1-1-2013

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10.1007/s13384-013-0139-3
This is an Author's Accepted Manuscript of: Newhouse, C. P. (2013). Learning with portable digital devices in Australian schools: 20 years on!. The Australian Educational Researcher, 41(4), 471-483. The final publication is available at Springer via here

Learning with portable digital devices in Australian schools: 20 years on!

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Abstract

Portable computing technologies such as laptops, tablets, smartphones, wireless networking, voice/stylus input, and plug and play peripheral devices, appear to offer the means of finally realising much of the long heralded vision for computers to support learning in schools. There is the possibility for the technology to finally become a ubiquitously invisible component of the learning environment, empowering children to attempt feats well beyond their current capabilities. These technologies are finding a place in many schools, and there has now been over two decades of research conducted into their use in schools. What is now known about implementing portable computing technologies in schools? What should educational leaders take from this research before making decisions about the technologies used in schools?

Keywords: mobile learning, computer supported learning environments, educational technology, computers in schools

Introduction

It has been 20 years since I started researching the first 1-to-1 portable computer program in a Western Australian (W.A.) school. At the time I thought that within 10 years this would be typical for all our secondary schools, but it has taken 20 years to get to what appears to be the tipping point (Greaves & Hayes, 2008). Of course, the use of computers in schools goes back to the beginning of my teaching career in the 1970s, but it wasn't until computers could be carried around that I was convinced that they could play a central role in improving teaching and learning. There have always been visionaries who have demonstrated the powerful ways that digital technologies could support learning, but this has generally not been realised in our schools (e.g. DeCorte, 1990; Papert, 1980). As the technology became more portable and powerful, and less costly, this dissonance was increasingly debated; typically becoming more about implementation strategies and changes to schooling and teaching, rather than the technology itself (e.g. Bebell & Kay, 2010; Dede, 2008; Ertmer & Ottenbreit-Leftwich, 2013; Weston & Bain, 2010).

Some Australian schools were early adopters of portable computing, and provided early research into what became known as, laptop or 1-to-1 programs (e.g. Rowe, 1993; Shears, 1995). In many ways this culminated in 2008 when the Australian government funded secondary schools, or school systems, to provide a computer per student; many used the funds to provide portable computing (Howard & Carceller, 2010). Personally, I have been fortunate to be able to conduct a substantial amount of research from the beginning, including from 2003 the first 1-to-1 program at a W.A. government secondary school (Newhouse, 1998, 2008). This paper discusses the continuing rationale for the use of portable/mobile computing systems in schools, and what we have learned over the past 20 years that can guide our future decisions in this area.

A rationale for computer-supported learning

Initially, computer use in schools was envisioned as that they would 'teach' students; even to the extent that they could replace the teacher with tutorial, and drill and practice software (Chambers & Sprecher, 1984; Cox, 2012). Fortunately, by the time schools could afford microcomputers the vision had broadened with more open-ended simulation, modelling, and tool software developed (Cox, 2012; Glenn & Rakow, 1985). For example, by this stage Papert (1980) had introduced Logo and the first word processors appeared.

There has always been a computer literacy rationale, but from the late 1980s, with increasing affordability, the major rationale became to support learning as an educational technology (e.g. DeCorte, 1990; Welle-Strand, 1991). Much of the research of this period tried to explain why this envisioned potential of the technology was not evident in practice (e.g. Plomp & Pelgrum, 1992). Often insufficient access to the technology was cited, and thus the arrival of laptop computers was heralded as a solution to this problem. With this started to emerge evidence of an impact on classroom practices, and ultimately student learning (e.g. Gardner, Morrison, & Jarman, 1993; Walker, Rockman, & Chessler, 2000), including some evidence from my own research (Newhouse, 1998). Since then portable computers have become smaller, more powerful and cheaper, as they have converged with mobile phone technologies to become more personal; leading to an aim to have every teacher and student with a device (Cox, 2012). This scenario has increasingly been referred to as mobile learning, that can occur anywhere and anytime (e.g. Kearney, Schuck, Burden, & Aubusson, 2012; Murphy, 2011). While most assume that some form of computer support is essential, I believe that a response to portability should be grounded in the rationale for using computer support, irrespective of the form of computer.

Technology is developed, and/or adopted, to solve problems associated with human need. Therefore, educational technologies should be developed, and/or adopted, to address any of the myriad educational problems with which we are faced. At all levels of decision-making in education (governments, school leaders and teachers) the problem to be addressed should be identified, before the technology is deployed in a learning activity, or new hardware or software is purchased, or policies and plans are drawn up (Ertmer & Ottenbreit-Leftwich, 2013; Howland, Jonassen, & Marra, 2012). The question starts in the classroom with the teacher asking, "Am I satisfied with the learning opportunities I can offer my students, are they relevant and engaging?" It is not difficult to argue that in Australian classrooms the response should be in the negative (e.g. Gonski et al., 2011).

For government and school leaders, investment in computer technology comes with an opportunity cost, and thus it is important to consider whether the resulting outputs, such as increased learning outcomes, or better use of teacher and student time, justify the costs of the inputs. What level of optimal investment, justifies a reduced investment in other inputs, such as buildings, books and teachers? More recent research has tended to support the notion that there is a threshold investment in technology, and teacher support, required to deliver significant increased outputs, in whatever way that is measured; from standardised test scores to the qualitative perceptions of stakeholders (e.g. Lei & Zhao, 2007; Vanderlinde & van Braak, 2010). For example, in their study Lei and Zhao (2007) found that the maximum improvement in Grade Point Average was associated with an average of 3 hours/day of computer use by a student. Clearly this level of use cannot be achieved with investment in only a few computers per classroom.

With every quantum leap in the development in digital technologies, there have been the early adopters, and warnings about what Papert (1987) called, 'technocentric thinking'. Few educators would admit to being technocentric, but it is difficult not to be distracted by the allure of the shiny new gadget, or the clever new piece of software. Rather, educational use of digital technologies should be viewed as one of many mediators in learning processes, and therefore decisions should be based on an understanding of the nature of learning, the learning environment, and the findings of reputable educational research (e.g. Fullan, 1995; Howland, et al., 2012). Solutions to educational problems should be built on generally accepted expert knowledge about learning and teaching, and this has changed considerably over the past 50 years. Increasingly, social and neuroscience research is supporting theories labelled with constructivism; described as, "that people construct new knowledge and understandings based on what they already know and believe" (Bransford, Brown, & Cocking, 2000, p. 10).

Learning occurs in a physical and psychosocial 'learning environment' (Fraser, 1994), creating what Salomon (1994) refers to as, "a system of interrelated factors that jointly affect learning in interaction " (p. 80). As interactive systems, computers have a place within the relationship milieu of this environment and thus an impact on learning outcomes. As a teacher, I have always found the "sources-of-knowledge" model presented by Pines and West (1986) helpful. It uses a two vines metaphor for the upward spontaneous growth of knowledge frameworks originating from the learner, entangling with the downward imposition of formal knowledge frameworks at school. The use of computers to support learning can then be envisaged as providing support for the learner dealing with that entanglement, in what Vygotsky (1978) refers to as the zone of proximal learning. Thus, the term computer supported learning is helpful, and decisions about using computers can be viewed in terms of the overall effectiveness of those supports (Ertmer & Ottenbreit-Leftwich, 2013; Howland, et al., 2012).

From my early research in the 1990s, I developed a mental model connecting the learning environment with factors affecting the use of computer support (Newhouse, 1998). The model starts with the learning environment, and largely plays out through the teacher from beliefs, attitudes and perceptions through to a response and level of facilitation, and then feedback loops back to impact on the environment. The other entities, such as students, and those external to the classroom, act as forces either encouraging or discouraging the use of computer support; what Ertmer and Ottenbreit-Leftwich (2013) refer to as enablers or barriers. The balance of forces determines a type of response from the teacher, which then leads to a level of facilitation of computer support, both in terms of amount of use and the meaningfulness of that use. This level of facilitation is moderated by the size of obstacles or barriers to be overcome, or removed, but is largely dependent on the type of response of the teacher; such as, toleration or investigation.

Providing ubiquitous access

Portable computing in education has come to mean *ubiquitous access* to computer processing, software and data (Murphy, 2011). Initially the strategy was to carry the hardware, software and data around using a laptop computer, or to carry data on a storage device. Increasingly now the strategy is to access data and/or software through networked servers (the cloud) on a range of devices. Devices may vary substantially in processing power, storage capacity and screen size, but increasingly have the capacity to support similar tasks and to share data (Cox, 2012).

The ultimate aim for many educators has been to provide ubiquitous access to adequate computer processing and software, for every student, relevant to their learning needs (Murphy, 2011; Pegrum, Oakley, & Faulkner, 2013; Rowe, 1993). This means that either every student carries a device, or can be given access at school and home through devices stored at those locations. A computer-saturated environment, in which students use portable devices, offers the flexibility within any classroom, or elsewhere, to use any number of devices required, without the need to move to a 'special' environment such as a computer laboratory (e.g. Rowe, 1993). This is ideal for the teacher with constructivist intentions, as envisaged by Collis (1989) over 20 years ago, "… every student has his [sic] own portable computer and can access the central resources of the school through any workplace of his choice" (p. 15).

For over 20 years there has been substantial research into portable computing in schools with the first studies to be well documented in the early 1990s; such as, some of the *Apple Classroom of Tomorrow* projects (Dwyer et al., 1991), the PLAIT project in Northern Ireland (Gardner, Morrison, Jarman, Reilly, & McNally, 1994), and a number in

Australian schools (e.g. Rowe, 1993; Shears, 1995). Increasingly as new types of portable computing technologies emerged teachers and researchers investigated their use in the classroom (e.g. Crawford & Vahey, 2002).

The pivotal early Australian research was conducted at Melbourne's Methodist Ladies College, with a strategy to change the culture of teaching to be more constructivist in nature (e.g. Loader, 1993). A few years later a number of additional schools conducted 'laptop trials' including the first reported instance involving a government school and wireless networking (Narracott, 1995). The latter technology provided a basis for some of my research at a primary school (Newhouse, 2001).

Within a decade, larger more focused research projects were underway that provided cautiously positive reports; such as, the *Anytime Anywhere Learning Program* that included a comparative study between 'laptop' and 'non-laptop' schools (Walker, et al., 2000). Then in 2002 there was a breakthrough initiative in the USA state of Maine giving all secondary students a notebook computer (Silvernail & Lane, 2004). In my own state of Western Australia this encouraged the government to set up the first 1-to-1 program in a public secondary school, and I was given the opportunity of evaluating this initiative over a period of eight years (Newhouse, 2008). And then, from 2008 a 1-to-1 program was implemented for government secondary schools throughout NSW and in many schools in other states in Australia (Howard & Carceller, 2010). Although much of the research has been focussed on secondary schools there have been notable examples in primary schools (Rowe, 1993; Suhr, Hernandez, Grimes, & Warschauer, 2010). Overall, this focus for research now spans about 25 years, and although it has revealed some disappointments and problems, increasingly it has uncovered the benefits of portability (e.g. Shapley, Sheehan, Maloney, & Caranikas-Walker, 2010b).

In countries such as Australia, for nearly 10 years, it has been realistic to call for every student to have a portable device; in fact the vast majority of senior secondary students already do so. Most research has reported evidence that students like using their own portable devices, and there have been more consistent and compelling reports of positive impacts on learning, beyond just the affect on motivation (e.g. Argueta, Huff, Tingen, & Corn, 2011; Bebell & Kay, 2010 ; Berry & Wintle, 2009; Lei & Zhao, 2007; Shapley, et al., 2010b; Suhr, et al., 2010). Naturally, all of the positive impacts found for non-portable computing, such as support for higher-order thinking, collaboration, active learning, productivity, problem-solving and authentic assessment, also apply for portable computing, but tend to be amplified (Drayton, Falk, Stroud, Hobbs, & Hammerman, 2010; Ertmer & Ottenbreit-Leftwich, 2013). For example, I have identified the use of portable computing being associated with substantial increases in the use of the technology for a wider range of activities, with greater focus on the investigation of the real world, increasing student productivity, increasing student engagement, increasing authenticity of assessment, knowledge building, student independence and collaboration (Newhouse, 2008; Newhouse & Clarkson, 2008). These meaningful uses of the technology for learning are typically associated with more process-oriented rather than content-oriented outcomes, with the flexibility of portable computing leading to support for a wider range of activities implemented in a greater range of ways (e.g. Argueta, et al., 2011; Bebell & Kay, 2010; Berry & Wintle, 2009; Lei & Zhao, 2007; Lowther, Inan, Ross, & Strahl, 2012; Rowe, 1993).

Despite the increasingly positive evidence from research, teachers' responses continue to vary from great enthusiasm to hostility, although as the reliability and usability of the devices, software and networks have improved, acceptance has increased. Many teachers have found the technology liberating, allowing them to implement the more constructivist pedagogies they have always wanted to use, but found too difficult in the past (Argueta, et al., 2011; Becker, Ravitz, & Wong, 1999; Newhouse, 2008). Clearly portable computing is a powerful force on teachers encouraging greater facilitation of computer support for learning, while overcoming some barriers (Bebell & Kay, 2010; Shapley, Sheehan, Maloney, & Caranikas-Walker, 2010a). This is not to say that all opposing forces and obstacles disappear.

Obstacles and opposing forces

Despite increasing realisation of the potential of portable computing, most researchers have still reported a number of barriers (Ertmer & Ottenbreit-Leftwich, 2013). In fact, Hew and Brush (2007) claim to have identified 123 barriers to using computers in schools that they distilled to six categories that concerned: access to resources; teacher knowledge and skills; institutional leadership and operation; teacher attitudes and beliefs; assessment; and curriculum 'culture'. Ertmer and Ottenbreit-Leftwich (2013) identify external and internal barriers that I refer to as obstacles that can be overcome or removed by an external agent, and opposing forces that need an internal change in the teacher. Some early barriers such as high costs of hardware, unreliability, and weight, have diminished (Murphy, 2011; Newhouse, 2008). From early days some teachers have found the management of the dynamics of the classroom environment difficult (Sandholtz, Ringstaff, & Dwyer, 1992), for some a lack of confidence and technical skills has been a barrier (Gardner, et al., 1994; Shapley, et al., 2010a), and for many beliefs associated with teacher-centred pedagogies have limited facilitation of computer support (Ertmer & Ottenbreit-Leftwich, 2013; Newhouse, 2008). I have classified the barriers as technical, personal experience and beliefs, organisational, and pedagogical.

Technical barriers are disappearing rapidly although it wasn't until the early 21st century that many were adequately addressed by improvements in hardware and software, and the advent of affordable wireless networking (Cox, 2012; Drayton, et al., 2010; Newhouse, 2001). Greaves and Hayes (2008) reported that robustness and larger screen size were now more important factors than weight, and that battery life was approaching the five hours thought necessary. There are often barriers using new technologies in old physical environments such as, inappropriate desks and a lack of power outlets (Hew & Brush, 2007). Also most devices are not designed for children to use and therefore are not adequately robust, requiring schools to typically maintain around 10% of devices as spares (Crawford & Vahey, 2002; Newhouse, 2008). Further, where devices such as laptops are used in more informal environments, ergonomics is a concern, but this may be addressed by careful design and management of student use of the devices (Straker, Maslen, Burgess-Limerick, & Pollock, 2009).

Technical barriers may be dissolving rapidly but unfortunately the same cannot be argued for non-technical barriers such as limited teacher skills and experience, constraining school organization, inflexible curriculum and pedagogy, and unhelpful perceptions, attitudes and beliefs (Ertmer & Ottenbreit-Leftwich, 2013). Largely these are barriers to any computer use, not just portable devices, and they tend to hark back to the rationale for computer use to support student-centred constructivist pedagogical practices. Hattie (2003) argues that in general the teacher accounts for 30% of variance in achievement by students, and therefore is the most important factor that can be influenced.

Personal experience and beliefs barriers are related to teacher skills, knowledge, and experience in facilitating computer support for learning (Hew & Brush, 2007; Means, 2010; Vanderlinde & van Braak, 2010). Having student-owned devices has tended to diminish the effect of teacher operational skills (Lowther, et al., 2012; Newhouse, 2008) although it has always been more likely that teachers with limited skills will feel inadequate and deskilled in computer-supported learning environments (Sandholtz, et al., 1992). However, teachers still require skills, knowledge and experience in what more recently Mishra and Koehler (2006) have referred to as TPACK (Technological, Pedagogical and Content Knowledge). That is, the capability to plan and implement computer use to support pedagogical strategies appropriate to convey particular curriculum content. This is critical, no matter how portable the computer technology, although it could be argued that increased portability provides greater flexibility for teachers in developing this capability. These TPACK capability obstacles can be readily addressed through the provision of targeted curriculum and technical professional support (Ertmer & Ottenbreit-Leftwich, 2013). Irrespective of knowledge, skills and experience differences there are typically some teachers who have a more positive active response to the potential of computer support (Hew & Brush, 2007). They tend to employ pedagogies, and create learning environments, that demonstrate constructivist-type beliefs (Berry & Wintle, 2009; Lowther, et al., 2012; Shapley, et al., 2010a). Teachers with more instructivist beliefs tend to only facilitate computer use for lower cognitive tasks such as information access and presentation (Drayton, et al., 2010; Ertmer & Ottenbreit-Leftwich, 2013) and quickly give up when they encounter obstacles (Hew & Brush, 2007; Newhouse, 1999). Inan, and Lowther (2010) estimated that teacher readiness and beliefs explained 0.84 of the variance in 'laptop integration'.

Organisational barriers are external to the teacher; in particular, school leadership, policies, practices and organisation (Hew & Brush, 2007; Means, 2010; Vanderlinde & van Braak, 2010). For example, school leadership may provide all students with portable computers, a high quality networked infrastructure, and "informed and consistent administrative policy" that encourages teachers to try new approaches (Drayton, et al., 2010, p. 44). Alternatively a school may have short teaching time periods, isolated teachers, and no computer use policies to guide practice; all of which mitigate against computer support for learning (Gardner, et al., 1994). I believe that these are obstacles that are relatively easily removed by school and school system leaders. For example, I have noted the value of a school appointing a 'Curriculum Director' who has the responsibility for supporting teachers in integrating computer support for learning (Newhouse, 2012).

Pedagogical barriers concern the relationship between the curriculum and teachers' pedagogical beliefs and practices. We have discussed the link between pedagogy and computer use, however, all aspects of the curriculum may either encourage or discourage teachers. For many, computer use is still seen as a dispensable appendage, "outside the curriculum" (Hill, Reeves, Grant, & Wang, 2001, p. 61), and yet initially school leaders aimed to support more open-ended and flexible curriculum (Loader, 1993). What teachers believe about the nature of teaching a particular section of the curriculum is likely to influence how, or whether, they use computers in their teaching (Drayton, et al., 2010; Hew & Brush, 2007). Where a curriculum is very prescriptive, with a focus on discrete bits of content, many teachers will see computer support as unnecessary. This effect is sometimes noticeable in differences in use between subject areas, dictated by subject 'cultures' and assessment requirements (Gardner, et al., 1994; Hew & Brush, 2007). It is not surprising that the use of computers is minimised where hand-written limited response exams predominate. I have consistently found that where the requirements of paper-based exams predominate teachers are less likely to implement computer support for learning; for example with older and/or higher ability students (Newhouse, 1998). I believe that at this time assessment policies and practices form the major remaining obstacles.

Decisions for implementation

When I started teaching in 1979 at my school I had access to one terminal and modem to connect to a mainframe computer. Today there is a bewildering array of options varying in size, capacity, speed, connectivity and cost. In deciding to implement mobile/portable computing there have been four main interrelated types of decisions to make.

1. The degree of operating environment standardisation.
2. The degree of user control.
3. The degree of hardware and software portability.
4. Ownership.

I believe the third decision type is now just a question of the best way to provide maximum portability to allow students access anywhere-anytime. For example, to what extent should students carry a device with software, such as a netbook or tablet, and to what extent should software and data be located independent of the device, as illustrated through 'cloud computing'? The day of the fixed paradigm where the student comes to the computer system in a laboratory is drawing to a close. There is now ample evidence that portable devices are the best way of providing ubiquitous access that enhances the invisibility of the technology, reduces a techno-centric focus, and better supports constructivist learning environments (e.g. Berry & Wintle, 2009; Murphy, 2011).

The first two types of decisions typically contrast computer system security and maintenance against computer-supported learning, and are a source of obstacles. Those responsible for the former tend to advocate maximum standardisation and minimum user control, while those responsible for the latter want maximum flexibility and independence. However, in the extremes a system with which nothing can be done is very secure and easy to maintain, while a system with no consistency or controls becomes chaotic and unusable. The control end of this debate is often associated with a 'thin client' model, in some ways harking back to the dumb terminal with which I started (e.g. Hew & Brush, 2007). Proponents of the use of highly standardised and centralised systems tend to borrow arguments from other industries. These typically fail to account for the substantial differences between the core teaching and learning functions of education, and the purely administrative functions. Thus, a balance is needed, to provide a system with enough user control and connectability to permit students and teachers to choose from a large range of options for computer support for learning.

Finally, there is the question of ownership that is related to the first two decision types. As the devices become increasingly portable and comprehensive, and less expensive, it is almost certain that they will be 'owned' by students and this will almost certainly encourage more meaningful use (Shapley, et al., 2010b). There are three main concerns within the ownership question: cost, security, and personal identity.

The cost of portable computers will always be more than an equivalent non-portable system. However, it has become more reasonable to ask governments, sponsors or parents to buy systems. Ultimately what is important is whether each student has his/her own computer, not who pays for it.

The security, both physical and logical, is of concern for all stakeholders. The physical security of personally owned systems becomes largely the responsibility of the user, but the logical security is largely the school's responsibility. The research is mixed on physical security with the outcome largely dependent on school management processes, but it is certainly less of a concern where the student owns the device. Logical security may present an increase in cost for school network maintenance but this is offset by the reduced responsibility for maintaining the devices (Newhouse, 1998). The much improved quality and availability of sophisticated network control tools have also readily addressed these concerns.

How children interact within their environments impacts on their sense of personal identity, including when using technology, and is critical for their healthy development. Personal computer systems have evolved to allow more personalisation and they are most productively used when they become a 'part' or extension of the user (Rowe, 1993). However, this will reduce the capacity of teachers and school support to provide operational help and thus students need to become more independent users (Donovan, Green, & Hartley, 2010). Traditionally the use of personally owned devices at school has not commenced below about 10 years of age with class sets of devices used with younger students.

Does it matter which device is chosen? Traditionally much time has been spent debating this choice. I have argued that decision-making should start with learning, not with the devices, and yet ultimately a student needs a device. Unfortunately, or fortunately, there is such a range of devices varying in size, power, storage, operation, appearance, cost and connectedness. What components of a system do students need to carry? Is a small mobile device that plugs into other devices and networks adequate, or should it at least include some applications software and data storage? The growth of 'cloud computing' applications and storage has supported small mobile devices plugging into larger systems. At the same time many mobile devices are used independently with small custom-designed applications (apps) for specific tasks. Ultimately it is not the particular device that matters, rather how its use supports a learning environment and types of learning activities (Ertmer & Ottenbreit-Leftwich, 2013). For example, with younger children a robust, small, and easy to manipulate device is required, perhaps a tablet kept at school. Older children need access to more sophisticated and complex software tools, so perhaps netbooks that connect to larger screens and input/output devices, carried between home and school. The reality is that increasingly most devices can do most things a student would need to do and therefore there may be many devices that are equally as appropriate. This is at the heart of the Bring Your Own Device (BYOD) strategy.

Conclusion

After over 20 years of evidence that has increasingly indicated the success of providing ubiquitous computing access through the use of portable digital devices, there is a basis for widespread implementation in schools. If we want to create more student-centred learning environments based on constructivist understandings, and if we want to empower children as learners, then we know we can use such devices to support these aims; assuming we also have reliable networks, adequate technical support, appropriate software, informed and effective school leadership, relevant curriculum, well-prepared teachers, and connected local communities. As for calculators in the 1980s, the reducing cost of the devices is increasingly suggesting that students should own their device(s). The perennial questions about which type of device and what components should be portable should be the last questions addressed after the vision and plan for how the technologies will be used to support learning is agreed upon.

Reflecting on my own struggles from 1979 to provide the technology that I have found so empowering, to empower my students, I have so often felt that we were near to the tipping point that would transform the learning experiences for children in our schools. Each time I have seen glimpses in some classrooms of what could be, but the big ship of schooling has hardly deviated. If turning the ship was just dependent on having the technology available then we are way past that point, however, it is more likely to depend on our collective will to evolve the appropriate pedagogical understandings amongst our teachers, school leaders and communities. Only then will we get the return on many decades of investment in digital technologies in schools.

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