Investigating Choices of Appropriate Devices for One-to-One Computing Initiatives in Schools Worldwide

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***Abstract*—The use of technology in schools is rapidly increasing – today most notably through the one-to-one (1:1) programs that are being implemented all around the world. Considering how new technologies are emerging fast and obsoleting others in schools, there is a need to continuously monitor and understand the features of various devices in terms of embedded technology and interaction with users. This paper therefore presents the nature of computing devices used in 1:1 computing programs in schools around the world, including investigating the benefits and drawbacks, by means of a systematic literature review and a survey conducted in some schools in Sweden. The paper also presents findings based on how the various uses of technology affect cooperation practices as well as personal exploration.**

***Index Terms*—One-to-one computing, computer integration, constructionist learning, one laptop per child, 21st century skills.**

I. Introduction

The idea of 1:1 (one-to-one) computing has become an important topic in education in recent time, not only because of the advancement of new ubiquitous technologies, but also for its pedagogical importance especially when it comes to constructionist learning. '1:1 computing' generally refers to the use of a computing- and communication-device as a personal tool in school-work by an individual student irrespective of time and location. This definition is compatible with the concept of 'ubiquitous computing' that includes laptops, tablets, and other handhelds devices that are designed to function with internet and in free mobility.

In the field of education it has often been argued that using technology may facilitate a shift towards a more constructivist [1] or collaborative pedagogy [2] and those teachers are challenged to support collaborative learning in new ways [3]. According to constructivist theories, learning is an active act of producing reality (knowledge) as opposed to passively receiving it. However, how this production of reality is theorized differs between different versions of constructivism; from the individual/cognitive focused constructive subjective psychology to cultural/social focused on the production of realities through interaction and collaboration [4]. For one version of constructivism, Seymour Papert [5] has been important in establishing technology's role for constructionist learning. According to him, 'learning' is seen as a process of "reconstruction rather than as a transmission of knowledge" [6]. Papert in this regard suggested that learning processes in schools should be governed by "creating an environment in which the child will become highly involved in experience of a kind to provide rich soil for the growth in intuitions and concepts for dealing with thinking, learning, playing, and so on" [5]. In this direction, one of the first practical initiatives on implementing constructionist learning for children with computers was the development of programming language called 'Logo' in 1967. Following such initiatives, Alan C. Kay, who was closely associated with Papert for promoting and implementing computer based educational constructivism, developed a laptop computer for children in 1970 based on the sketches of the KiddiComp called 'Daynabook'

In 1990, the Methodist Ladies College (MLC) in Melbourne, Australia became the pioneer of implementing 1:1 when they introduced laptop computers for students from 5th to 12th grade [7]. Afterwards, there have been many implementations of computers for school children worldwide - mostly located in USA. Probably, the most intriguing examples on implementations of laptop program are (1) the distribution of 32000 Apple's iBooks for all Maine (USA) 7th and 8th grade students in 2002 and 2) introduction of XO (100$) laptop in 2006 by 'One Laptop per Child' (OLPC), a US-based non-profit association pioneering in designing as well as promoting low-cots laptops, specially designed for the children of developing regions. Apart from the Maine initiative [8], which has been the inspiration for other programs, there has been a lack of thorough impact evaluations. This is a shame because the findings from Maine showed that impact on learning is associated with complex implementation issues. Other impact-studies have shown positive, negative and even 'no-effect' in case of students, teachers and teaching, the classroom environment, and community. Commonly mentioned positive impacts on students are increased 'engagement and motivation' [9], [10], 'quality of academic work and achievement' [11], [12] and 'independent learning' [9], [13], [14]. On the other hand, distractions [15]-[17], insignificance to academic achievement [18], [19], psychological as well as physical strains [20], [21], and over-dependency on computers [22], [23] are some of major negative impacts.

With the overwhelming speed of technological innovation, new tools are emerging fast and obsoleting the existing ones, for example, a transition from desktop to ubiquitous computing devices. Chan *et al*. [24] in this case state that we need to explore new and powerful properties for 1:1 technology as learning environments transform from desktop to progressively powerful portable devices. Each type of device with common core functionalities is embodied with certain features specific to certain models. The models that are being used in 1:1 programs usually depend on the scope

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and constraints of the programs in certain learning contexts. While 'scope' is generally aligned with the short and long-term learning goals, in most cases, this tends to compromise with the affordability, accessibility as well as availability of resources (e.g. financial, technical infrastructures) in a specific time period. Therefore it is important to understand the nature (embodied features and use) of computing devices used in 1:1 programs so we can plan for deploying appropriate tools during the implementation.

Given this contextual background, this study investigates several aspects (e.g. features, use, benefits and drawbacks) of various computing devices deployed in 1:1 schools - in general by means of a comprehensive content analysis available online, as well as using data from a 3-year project (case study) researching the 1:1 use of computers in some schools in Sweden.

II. Methods

This is a qualitative study based on a literature review as well as survey-data from a large research project investigating the use of computers in 1:1 schools in Sweden. We have used Webster and Watson [25] as well as Okoli and Schabram [26] guidelines in order to ensure a rigorous review process. The keywords that we used during the search were 'one laptop per child', 'one-to-one laptop program in schools', 'one-to-one computing ', 'computers in the classrooms', and 'one-to-one computing devices'. We also alternatively used '1:1' instead of 'one-to-one' after an initial search. We started the search with those key words through some major journal databases (e.g. ABI/Inform, EBSCOHost). However, although some literatures were useful for understanding contexts and phenomena, there were comparatively few that described the devises used in 1:1 programs. Therefore we used 'google search' with the same keywords and found some relevant literatures even though those were mostly evaluation and promotional reports published by state or provincial offices, NGOs, vendors (e.g., Intel), and academic research centers worldwide. Given the relevance and importance to the subject under investigation, we have also included findings published in some online articles, interviews and dissertations. After going forth and back in the review process, we sorted and grouped the findings under certain categories in accordance to the 'concept centric' guidelines of Webster and Watson [25].

In regard to the case study, we have been part of a research project during 2010-2013 investigating the effects of the implementation of 1:1 in schools. This research has taken place in Sweden in an environment where the distribution of computing devices is rapidly increasing in schools. There were 18 participating schools in this project and it was decided that a group of researchers from both Educational Science and Informatics should follow the development of these schools over a period of three years. During these three years the research group has monitored and analysed the effects of the 1:1 initiative. Evaluation criteria related to students' learning and development, teachers' roles and methods, school management's steering, and school-home relations. In our research project we annually send out surveys to teachers and students. For comparative reasons, most of the questions were the same. However, due to the frequent discussions in schools about what technology to invest in, we included questions about technology use in the last survey (2013). All surveys had been on-line and linked to the surveys were distributed to teachers and students via e-mail. In 2013 the teacher survey yielded 455 answers representing the 18 schools in Sweden. The student survey was designed in two different ways in order to allow for age differences. One student survey was distributed to compulsory school students (ages 10-15) and one to upper secondary level schools (ages 16-18). 18 schools participated and altogether 2523 students responded to the survey. The general approach in regard to data analysis was to summarize closed-ended questions in the surveys in percentage numbers. In cases where scale based qualitative measures (ordinal data) were used, the median was calculated. We have also made a qualitative analysis of the comments from the teachers on the benefits and drawbacks of the technologies in use.

III. Results and Discussion

The introduction of technology in schools has apparently been pushed by technology developers and also by a need for schools to reflect the increased use of technology in our society as a whole. Since the 1990s, school education programs around the world in general have been demonstrating their immense interest in integrating classroom technologies in order to improve learning from the predominant traditional settings in many ways – however often drawing on the constructionist ideas. For example, in the Maine program, the Task Force [27] laid out clearly that "true integration with Maine's Learning Results requires a program not focused on learning about computers, but a focus on using computer technology as a tool to learn problem-solving, critical-thinking, teamwork and communication skills across all content areas, and encouraging teachers to adopt this kind of approach" [27]. Often the 1:1 programs have been associated with skills that are considered "new", not part of the traditional school curricula, earlier often called 21st century skills, such as critical thinking, communication and teamwork skills. For example, the Michigan 'Freedom to Learn (FTL) program stated five goals, four of which are not core curriculum goals, and even the fifth (number 1) points beyond the core curriculum to new types of skills required in the 21st century:

1) Enhancing student learning and achievement in core academic subjects with an emphasis on developing the knowledge and skills requisite to the establishment of a 21st century workforce
2) Providing greater access to equal educational opportunities state-wide through ubiquitous access to technology
3) Fostering effective use of the wireless technology through systematic professional development for teachers, administrators and staff
4) Empowering parents and caregivers with the tools to become more involved in their child's education, and sharing of best practices among participants
5) Supporting innovative structural changes in participating schools and sharing of best practices among Program

participants [28].

Also adhering to the constructivist theory, the mission statement of OLPC highlights two important expectations – children's 'self-empower learning' and their engagement in 'own education'. In the latest Swedish national curriculum [29], the same skills are addressed in addition to stressing the need for developing knowledge in using digital technology. The study by Melhuish and Falloon [30] on mobile learning (iPad in their case) finds five distinct affordances of mobile devices for education that could enhance the area of constructivist learning. These are – portability, affordable and ubiquitous access, situated or 'just-in-time' learning opportunities, connection and convergence, and individualized and personalized experiences.

IV. Categories of Adopted Devices in 1:1 Programs

In complement to the Richardson *et al*. [31] study, we find that the devices adopted in 1:1 programs in schools can broadly be categorized into the four categories (Table I), such as low-end subnotebook, full-size standard Laptop, Tablet pc and Handheld. While there are many common features embedded in these devices, they are different to each other generally in terms of data processing speed, price, display size and weight, runtime battery life and specialized functionalities. According to our literature review, it is not exactly known why a certain type of computing device is used for a certain educational program. However, this can be apparent that altogether there are five broad issues that play an important role in the implementation decisions. They are: educational development policy agenda, availability of adequate funding and budget, affordable cost and suitable features of the devices, offers/proposals from the vendors, and influence of the donor agencies and NGOs. According to ITU [32] the implementation of low-cost computing devices (LCCD) in schools is a complex undertaking as it has an impact on classrooms, teachers and teachings, distribution of educational materials and curriculum, school funding and infrastructure. The infrastructures in this case generally include physical, social and cultural resources, such as electricity, buildings, furniture, connectivity, management, technical support, pedagogical support and parental involvement [33]. Due to such complexities, developing countries generally implement computers in education projects with several partners under the overall coordination of the country's ministry of education. In this regard, international organizations, such as 'Mobile for Education Alliance', which includes among many USAID, World Bank, Inter-American Development Bank, Internet Society, UNESCO and UNICEF, contribute significantly on supporting identification and applications of mobile technologies for the wide range of educational development. Due to widespread popularity of portable technologies and their potential use in the educational reforms, 1:1 program has even become a political agenda.

TABLE I: General Categories of Computing Devices Used in 1:1 Programs

Indicative Properties	Low-end Subnotebook (Netbook, Mini Laptop)	Standard Laptop	Tablet pc	Handheld
1:1 examples	OLPC's XO, Intel's Classmate, Asus Eee, HP2133, Lenovo IdeaPad S9/S10, Acer Aspire one	Apple MacBook (replacement of iBook); Lenovo X230 and ThinkPad X41; HP625,6730b, 4520, and 4720; Dell Latitude E6400	XO Tablet, Apple iPad, Aakash (US$35), Acer Iconia, HP TouchPad, HP ElitePad	Personal Digital Assistants or PDA (iPOD Touch, Palm, Acer N Series), Smartphone
Price	200 – 675 US$	400 – 2150 US$	130 – 1200 US$	50 - 1200 US$
Speed (CPU)	0.90 – 1.60 GHz	1.80 – 2.50 GHz	0.80 – 1.60 GHz	0.20-2.70 GHz
Display size	18 - 26 CM (7.0"-10.0")	30 – 43 CM (12.5" – 17.0")	18 - 29 CM (7.0" – 11.6 ")	7 - 13 CM (2.6" -5.2")
Weight	0.90 - 1.58 KGs (2.00 –3.50 lbs)	1.30 – 3.00 KGs (2.86 – 6.60 Ibs)	0.30 -1.00 KGs (0.68 – 2.20 lbs)	0.088 -0.200 KGs (0.19 -0.44 lbs)
Battery runtime	3-10 Hrs	3-25 Hrs	7.5 -10 Hrs	4.5 – 10 Hrs

A. Low-End Subnotebook

The low-end subnotebook, which can also be described as 'mini notebook', is generally characterized by inexpensive and ultraportable low powered smaller netbook designed for specific purposes, especially for education. Notable examples in this category include, the XO PC designed and distributed by OLPC and the 'Classmate' PC which is based on the reference design of Intel's Learning Series with the partnership of Lenovo. Some other low-end subnotebooks adopted in 1:1 programs include Intel powered Asus Eee PC (700, 901) which is reported to be used in some primary schools in USA [34], [35], Slovakia [36], and in several regions across Russia [37], HP 2133 in Switzerland [36], Lenovo IdeaPad S series (9 and 10) in Australia and Slovakia [36], [38], and Acer Aspire One in Australia [38] and Ethiopia [39].

According to an investigation on a country-wise large scale 1:1 initiatives worldwide carried out by Richardson *et al*. [31], Intel's Classmate PC competes with XO computer which in together share 92% of the total global market share. Out of around 8.48 million distributed devices, Classmate PC and OLPC's XO computer share 58 % and 34% of the global market respectively, followed by other computing devices with certain brands such as Lenovo computers (3%), other several types of Netbooks, Notebooks and Tablets manufactured by Apple, HP, Asus and Acer. However, although the number of distribution of Classmate PC is larger than the XO, the status in terms of number of countries that use these models is the reverse. According to the report

published by laptop.org [40] about 2.5 million XO laptops were shipped around the globe. The regions include Africa and Middle East (Ethiopia, Gaza, Ghana, Rwanda, Sierra Leone) North America (Canada, Mexico, USA (Birmingham, Alabama), Caribbean and Latin America (Argentina, Colombia, Haiti, Peru, Uruguay), Asia (Afghanistan, Cambodia, India, Mongolia), and Oceania (Australia, Oceania's islands, including Papua New Guinea). On the other hand, the regions that are so far covered by 'Classmate' PC include, Latin America (Mexico, Brazil, Venezuela, Argentina), Africa (Libya, Seychelles, Kenya), Asia (Terengganu state in Malaysia, Indonesia, India, Vietnam, Thailand), Europe (UK, Italy, Portugal, Greece, Serbia, Russia) and North America (USA, Canada). The data referred to by Richardson *et al*. [31] shows that so far 58 countries have adopted XO while it is 15 countries for Classmate PC. According to this study, "[t]he classmate PC is most prevalent around the world and is being used in fewer countries, but in larger initiatives than the XO laptop. The XO laptop is second most prevalent around the world and is being used in many countries' pilot programs in an attempt to determine the potential benefits of providing laptops to all students and teachers" [31].

An obvious advantage of the low-end subnotebook is that it is cheaper than the regular laptop and this is one of the reasons why it has become so popular in developing countries. There is, however, a shortage of academic literature focusing on evaluating the usability of several LCCDs used in formal educational settings. One exception is the study of Sibanda [41] who conducted an empirical study among some students and teachers at some schools in South Africa regarding the comparative usability of three LCCD, which were OLPC XO, Intel Classmate PC and Asus Eee. Table II provides a summary of the results of her study.

TABLE II: SUMMARY OF THE USER STUDY RESULTS [4]

Netbooks	OLPC XO	Intel Classmate	Asus Eee
Advantages	Carrying handle; webcam	Fast speed; bigger screen and keyboard; easy to use; webcam; carrying handle.	VGA port; portability
Disadvantages	"The cursor gets stuck"; slow speed; it looks like a children toy.	Absence of VGA port	No webcam; small screen display and keyboard
Usability	With difficult	With ease	With ease
Preference of learners	third	first	second
Preference of teachers	third	First and second	First and second
Recommendations	Primary school learners	Secondary school learners and teachers	Secondary school learners and teachers

According to her findings, both students and teachers thought that the Intel Classmate was the most usable device for secondary school learners - mainly due to its larger screen display, keyboard and overall easier familiarity. On the other side, participants in the study felt that OLPC XO was better suited for small children and had been the least intuitive for the older students in secondary schools in comparison to the Classmate and Asus Eee. Kraemer *et al*. [42] in this regard state that "OLPC was much stronger in developing innovative technology than in understanding how to diffuse it may reflect the engineering orientation of the organization and its lack of understanding of the needs or interests of the nontechnical people who will ultimately buy and use the innovation" [42].

In our researched schools (case study) there are no uses of the low-end subnotebook and we consequently do not know how this device would be viewed in comparison to the other devices that are in use. In earlier attempts with 1:1 in Swedish schools there were some uses of low-end sub notebooks, but in more recent years – and in our studied schools – they have been discarded mainly due to their shorter battery time - students in Swedish schools are notoriously known for always forgetting to charge their computing devices.

B. Standard Laptops (Or Notebook)

This category includes portable personal computers with most of the similar components of desktop, such as a DVD/CD-RW drive. In comparison to the other categories as shown in Table I, a standard laptop in general is expensive, but much better in terms of processing speed, display screen and runtime battery life. It possesses more physical components, spaces for data storage, application software and working memory. Due to their high costs, use of standard laptops in 1:1 programs is generally common in the developed world, such as the USA and Australia.

Lenovo laptop and Apple MacBook are the most common brands adopted in the 1:1 programs for schools. According to Richardson *et al*. [31], Lenovo laptops share 3% of the global large-scale 1:1 deployments. The study also reports that Lenovo ThinkPad (e.g. X41, X230) is a common laptop that has comparatively robust computing capabilities and is typically priced for mass purchasing. Schools that use Lenovo laptops include e.g., the Saint Mary's School (x41) and Greensboro Day School (X230) in North Carolina, USA. Following the Lenovo laptop, Apple MacBook makes up 1% of global 1:1 deployments [31]. Apple apparently plays a dominant role especially in the US market. According to a survey among 500 US school districts regarding a five-year forecast on America's digital schools, Apple laptop was alone expected to constitute 24% of the fastest growing digital devices in education [43]. While Lenovo ThinkPad runs through a 'windows' operating system, Apple offers its own operating system called 'Macintosh'. In fact, Apple iBook is the predecessor of MacBook, which was primarily targeted for beginner´s level at the educational market during the period 1999-2006. With the introduction of iBook, Apple sold 23,000 second-generation iBooks to the Henrico County

Public School for their 1:1 laptop program. Since Apple Computer received a formal contract from the Department of Education, this model was also used during the early implementation phase of Maine Learning Technology Initiative.. As was found in the literature review, schools which have also used Apple laptop include e.g., International National School of Indian in USA, Eastern Townships School in Quebec, Canada and Tianjin International School in China.

In our case study, we find that the standard laptop is most preferred by the teachers (56 out of 87 teachers that answered this question). The advantages that the teachers mainly mention were that they are better for typing, doing layouts with and because they can use CAD-programs and CD/DvD-players. According to one of the respondents, "*The PC is best for typing -it has a proper keyboard – and it is also good for the students when they work with layouts."*

Many teachers also point to the need for CD/DVD-players since many schoolbooks they use in parallel come with extra material in the form of CDs or DVDs. One of such comment is "*Additionally we need a docking station for the DVD-readers that we need for language training and exercises that come with the schoolbooks and all special material that is individually designed*"

On the downside, the teachers mention the ergonomic aspects of carrying a computer to and forth to school. In our surveys we found that 30 % of the students complain about physical problems because the laptop is heavy to carry [44] – tablets and mobile phones are far more easy to carry.

C. Tablet

'Tablet' is a single portable computing unit typically larger than 7 inches (or 18 cm) that assembles together, in addition to touchscreen, digitizer pen, accelerometer and most of the essential components of a standard laptop. These essential components include features such as camera with microphone, Wi-Fi and virtual keyboard. The hybrid version of tablets, such as 'Convertible' and 'Booklet' tablets, are generally described by its technical attachment of display screen (flip, twist or fold), keyboard, and connectivity properties (e.g. HDMI). Depending on the size and availability of certain technical properties, hybrid tablets are sometimes interchangeably known as hybrid 'Netbooks'.

Due to powerful portability, robustness, and fast evolving inclusion of innovative features, adoption of tablets in 1:1 programs has rapidly increased. Based on the current trend of innovations, it has been argued that a standard tablet (e.g. iPad) can replace a netbook or laptop computers at least for most people [45]-[47]. Ackerman [46] in this regard, for example, is of the opinion that "while it hasn't been a laptop-killer, the iPad to date has certainly been a Netbook killer, contributing to the rapid decline of that very specific category". Likewise, the Albert Education [48] reports that the tablet (83%) is seen as one of the fastest growing digital devices among the schools in USA. Apple iPad, which is run through its iOS, is the most widely diffused tablet in education programs, followed by other brands, such as Android based XO Tablet, inexpensive (US$35) 'Aakash' promoted by the Government of India, Acer Iconia, HP TouchPad and Windows-8 based HP ElitePad. Richardson *et al.* [31] find that iPad has currently a quick adoption rate because of its design, innovative software interface and robust ecosystem of apps.

There are some reports that evaluate tablets as a tools for education in schools [36], [49]-[53]. Chen and Sager [53] describe a tablet as a 'presentation technology' which can be used in order to facilitate interactive learning for three major pedagogical functions: demonstrating the process of problem solving, providing visual aids, and keeping a record of instructional content. The Heinrich [51] empirical study assessed the impact of tablets among the students and teachers of a secondary school at the Longfield Academy, UK. They found that the use of tablet devices resulted in a positive impact on collaborative learning and caused changes in the pedagogy. The students were more motivated when using iPads and the use was particularly strong in English, Math and science classes. iPad in general is easy to use and helps to improve the level of collaborative working environments. The results concluded that "such devices cannot be dismissed as mere toys or distractions and while they bring with them technical and management issues, these are far outweighed by increased student motivation, progress and collaboration." [51]. Referring to some earlier research [30], [51], Burden *et al*. [49] stated that touch sensitive devices, such as iPads, are highly individualized technologies; they are not shared and therefore it is important to understand the 'use' and 'controlling' (if any) aspects of such devices at home by children. Based on a survey among some primary and secondary schools in Scotland, Burden *et al*. [49] found that 78 per cent of the parents had some rules regarding the use of touch sensitive devices at home by their children and only 18 per cent applied these rules strictly – something which might risk to lower the perceived value of an individualized device such as the iPad. Given the optimism on the use of the dramatically emerging tablet devices in the context of education in general and pedagogical affordances [30] in particular, Burden *et al*. [49] assert with observations that " there has been a noticeable shift from using them [tablet devices] to perform the same tasks previously undertaken though desktop computers or laptops, with teachers and students identifying myriad opportunities to exploit learning in different contexts, through collaboration, mobility, construction and learning in informal spaces. This would appear to be the emerging challenge facing teachers who are wishing to deploy tablet and touch sensitive devices like the iPad, as they seek a sound pedagogical rationale which justifies the purchase of these technologies along grounds which do not simply replicate or repeat what can already be achieved through existing fixed solutions" [49].

According to our case study, when the teachers in our survey discuss tablets they only discuss iPads because these are the tablets that our researched school use. When it comes to their advantages and disadvantages the opinions are diverse and in many cases more emotionally loaded. Teachers seem to love or hate them. The teachers who love iPads refer to how straightforward and intuitive they are, how easy they are to carry around and how they enable an easy integration of sound, pictures and speech.

"I am convinced that the iPads will take over in all schools. The advantages are many and they offer a new way of working where we can combine sound, pictures and speech. The iPads

also work great for special school pedagogy because they are so straightforward and intuitive"

Many teachers also refer to ergonomic aspects because they are less heavy to carry: "Working with iPads enables a different ergonomic work process. The weight is important and it is important to have knowledge about and prevent pain and injuries."

For those teachers that do not like the iPad at all, they refer to how it is difficult to use for typing, how it is used as a toy and for facebooking and how the software management using apps is cumbersome: "*I do absolutely not want the students to have a tablet the way the circumstances are right now. They have to be able to write properly and for a long time using a keyboard. The iPad is more of a toy and is mainly used for surfing and facebooking*."

"*Using tablets entails much extra work for the ones who are supposed to manage the apps and so forth. It takes a lot of effort to manage the apps, to buy them and keep them updated*."

A few teachers are less polarized in their judgments and describe how the benefits of the tablets depend on the task: "*I have tried many different devices in my role as ICT-mentor at my school. The regular laptop is clearly the most user friendly. Tablets are crap for writing, but for surfing and looking for facts it is brilliant. They also work very well for visual production*"

D. Handhelds

Handheld is a low-cost smaller-sized portable game console and multimedia device that typically functions as a personal information manager and enables users to access generally low-version Internet services. Depending on the use, handhelds can be referred to as Palmtop, Personal Digital Assistants (PDA) or even a standard Smartphone [54]. Most handhelds have touchscreen technology with a full physical or virtual keyboard. Examples include Apple's iPod Touch, Palm, Acer N Series PDA and Blackberry.

Due to smaller screen size and limited functionalities, adoption of handhelds in 1:1 computer program is not so common. However, there are few test-based implementations cases reported at some schools, such as Riverdale Primary School in Cleveland, USA, Fort Smith Public School in Arkansas, USA [35], some elementary schools in Texas Panhandle, USA [55], Copland Community School in the UK and some schools in Victoria, Australia [56]. It is reported [49] that Australia has been a pioneer of the first deployments of touch sensitive handheld devices, including iPod touch.

Given the technical limitations, handhelds are generally used for swift ways of doing practical tasks in learning, such as spell check, speed math, and vocabulary building. Alexiou-Ray and Wright [57] found that students used handheld devices during traditional instructions such as handwriting a study, reading a paper book, and drawing cartoon. They also stated that one of the major technical problems for handhelds are the interdependence on third-party educational software. Solomon [55] described 'practice task' as the biggest benefits of using Palm handhelds. The study reported that students had proven to be getting perfect scores on the spelling tests with the use of Palm handhelds as opposed to the students with the old system of flashcards and worksheets. According to the principal of Baker Elementary School in Canadian, Texas, "The Palms have been a great tool to help reinforce lessons by using hands-on activities to enhance learning in both reading and math [...] The vocabulary building has been tremendous as well as the math speed games." [55]. The use of iPod Touch has rapidly become popular. Murray and Sloan [56] stated that handheld devices help to improve students' level of literacy and numeracy. In particular, the study found that the use of the iPod Touch encourages student interaction in blogs, podcasts and Web pages. Kuhlman *et al.* [58] contended that handheld computers are more appropriate for first-grade students and can be used as supportive tools for young emerging and developing writers.

When teachers in our survey describe the use of handhelds, they talk about mobile phones and in almost all cases they talk about smartphones since this is the most common mobile phone use of youths – 94% of people in ages between 12-25 have a smartphone in Sweden [59]. There is no school that we have researched that has provided the students with a mobile phone – all mobile phones discussed relate to the students' personal mobile phones that they have brought from home. The benefits the teachers mention with the smartphones are that they are light, flexible and their Internet connections usually work better than the provided laptops or iPads:

"*The mobile phone is like an extension of the body and they are fast for communication. It feels like most students could do most their tasks only using the mobile so why should everyone have a computer?*"

"*The computers we use in our school do not have the capacity required for using the applications that are expected in the course. Additionally they are generally slow in connecting to the net – the mobile phones are 3 times faster in connecting*"

On the negative side the teachers mention that the screen is too small:

"*The mobile phone is very handy but the screen is far too small*"

Interestingly enough no teachers mention the fact that it is harder to write (type) on a mobile phone as they did when they discussed tablets. Most likely this is because they do not see the mobile phone as a full option to the laptops.

E. Summary of the Results

Based on our findings from both research and practice we summarize the benefits and drawbacks of the different devices used in 1:1 schools and analyse them in relation to their impact on constructive practices (see Table III).

According to our survey, whereas the standard laptops are mainly preferred, many teachers in our case study also called for combinations of different technologies. The following comment is worth mentioning in this case: "*Personally I believe that the Mac and tablet can be good complements for each other. It would be very good if we could use both the computer and a tablet. I think it is important that the students have a diverse technological environment consisting of e.g., Mac, PC, iPad and mobile phone*"

However, our investigated schools have tight budgets and none of them have been able to show any return of investment (rather the opposite) regarding their 1:1 investments.

Therefore it is not likely that the schools will be able to provide the students with more than one technology.

TABLE III: SUMMARY OF THE BENEFITS AND DRAWBACKS OF DIFFERENT DEVICES USED

Technology	Benefits	Drawbacks	Interaction, communication and use
Low-end Subnotebook (Netbook, Mini Laptop)	Inexpensive Ultraportable Customised to specific learning goals	Limited features Low powered Specific to defined educational programs	Support for interaction, communication and negotiation, but also individual exploring
Standard/Regular laptop	High powered, good speed and better display Enhanced features Good for typing Especially longer texts) Good capacity for doing layouts, the use of CAD-programs etc. Possibility to connect CD/DvD-players	Expensive Heavy-weight which affect students' health when carrying a computer to and forth to school	The regular laptop can support interaction, communication and negotiation depending on which applications are in use. Sharing documents is a common theme in our researched schools and here the laptop works well will its beneficial keyboard, which makes it easier for students to write longer texts and also comments on other students texts. Individual exploring is also enabled via access to the web.
Tablets	Presentational technology Straightforward and intuitive Light-weight – easy to carry around Easy integration of sound, pictures and speech Touchscreen	Difficult to use for typing Used as a toy and for facebooking Software management using apps is cumbersome	The tablets can support enhanced interaction, communication and negotiation depending on which applications are in use. Sharing documents is a common theme in our researched schools and here the laptops can works well, however with some limitations when it comes to typing longer texts and commenting on others. Individual exploring is enabled via access to the web and the intuitive character of the tablets may facilitate this exploration to a large extent.
Handhelds	Light-weight Inexpensive Flexible enables swift way of doing practical tasks	Small screen Limited functionalities Interdependence on third-party apps	The handhelds can support interaction, communication and negotiation depending on which applications are in use. More advanced collaboration and team-working – apart from e-mailing and chatting is however restricted due to the limited possibilities of texting. Sharing of documents is not possible in any larger extent. The handhelds are however beneficial when it comes to individual exploring. Not only are the handhelds connection to Internet usually better but the more private nature of handhelds enable student to e.g., look up a word they do not understand without the risk of anyone else seeing which word the student did not understand.

Age differences also seem to be an important issue to look at. Younger students use tablets to a much higher extent and they do not have a personal mobile phone in the same extent that the older students do. Older students use the laptops provided by the school and integrate their personal devices (mobile phones and tablets) that the students bring. For this to be a feasible solution, the teachers need to know which personal devices the students have and more surveys before start of the semester are needed – you do not only need to get to know which kind of students you will be getting in order to be prepared to do a good job – you also need to know which technologies they bring with them to school.

V. CONCLUSIONS

This paper presented the status of various devices used in

1:1 programs around the world based on a systematic content literature review and survey data from a research project in Sweden. We have grouped the findings under certain categories (see Table 1) and have evaluated the merits of each kind of computing device in terms of their embedded features, use, benefits and drawbacks. Findings indicate that there is no single category of device that is being used in most of 1:1 computing initiatives. Rather, we have learnt that instead of relying on one technology (e.g., iPad only) schools should be flexible enough to create a diverse technological environment. An imbalanced design between scope and constraints of a program possesses risks of turning a project unsustainable. Sustainability of computing tools used in 1:1 programs in schools not only depends on the stable socio-technical infrastructures of respective schools, but also the support of external organizations, teacher preferences, organizational values and existing norms.

We hope that the findings of this paper could contribute to the theories relating to technology integration in learning as well as to practices especially in case of choosing appropriate computing devices for the effectiveness of an 1:1 computing program in a particular educational context. This paper could also guide future research to investigate in detail how the features of certain computing devices influence the theories of constructionist learning at the school level under several socio-economic and technological settings.

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