Optimising the interaction of children with information and communication technologies

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Abstract

This paper outlines the major changes in the lives of children in industrially advanced countries associated with the increased interaction with information and communication technologies. The potential opportunities and threats to the cognitive, social, physical and visual development of children are reviewed to emphasise the importance of optimising the interaction. The change in children's use of technology also poses opportunities and threats for ergonomics that we should note if our profession is to continue being relevant and useful into this century. The paper ends with a pathway to the development and implementation of guidelines about child ICT use for different groups of guideline users.

1 Introduction

1.1 The ICT Revolution of Childhood

The capabilities of information and communication technologies (ICTs) are creating a revolution in education and in other aspects of children's lives. Foremost amongst the current generation of ICTs are personal computers, either desktop or laptop, with internet connectivity. Other common ICTs are palmtop computers, mobile phones, TV, video, console and hand-held electronic games. Children are using computers to perform tasks related to their occupation as a school student, to support their hobbies and leisure interests and to enhance their daily living. Toffler (1980) described an information based 'third wave' of human society following on from the agricultural and industrial societies. The magnitude of this change in society is only now becoming apparent, with the change in the lives of children a stark example. To

highlight the rapid evolution of ICTs and the impact this has had on what children do, one can compare a notional Australian 12 year old boy in 1953 and in 2003.

The 1953 boy rides his bike home after school carrying his science textbook and football gear. At school today he was learning grammar and long division by copying what the teacher had written on the blackboard and then writing it out several times with pen and ink. After a snack he rides to the neighbourhood library, meets his friends and looks at the two available encyclopaedias for their homework on clouds. They jot a few notes in pencil then spend the rest of the afternoon riding their bikes and climbing trees. He returns home at sunset and eats dinner then reads his textbook chapter about clouds and hand writes a page of pencil notes with another page of sketches copied from the textbook. After homework he listens to a comedy show on the family's new radio before bedtime.

The 2003 boy is collected from school in a car by his parent, with his school bag containing a laptop computer and football gear. At school today he was learning about different types of poetry and the use of statistics in advertising. For the poetry he worked in a group to find examples of free verse and rhyming verse on the internet, wrote a poem in each style collaboratively, then shared the poem with the sister school in Japan. On the way home he got an SMS message from his friend suggesting they start work on their homework project at 16.30. When he gets home he eats a snack whilst watching TV then logs on to the internet and e-chats to his friends about how to do their homework on clouds. He uses a digital camera to capture an image of the clouds outside whilst his friends search international bureaux of meteorology sites for images of other types of clouds and detailed information on cloud formation. They

then jointly type their 6 pages of notes, illustrated with images of clouds and print it out on a colour printer. While some of the group are finalising the document, the others are playing a virtual game. After homework and dinner he shares a couple of MP3 files and edits his playlist. Before bed he watches a DVD on his laptop.

The 2003 children's world is far more information rich, the social networks include local friends and virtual friends in other countries and their physical life is more sedentary.

For children in industrially advanced countries today, powerful ICTs are

- widely available,
- frequently used and
- used for long periods of time

For example, USA census data figures indicate that 71% of USA households with children aged 8-17 had a computer at home in 1999 (Turow and Nir 2000). In the UK, recent figures show that 77% of 14 year olds (Harris 1999) and 89% of a sample of 360 8 and 10 year old children from three UK schools (Mumtaz 2001) had access to a computer at home. And in Australia, an Australian Bureau of Statistics (ABS) (2000) report found that in the 12 months to April 2000, 95% of children aged 5-14 years used a computer at some time.

Children do not only have computers around them at home, but are using them frequently. The ABS study referred to above found that 85% of 12-14 year olds and 76% of 9-11 year olds used computers at least twice a week. Even children in the

younger age ranges were frequent users, with 63% of 5-8 year olds using a computer at least twice a week. Recently figures from a survey of a random sample of 1600 Western Australian children that have been tracked from birth (the RASCALS study) showed that at five years of age, 56% of them use computers each week (Straker 2001). In the study of UK children by Mumtaz (2001), 39% of 8 and 10 year old children were using the computer at home every day.

For some children, their frequent use of computers at home means that they spend a considerable proportion of their free time doing this single activity. The ABS reports that in the two weeks leading up to the 2000 survey, 13.6% of boys and 4.2% of girls aged 9-11 years spent more than 20 hours over those two weeks playing computer games. In Hong Kong, Ho and Lee (2001) found that 12-14 year olds were spending, on average, 137 minutes using a computer every day. In the USA, Turow and Nir (2000) found that 2-17 year olds with access to a computer at home spent, on average, 97 minutes on a computer or related technology each day.

The above figures indicate that our children today are faced with such changes to their daily activities compared with previous generations that we must seriously assess the impact on their health and wellbeing. This change in our children's lives also provides challenges for our profession.

1.2 Opportunity and threat for ergonomics

This revolution in ICT use by children provides an opportunity for ergonomics to become a significant part of the knowledge and skills of the next generation. However

there is also a threat that ergonomics will not be able to adequately meet the needs of this generation.

Ergonomics will need to change and adapt to meet these new needs. For example, in the 20th century ergonomics assisted technological developments to reduce the heavy physical exertions and thus helped ameliorate negative health and productivity outcomes for heavy industry. However, in the 21st century the major musculoskeletal disorder risk may be postural monotony from seated operation of computers. The provision of mechanical power rather than human power will not reduce these risks (in fact that approach has increased the risks) and other approaches will be needed.

It may also be a mistake for ergonomics to presume that the knowledge developed in the 20th century about adults using computers in offices can be applied to children using computers in the current decade. Much of that knowledge, and the standards and guidelines based on that knowledge, are now obsolete, as the computer hardware and software technology has changed, and as the way people use computers has changed. Further, children may use computers differently to adults (Harris et al. 2002). In fact the way children use computers may be our best prediction of how adults will use technology in the future.

Whilst some ergonomics approaches and knowledge may be obsolete, conceptually ergonomics is well placed to be of significant use to this generation. The focus on the interaction of people within a sometimes complex system provides a simple yet useful construct around which to develop knowledge of ICT use. Using this basis to direct

research, ergonomics can become a significant contributor to the quality of life of the next generation.

Ergonomics research should be targeting the interaction of children and ICT to develop an understanding of the complete system. Figure 1 illustrates the potential areas of impact of ICT on the child and highlights that each area may result in either positive or negative outcomes for the child.

Insert Figure 1 about here

2 Impact of ICT on children's development

2.1 Potential opportunities provided by ICT

2.1.1 Cognitive development

A number of studies have found ICT to have a positive impact on outcomes important to cognitive development such as critical thinking, problem solving and motivation.

The Apple Classrooms of Tomorrow (ACOT) project was a ten-year study to look at what would happen in a school when children were given unlimited access to technology. In several selected schools in the USA, Canada, Europe and Australia, Apple provided the technology and training to allow top-line technology use in the learning process. The results were impressive with improvements in learning

outcomes for children and great advances in learning approaches and motivation for the teachers (Apple 1995).

Although the examples provided by studies such as the ACOT project are impressive, they suffer from being largely case study designs and may mainly illustrate the impact of enthusiastic users of a teaching method on school children. Large-scale tests of the impact of ICT on children's learning and cognitive development have been more scarce. However, Attewell and Battle (1999) gained an objective assessment of home ownership of computers on school achievement by re-analysing the data from the USA National Educational Longitudinal Study of 1988 (NELS88) in which data on 18,000 children was available. They found a significant effect of home ownership of computers on Maths and English performance and school grade, even after controlling for socio-economic status, race, gender, family structure and social/educational experiences.

Most recently a major study of the impact of ICT on school children has been completed in England. The ImpaCT2 study looked at (amongst other things) the impact of school and home use of ICT on key learning areas for 700 children at ages 10-11, 13-14, and 15-16 from 60 schools across England. In all cases, children who were higher users of ICT had greater gains in English, Match and Science than those children who were low users of ICT (Harrison et al. 2002). These gains were particularly impressive as the usage of ICT was relatively low in some learning areas (and were reflected in reduced mean relative gains for high ICT users), but the pattern of results was consistent and persuasive.

2.1.2 Social development

ICT use for today's children is often synonymous with the use of the internet and email. These technologies emphasise communication and interaction and therefore offer children the potential to socialise in ways that have not been possible for earlier generations of children.

The computer can become a focus of social interaction for children, as observed by Heft and Swaminathan (2002) in a study of pre-schoolers using computers at school. They noted that the children would use the computer as a focus for social discourse and as a tool to encourage interaction with peers. Similar findings have been observed for teenagers playing computer games at home. Orleans and Laney (2000) report their findings of rich and positive socialisation for teenage adolescents using networked computer games to develop cooperative play, task-focussed communication and social problem solving and role playing. All these skills are important for children and are in contrast to the stereotype of the teenage boy alone in his room becoming more and more isolated and socially impaired.

Roberts, Smith and Pollock (2000) tracked new users of the internet over six months and found that the use of chat rooms led to a reduction in social anxiety and an increase in perceived social skills by users, including adolescents. They note that people's virtual world of communication can become fully integrated into their real lives and provide a social network for people who would, for reasons of geographical, psychological or physical limitations otherwise have impoverished communication with others.

Thus ICT provides varied opportunities for social interaction and social skill development. The potential for, in particular, adolescent boys, is that they are provided with a means of communicating with their peers and others that is otherwise unavailable either through a lack of social skills or opportunity.

2.1.3 Life attitudes and skills development

ICT use in childhood provides an opportunity to develop positive attitudes to interacting with computers and technology in general. Children who are exposed to computers exhibit low levels of computer anxiety (Todman and Lawrence 1992) and show strong positive attitudes towards computers and technology (Moseley et al. 2001, Somekh et al. 2002). Although boys and girls have been found to have different attitudes towards computers, with girls perceiving computers to be less interesting and useful than boys (eg Colley et al. 1994), there are some indications that these differences are decreasing with increasing use of computers by girls and an increase in girl-friendly software (Arrowsmith 2001).

The existence of positive attitudes towards computers will be likely to make future adults willing and happy to interact with the technologies available to them at the time, which will reduce barriers to employment and development of skills that are needed in future work.

Aside from generic computer skills, specific occupationally useful skills may also be developed through children's use of ICT, for example word processing, data retrieval and manipulation of numbers in spreadsheets and touch typing.

ICT skills important to personal selfcare may also be developed in childhood. For example information searching on the internet to acquire consumer information and internet interaction to perform personal banking tasks.

2.1.4 Fine motor development

Fine motor skills involve the coordination of visual perception and finger and hand movements. ICT interaction usually requires fine visual perception and finger dexterity and there is some evidence to suggest it may assist the development of fine motor skills in children (Yuji 1996).

The current evidence therefore suggests ICT use by children can have a positive impact on development, particularly cognitive, social and fine motor. However other evidence suggests there are some threats associated with ICT use by children.

2.2 Potential threats from ICT

2.2.1 Cognitive development

In contrast to the positive picture of ICT impact on scholastic achievement outlined above, other recent studies have produced very different results. So while the ImpaCT2 studies in the UK report positive outcomes for children using ICT at school and home, over a similar period the British Educational Communications and Technology Agency (BECTA) found no significant correlation between English and Maths attainment scores for children at age 7 and the level of ICT resourcing in schools (BECTA 2000). In addition Moseley, Mearns and Tse (2001) found a significant negative correlation between Maths attainment and time spent using a

computer at school. The apparent conflict between the results of Moseley, Mearns and Tse and those from the ImpaCT2 study can be explained when the nature of ICT use is compared. The ImpaCT2 study looked at ICT use related to specific academic outcomes (such as time spent using a computer for Maths-related activities), whilst the Moseley study looked at total time on the computer. What Moseley et al.'s study showed was that a large proportion of children's computer time was spent playing games and it was specifically the game-playing time that correlated with the decreases in attainment.

It appears that if children are given the freedom at school to play games rather than engage in school-related activities, that the potential positive outcomes of ICT use on cognitive attainment may be lost. Such an outcome is understandable if teachers use ICT as a means of distracting troublesome children in the class so that they can allow the majority of the class to progress towards educational goals. In these cases the social and educational environment impinges on the potential for technology to assist children develop cognitive skills.

Similarly, from a wider educational perspective, there is the potential threat that large-scale compulsory ICT use may channel a substantial proportion of finite educational budgets to ICT hardware and away from other projects. In certain child-teacher-educational environment systems, the trade off between expenditure on ICT needs and other needs may produce poorer educational outcomes for children and threaten the enthusiasm and morale of competent, professional teachers.

It is possible that the early evidence demonstrating positive impacts on educational development has been from a specialised group of technology-enthused 'early adopter' teachers. As ICT integration becomes expected of all teachers, some of whom will be less motivated to apply it to its full potential, it is likely that students will not gain the same positive results. Educational authorities are currently concerned about this threat and many have embarked on substantial professional development programs for teachers. For example in Queensland, Australia, certain schools have been earmarked as Centres of Excellence, which provide a resource for teachers from adjoining areas to provide examples of top class pedagogy. These schools include ones highlighted for their use of technology.

The potential for improvements in cognitive development may therefore not always be realised. This potential limitation should be used to temper the enthusiasm of technology advocates who view ICT as a panacea for educational ills to allow a more considered view of the impact of technology on children's cognitive development.

2.2.2 Social development

Many sections of the media have voiced concerns about the potential damaging impact of ICT use on children's social development. The image of the teenager stuck in their bedroom for hours each night, unable to socialise with their peers, parents or teachers is one that fills many parents with dread. Reports of computer addiction to electronic games and parents' apparent lack of power to change their children's habits creates a concern in the community that ICT can have a negative impact on social development.

In reality there is little research that shows that there are detriments in social skill development. Many of the changes in children's behaviour seen by parents may simply reflect the normal withdrawal that adolescents exhibit generally in their teenage years. The fact that some adolescents choose to withdraw to their bedroom may be independent of the availability of ICT. Roberts, Smith and Pollock (2000) report that shy individuals who used the internet for six months showed significant reductions in their shyness, suggesting that the internet and the use of on-line communication strategies was beneficial, not detrimental for shy people. They argue that 'computer addiction' may be better seen as a phase of intensive use of computers as individuals become fascinated with ICT's potential, but that the vast majority of individuals will pass through this phase and either become bored, or integrate the use of the technology into their everyday lives such that their social functioning is not impaired.

Although poor social skill development may not be associated with computer use, there are genuine concerns amongst public health and welfare professionals that children may become unknowingly the targets of Internet predators and paedophiles. Police groups in many countries have issued warnings about 'safe' internet use that protects children from unwanted interactions. For example, the Federal Bureau of Investigations offers parents advice on how to protect children whilst on the Internet (Federal Bureau of Investigations, 2002) and the UK Home Office has recently started a KidSmart Initiative which will deliver advice to children between the ages of 8 and 11 about how to surf the 'net safely. Sadly, in a global communication world, children can access all parts of the world and all sections of society within the world. They

need to be taught skills to protect themselves from danger that would not be needed when they are in restricted and controlled physical environments.

2.2.3 Life skills and attitudes development

Whilst well managed interaction in childhood may result in positive attitudes to ICT, negative attitudes may develop if children's early experiences are poor. There is therefore a threat of wasted community and family resources where large investments were made in providing ICT access only to result in children developing an aversion to ICT use. Further, if ICT is used unwisely, children may develop restricted attitudes to the potential of computers that may impede their innovative use of ICT as adults.

Such an outcome may result if significant computer anxiety develops from a child's interaction with ICT. This could occur because computer anxiety does not always decrease with increased exposure to computers. Anderson (1996) found that, although computer anxiety correlated with computer experience, perceived computer knowledge was a better predictor of the level of anxiety felt by a user. Anderson notes that many users of computers may have spent many hours interacting with a computer system, but may know little about how the computer operates. Under these circumstances, anxiety may increase for users if they enter a different computer environment. Gos (1996) supported these findings with the observation that ratings of unpleasantness of previous computer experiences correlated significantly with perceived computer anxiety.

The lesson from these studies is that the quality of the experience for a child using the computer will direct the level of anxiety they experience when using ICT. A child

who is anxious about using a computer may be less willing to explore new technological advances and thus limit his or her ability to exploit these advances as they occur.

2.2.4 Gross motor development

One of the most widely publicised threats associated with children's use of ICT is the negative impact on physical health (Armitage 1999, Hancock 2000, Straker et al. 2000, McGrane 2001).

Recent studies have found that a substantial proportion of children report discomfort associated with significant amounts of ICT use (Harris and Straker 2000). Discomfort is used as an early indicator of the development of activity related musculoskeletal disorders and whilst the majority of children report mild levels of discomfort, some children have reported severe discomfort (Straker 2001). Neck and upper limb is the most common location, followed by low back (Balague et al. 1999, Straker 2001, Hakala et al 2002). This early evidence is disturbing as this pattern is similar to the problems reported in adult workers.

Part of the risk of musculoskeletal disorders may be associated with children using ICT in workstations either designed for adults, or not appropriately designed for children (Laeser et al. 1998, Oates et al. 1998, Zandvliet and Straker 2001, Barrero and Hedge 2002). A recent laboratory study has provided clear evidence that the physiological and biomechanical stresses associated with children's use of computers are different to those experienced when children work with paper (Straker et al. 2002).

However the lack of postural variety may be the greatest risk factor (Mathiassen and Christmansson in press).

Aside from the direct stresses on the neck and upper limb and low back associated with ICT use, there is also a health threat from increased sedentary activity. Moderate and vigorous physical activity is declining in children (ABS 2000, NCHS 2000, Cavill 2001). Physical activity is important to normal musculoskeletal development in children (Bauman et al. 2002). There is concern that increased ICT use will further reduce physical activity which may result in this generation of children never developing musculoskeletal systems as strong as previous generations. This is likely to increase the risk of osteoporosis and other musculoskeletal disorders. Reduced moderate to vigorous physical activity has also been associated with other significant causes of morbidity and mortality including coronary heart disease, diabetes, colon cancer and depression (Janz 2002, Pate 2002). There is a lack of research on light to moderate activity with high postural variety in children, yet this type of activity may form part of appropriate stresses necessary for normal tissue development.

2.2.5 Vision development

A further potential threat to children's development may come from extensive focussing on close objects which may strain the visual system and result in structural changes to the orbit creating myopia. There is some evidence that excessive book reading may result in refractive changes in the eye and a recent study found evidence of refractive changes associated with computer work (Tan et al. 2000).

The evidence therefore suggests there are real threats to the cognitive, social, physical and visual development of children from increasing ICT interaction by children. It is therefore vital that the interaction is well understood to enable its optimisation.

2.3 Factors influencing the nature of the ICT –child interaction

An essential aspect of the ergonomics view is that the interaction of humans is complex and multifactorial with many elements within the system influencing the nature of the interactions. Much of the past research on children and ICT has been limited by a focus on single elements in the system and single system outcomes. However there are clear indications of the system elements that may impact on the nature of the interaction. Critical elements include the individual child, their peers, supervising adults, the technology used, the task performed and the context within which it is performed.

The child and ICT elements, such as anthropometrics, age, and gender, for the child and hardware and software design for ICT, may be taken as read. However we wish to highlight the potential for other factors outside the simple system to influence the interaction. The purpose of this section is not to provide a complete review of these factors, but to highlight their existence and therefore the necessity to consider them within any evaluation of children interacting with ICT.

Supervising adults such as parents and teachers can have considerable influence over children's interaction with ICT. Within a school context teachers can influence the ICT hardware and software, furniture and environment to some extent, but have more influence over tasks performed and how those tasks are organised. Parents also influence the purchase of technologies and have varying levels of influence over what tasks are performed and when.

Peers are a very powerful influence on children's attitude and behaviour. Anecdotal evidence suggests children desire ICTs which have high value within their peer group. Peer ICT ownership and use provide common opportunities for children to learn skills and attitudes**.**

The technical development of ICT hardware and software has resulted in increasingly capable computers. This increasing capacity fosters increased use, making optimisation of the interaction more important. Miniaturisation has created portability and new opportunities for increased ICT use. However miniaturisation has also resulted in more constrained postures during use. Horizon technologies of large wall screens, speech input, and remote pointing may offer greater postural variety.

Tasks commonly performed by children using ICT include: searching and retrieving information using internet browsers, writing and production of documents using word processors, drawing and manipulation of still and video images using graphics packages, using spreadsheets for mathematics and representation of numbers in graphs, playing games for entertainment and using mail software for email communication.

The context of use incorporates the purpose and environment of use. The purposes for performing these tasks include school work/ home work, own interests/studies, and communication/self care. Common environments of use include school classrooms, home offices, and increasingly bedrooms and living rooms as ICT become more portable. Within school classrooms there is a wide range of ICT integration, from computers being electronic babysitters for children out of step with class processes to computers being integrated into a substantial proportion of learning tasks within the classroom.

All of the above elements must also be considered within a temporal context. Children's needs and ways of interacting with ICT and the relationships between all the system elements will change rapidly as both the child and the technology develops. The way that system elements interact and impact on each other will be very different for a 5 year old child today than for a 5 year old in five years time or for the original 5 year old at age 10.

Figure 2 tries to capture these social and technical elements into a model of children's interaction with ICT and is based on adaptions to the classical ergonomics human-machine interaction model by Harris et al. (2002).

Insert figure 2 about here

3 Pathway to Evidence Based Guidelines

A basic assumption in ergonomics is that knowledge derived from scientific exploration can be used to guide the development of more optimal interactions between people and technology in all its forms, and that this approach is more efficient than trial and error. Thus an important role for ergonomics is the provision of advice to key players in the optimisation of the interaction between children and ICT. Whilst different information may be of use to different players, certain principles may apply whoever the guidance is prepared for.

3.1 Principles

We believe that guidelines should be developed using the following principles:

- Transparent supporting evidence
- Culturally sensitive
- Not limited to current technology
- Balance outcomes
- Living
- Edited to suit target groups

Guidelines should be based on the best available evidence to maximise the correctness of the guidelines. There is a threat to ergonomics that it receives widespread publicity for a guideline that subsequent research finds to be incorrect (for example the widely promoted recommendation for computer displays to be at sitting eye height is currently under threat (Pollock and Straker 2003)). The trust the public has in ergonomics would then be shaken, and the uptake of future guidelines diminished as

people wonder whether these too will be found to be incorrect. Thus ergonomics needs to be open and honest in the quality of the evidence to support each guideline. There are therefore likely to be guidelines which are supported by a range of good quality research sources, and other guidelines which are only supported by the opinion of some researchers. Guidelines users can then focus their resources knowing the surety of the guidelines.

However being too conservative in describing gained knowledge risks isolating ergonomics to the ivory tower, whilst disciplines willing to sell simplistic messages are more likely to get the media, and thus public and governmental attention. An alternative approach is to be more definite in our uncertainty. The approach taken with the weather forecasts and outlooks in several countries could be fruitfully examined. Weather forecasters recognise that they can never predict the weather exactly, but they can predict the likelihood of rain on a particular day, or over a particular period of time. Similarly, whilst ergonomics cannot be certain about the impact of a particular risk, we can make reasonable estimates of effect sizes and thus be able to offer users information on the relative likelihood of a particular outcome. This would have the double benefit of providing the users with better information, but also of portraying ergonomics in a positive light.

Guidelines should be culturally sensitive. Ergonomics has tended to be ethnocentric in the past, with little consideration of the physical, mental and social diversity of humans outside major European and North American groups. (For example the ergonomics literature on seating consistently assumes that chair sitting rather than floor sitting is the norm (Gurr et al. 1998)).

Guidelines should try to be based on general principles rather than current technology. The development of ICTs is likely to continue to be rapid, making technology-based research obsolete before it can be promoted as guidelines. Principle-based guidelines can also help technology developers to develop new technologies better suited to human needs.

The multiple areas of impact ICTs have on children suggest that there will be trade-offs between the benefits and losses associated with ICT use. For example there may be a broad trade-off between cognitive development and gross motor development, with better learning outcomes coming at the cost of poorer skeletal development. Thus the guidelines should assist users in balancing the outcomes.

As the knowledge base will never be perfect, and new technologies may create new interactions not adequately predicted by current knowledge, there will be a need for ongoing research and a need for the guidelines to be continually reviewed and renewed based on available evidence. A useful approach could be that used by the Australian Department of Foreign Affairs and Trade when issuing travel advices. Advices are supplied with the information that they are “current for (today’s date)”, when they were last reviewed and when they were last changed. This information would provide users with greater information about the currency and permanency of each recommendation.

Finally the guidelines should be developed for different users and be prepared with content and style appropriate to the user. As the needs of a furniture manufacturer,

early childhood teacher and teenager are different, guidelines need to be targeted for each specific group.

3.2 Development Process

Figure 3 represents a process for the development of evidence-based guidelines. The basic principles and specific guidelines should be developed based on quality research and be peer reviewed and discussed within the scientific community. A key purpose for the review and discussion is the detection of invalid or obsolete assumptions and the identification of gaps in the current knowledge requiring research. Following the achievement of some consensus, draft guidelines should be prepared and reviewed by the various target audience groups. This audience/user review should cover both content and style. Several iterations may be required to develop guidelines suited to users. Once developed the guidelines should be widely promulgated. Given the broad community interest in this area already demonstrated, ergonomics may be more successful than previously in using the mass media together with interactive ICTs to promote and distribute this knowledge. Alongside the promulgation there should be a strategy for the education of critical players: children, responsible adults, ICT industry and education authorities.

Finally, there needs to be a monitoring of the nature of ICT use and key outcomes. Currently very little is known about how children use ICT. We also need to better understand what ICT use means to children and what factors influence children's use of ICT**.** Ergonomics research should be monitoring technology trends to try to predict changes in use and monitoring actual usage patterns. Further, leading indicators of cognitive, social, physical and visual development should be developed and

consistently evaluated across diverse populations to improve our understanding and be early indicators of trends which need to be addressed.

Insert figure 3 about here

3.3 Implementation

Whilst there are considerable scientific hurdles to the development of guidelines supported by good levels of evidence, such guidelines will be of little value to people unless they are implemented. Again this is a threat to ergonomics, not only must the science be good, but so too must the translation of the acquired knowledge into practice. A systems approach suggests all elements in a system are important and thus guidance to equipment designers, education authorities, children etc. are all opportunities to optimise interaction The essential question is, How to get audience groups to follow guidance?

The optimisation of the interaction between children and ICTs will depend on various groups each implementing guidelines. However different groups may be encouraged to implement these guidelines with different approaches, as illustrated in Figure 4.

Awareness of the importance of the interaction between children and ICT needs to be developed amongst each group that contributes to the interaction: ICT producers, schools, teachers, parents and children themselves.

Education about the effects of the interaction also needs broad promulgation. Perhaps the most difficult area to influence in this respect will be home use of computers. Hence parental education will be a useful strategy towards optimising use. However there will also be a reliance on children themselves developing the knowledge and skills to use ICT appropriately. This will be a difficult task for ergonomics, as the broad introduction of ergonomics into children's education has only received small attention in the past. This need also presents a substantial opportunity for ergonomics to become a central skill for the future generation.

Teachers and schools can be guided to acquire and use ICT appropriately through the additional development of education policies and codes of practice. For example schools can include hardware and furniture guidelines in tender documents and teachers can be encouraged to facilitate postural change by scheduling task changes every 20-30 minutes.

Finally ergonomics experience has shown that designers and developers of technology can be guided to produce better products using standards and legislation. For example, children's game software developers could be required to build into their game rest break strategies to help children take breaks from the game and game hardware developers could be required to minimise vibration developed in simulator controls.

Through these four implementation strategies, each prime sector of the child-ICT system will be working towards the harmonious use of technology for the children's future well being.

Insert Figure 4 about here

4 Conclusion

The increasing use of ICT by children in industrially advanced countries offers an unprecedented opportunity for ergonomics to become a central part of life skills for the next generation. It offers the opportunity for ergonomics to escape from its conventional constrains of being focussed on adults in occupational settings. It offers the opportunity for ergonomics to engage with people and become a part of their daily lives. This major change in society also carries a threat to ergonomics. If the ergonomics knowledge base is not updated to the new situation, if obsolete information is used and poor outcomes result, there may be a societal disenchantment with ergonomics resulting in it being marginalised.

Whilst a failure to adequately optimise the interaction between children and ICT may signal the failure of ergonomics, more importantly it may result in a major lost of quality of life for many of this generation of young people. The resulting individual and community mental, social and physical health costs may be crippling to industrially developed countries. However, if ergonomics can conduct good science and aid in translating the gained knowledge into widespread practice, the interaction

of ICTs and children could be well managed thus enabling the realisation of opportunity for improvement in quality of life that this major change creates.

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List of Figures

Figure 1

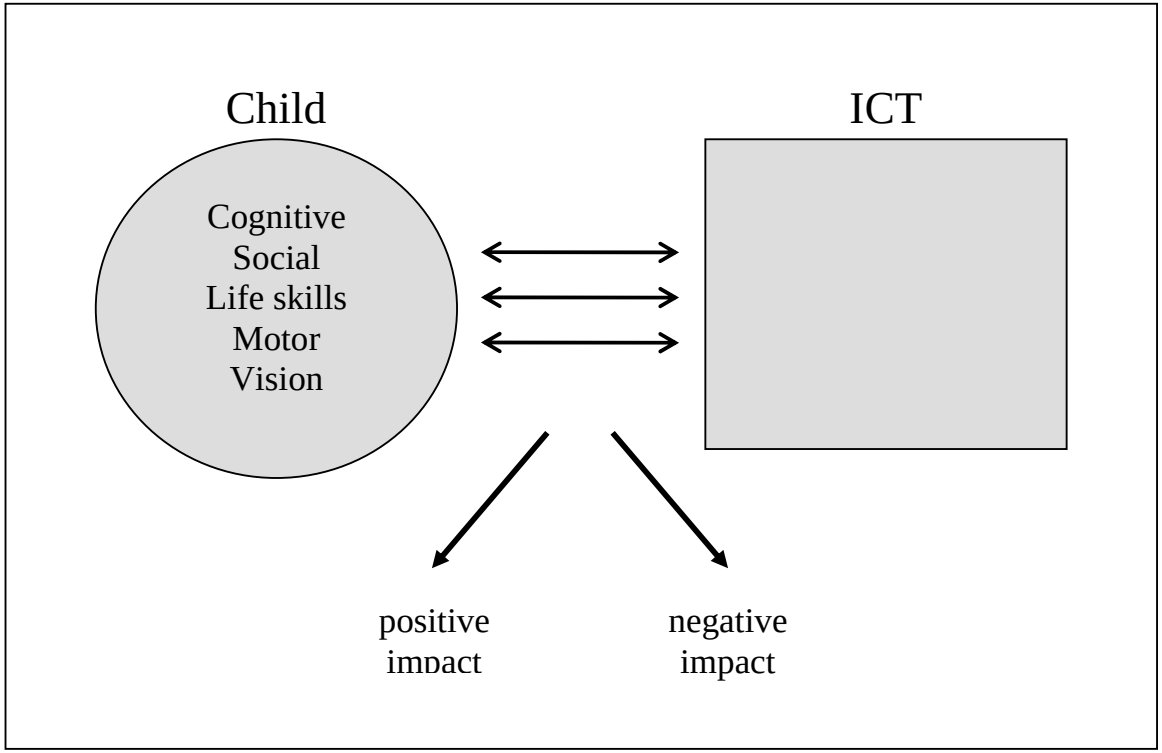
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Figure 2

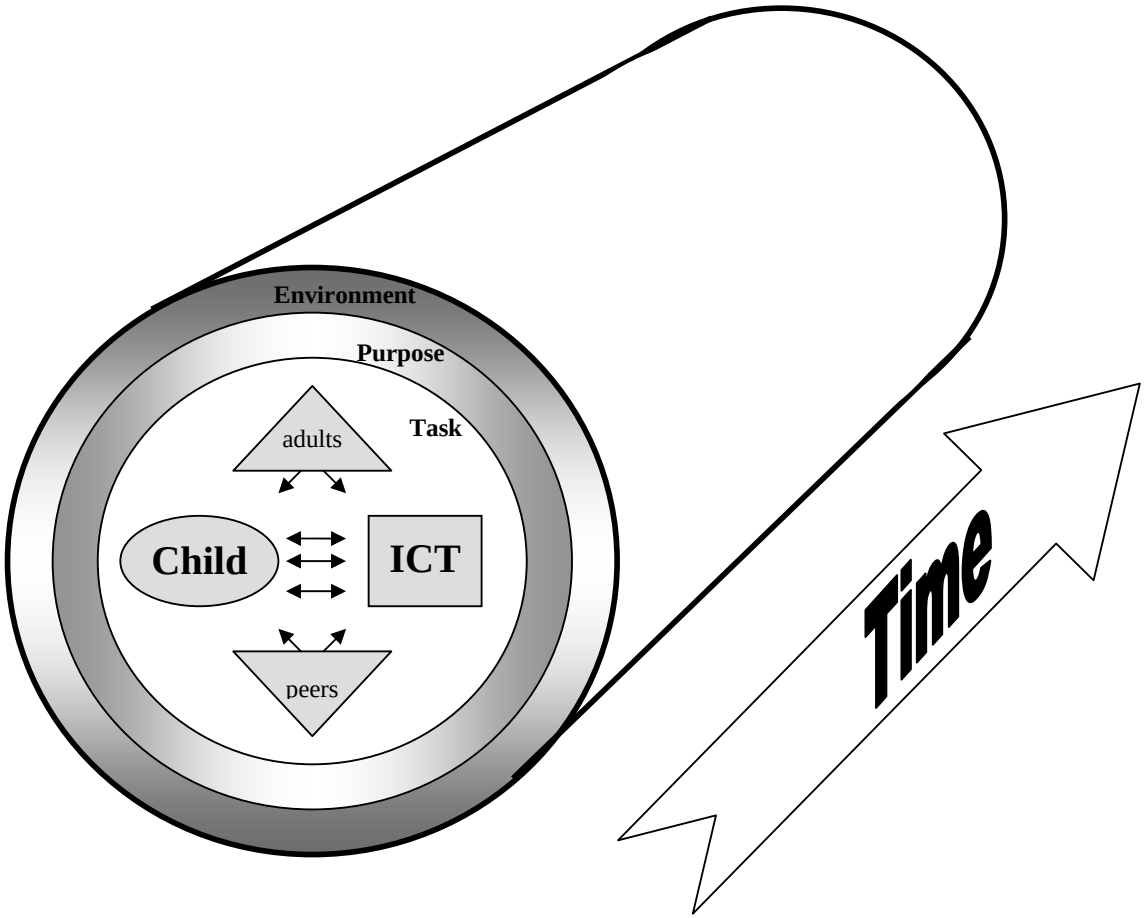
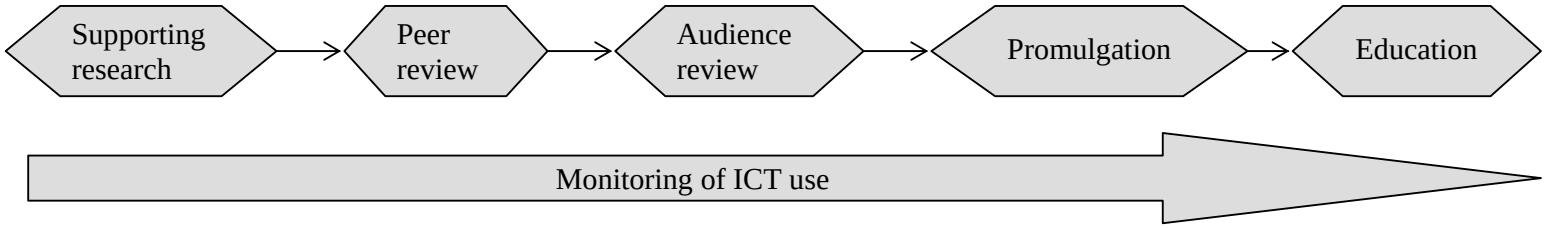


Figure 3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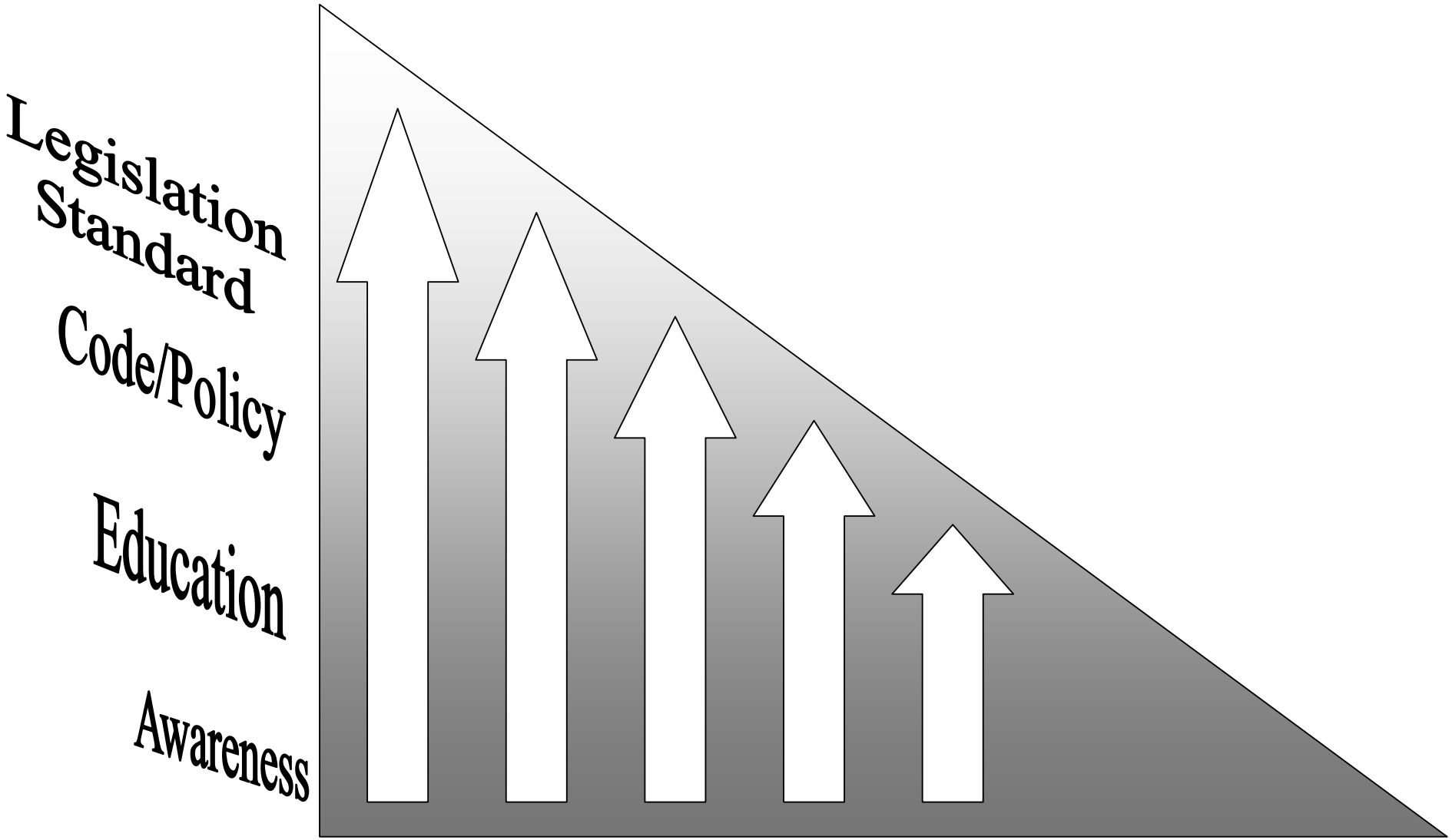
Legislation
Standard
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Awareness