of training** | - Providing training courses in dealing with the new devices, modern technologies, and new pedagogical approaches | - Preparing themselves (pre-service) by self-training<br>- Taking up opportunities for training offered at schools<br>- Knowing how to access to resources |
| **Lack of technical support** | - Providing continued technical support | - Relying on themselves to be able to solve problems in their use of ICT<br>- Accessing available support |

teachers by providing sufficient time to implement new technologies in the classroom. For example, a school can reduce the teacher's number of lessons or increase the daily lesson length.

Teachers also need to engage with this implementation. Teachers should take advantage of ICT resources offered at schools. They need to be prepared well before joining the teaching profession. Where training is absent, teachers can prepare themselves by enrolling in private sessions or by self-training. They should be open minded towards new approaches of teaching. Where support is lacking, they need to find ways to be able to solve problems involving their use of ICT in schools. Finally, teachers should acquire skills of self-organisation which will help them a great deal in conducting their classes when using ICT.

***Limitation.*** The purpose of this paper was to determine the present and future barriers that face science teachers in integrating ICT in their schools. Thus this study has focused on the teacher-level barriers and school-level barriers only.

It should also be noted that although this study focuses on significant barriers revealed by the research literature, there are less direct barriers to the use of ICT in the classroom. Some of these barriers, which are mentioned in the literature are lack of classroom management skills, poor administrative support, poor school funding, and poor fit with the curriculum (Al-Alwani, 2005; Balanskat et al. 2006; Becta, 2004; Beggs, 2000; Gomes, 2005; Lazaros & Rogers, 2006; Schoepp, 2005). While these barriers were not addressed here, they are still important and need to be investigated.

## CONCLUSION

The aim of this paper was to provide information on encouraging the desired improvement in the future teaching situation to those responsible for the integration of ICT into science education. The findings of this study indicate that teachers have a strong desire for the integration of ICT into education but that they encountered many barriers to it. The major barriers were lack of confidence, lack of competence, and lack of access to resources. Since confidence, competence and accessibility have been found to be critical components for technology integration in schools, ICT resources including software and hardware, effective professional development, sufficient time, and technical support need to be provided for teachers. No one component in itself is sufficient to produce good teaching. However, the presence of all components increases the likelihood of excellent integration of ICT in learning and teaching opportunities.

## Note

This paper is a part of PhD thesis which is currently being conducted by the author.

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