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A development support bubble for children

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Abstract. In this paper we describe an opportunity that Ambient Intelligence provides outside the domains typically associated with it. We present a concept for enhancing child development by introducing tangible computing in a way that fits the children and improves current education. We argue that the interfaces used should be simple and make sense to the children. The computer should be hidden and interaction should take place through familiar play objects to which the children already have a connection. Contrary to a straightforward application of personal computers, our solution addresses cognitive, social and fine motor skills in an integrated manner. We illustrate our vision with a concrete example of an application that supports the inevitable transition from free play throughout the classroom to focused play at the desk. We also present the validation of the concept with children, parents and teachers, highlighting that they all recognize the benefits of tangible computing in this domain.

Keywords: Ambient Intelligence, child development, tangible interfaces, validation

1. Introduction

Many visions of the future include computing power to be available everywhere and in everything, for instance visions like Ubiquitous Computing [1] and Pervasive Computing [2]. While we can readily observe technology in the real world moving towards the omnipresence of computing, we can also observe a lack of interconnectedness. The arisen technological possibilities are rarely used in an integrated manner, if at all.

The vision of Ambient Intelligence (AmI) presumes similar technological developments as the visions mentioned. However, in contrast, AmI focuses on the needs and desires of people and not on the technology [3]. By placing the needs of the human at the center, AmI has a natural tendency to apply any available computing resource in the environment towards the same end. This different premise causes AmI research to look into integrated applications and distinctive aspects of human computer interaction related to context awareness, personalization, adaptation and anticipation [4].

AmI addresses the problem of bridging the gap between what is technologically feasible and what the user is able to handle. As the latter is a widespread problem, AmI is relevant for a wide variety of application domains. But there is more. AmI can not only make life easier within a domain, like the home, but it can also facilitate the integration of aspects of everyday life such that they span domains. One example is integrating healthcare and wellbeing not only at home, but also in public spaces and in institutions like hospitals [5]. In the end the borders between wellbeing en healthcare, between at home and away, between self medication and professional care all fade, resulting in a continuous, homogeneous and persistent 'care bubble' around the user, that supports the user wherever he goes, whatever he does, demands little from the user and yields the best personal health and wellbeing possible.

Personal development is another example. If we take the personal development of a child, in the broadest sense possible as the central goal, how can

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we then apply technology to support this in a non obtrusive manner, assisting children to develop to their full potential without pressure? By applying the principles of AmI children may experience a smooth transition from playing at home to learning at school, compromising neither on the fun experienced nor on educational effectiveness. In fact both can be enhanced at the same time. In this paper we explore this vision.

1.1. Some characteristics of Ambient Intelligence

There are many aspects to AmI. We will focus on those most pertinent to this paper. First of all, AmI takes people as a starting point when designing (computer) interfaces to the pervasive computer power of the future. It reads computer interfaces here but the point of AmI, Pervasive Computing, Ubiquitous Computing and the like is that computers will be everywhere. So in fact it can be any interface. Actually, if we take the human centric approach seriously, the interface used may not be recognizable as a computer interface to the user, not even as an interface to a computer [6].

The interface between the user and any computer should be *easy to use* and *easy to learn to use*, not requiring the user to adapt to the computer, as is done until now, but instead adapt the computer to the user unnoticed. The threshold to start to use an application should be as low as possible, and using the application should require a minimal (or no) effort from the user. To achieve this shift of the burden, the interface needs to become more intelligent. One could say that the interface will have to learn to understand the user rather than that the user needs to learn to understand the interface. For the user, the interface should be like the interface a human would use if the computer would accept anything. This suggests the interface should be close to what evolution prepared us for to use, namely tangible interfaces as humans are, by nature, great at manipulating objects in space. Fortunately, there is a lot of research in this field being conducted, e.g. [7, 8].

Related to this is another challenge. As the expertise of more and more non-technical domain experts is required to understand the user and adapt the system to the user, it would be beneficial if these people could create applications by themselves, without having to explain their aims and application requirements to technical experts who are not domain experts. AmI applications should be *easy to create* and hence AmI can also apply to the tooling used to create applications. In such a case the domain expert becomes the end-user and the tooling should be tailored to their needs. Research in this field is emerging [9].

The second distinctive aspect we mention is personalization of the responses of the system. The system will get to know its users. It will learn things about them when they interact with it. And by knowing its users the system can tailor its responses to better fit each individual user. This goes beyond merely recording preferences and acting on them. The system should identify the strengths and weaknesses of the user and monitor them over time to be able to adapt to them. Also, the acquisition of this information should be done without the user noticing. The gathering of personal information should not be a burden to the user but it should be embedded, engrained, hidden within the application.

1.2. Enhancing children's development with Ambient Intelligence

To assess the suitability of AmI for child development support, one only has to look at the characteristics of AmI: embedded, context aware, personalized, adaptive and anticipatory, and realize that these, apart from social aspects, pretty much describe a good parent or teacher. AmI applied to child development holds a promise to ensure a smooth transition from play at home to first play at school and then learning at school, but also an integration of play at home and learning at school, in the end creating a continuous, homogeneous and persistent 'development support bubble' around the child, that supports it wherever it goes, whatever it does and throughout its entire childhood. To give a sense of how this may work, we will discuss the aspects from the previous section applied to child development specifically.

The most obvious augmentation of current (pre)school learning environments is the integration of electronics and computing, as the resulting options for interactivity and connectivity offer many opportunities to enrich the learning experience and amplify the educational effectiveness. However, care should be taken that the result fits the children and their needs. We envision classrooms where computing indeed takes a prominent role but mostly hidden from sight through the use of tangible electronic interfaces that are embedded in the learning environment. In that context, two aspects are of prime importance.

The first aspect relates to the individual child and its developing abilities. For one, the electronics should be very accessible and easy to use by young children. The interfaces used should be simple and make sense to the children and the interaction with them should come natural to the child. This implies that, rather than that the children have to adapt to the new technology, the technology is adapted to fit the children. This also holds for the applications. As the child's skills develop, the application should adapt actively to the changing abilities. Individual needs of the children related to learning styles and personal interests can be taken into account as well. Tangible interfaces seem to fit these requirements to a unique degree [10].

The second aspect relates to educational yield. Electronics and computation should only be used in classrooms when they can actually improve the current educational process. This may sound obvious, but too often the technology takes center stage and the benefits for education are simply assumed. Areas of improvement could cover the following: promoting the active participation of each individual pupil, enhance the possibility to share and collaborate with peers and teachers, motivate children for tasks that are currently less attractive and support the different needs of each individual, including early signaling and remedying shortfalls in development. Direct feedback and assistance through the system can be part of this.

Taking both aspects into account will result in applications that are at the same time intrinsically motivating (fun) and educationally effective. In the remainder of this paper we will report on our investigations to validate that the electronic tangible learning console we have been working on, TagTiles, fits that bill and constitutes a first step towards AmI for children's development. We took a user-centric approach to investigate the feasibility and desirability of our concept. This involved children, parents and teachers. We first developed a number of applications that were implemented and tested with children, which we will discuss in Section 2. In Section 3 we will discuss the validation studies we conducted to test the concept with teachers, parents and other domain experts. In Section 4 we draw some conclusions.

2. The needs of the children

When considering the support of children's development, children are the main users and as such their needs and desires are paramount. We have developed a number of games that are intended to address specific skills. Each game was built on the same device, called the TagTiles console [11]. See Fig. 1 for the latest version of this console. The console includes a tabletop sensing board with an array of LED lights underneath and audio output. The games were specifically created to develop and improve distinct skills in the areas of cognitive [11], motor [12] and social development [13].

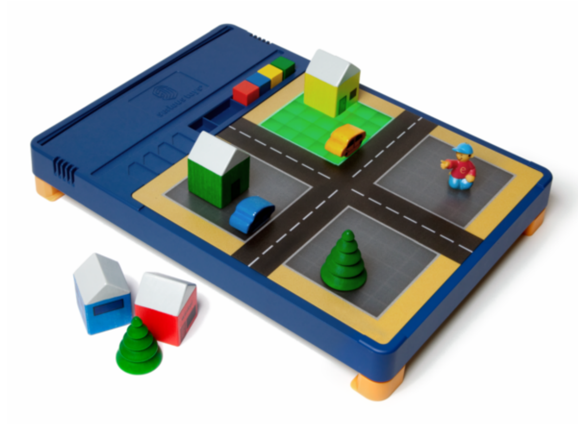

Fig. 1. Latest version of the TagTiles console.

Each of these games went through a full design cycle and was evaluated with children. These evaluations demonstrate that the challenges the games offer can be tailored to fit children of different ages and with different needs. The children are intrinsically motivated to undergo the embedded training because it is presented in the form of attractive games. In addition we have observed that separate skills can be trained in an integral manner with one game. Dependent on the (developmental) needs of the player(s), the challenge offered can be tuned to create the right type of training, addressing the proper combination of skills and offered at the right level of difficulty. We illustrate this idea with a game that was built to train social skills, though this game can be easily tuned to include training of cognitive skills, such as spatial insight, as well.

2.1. *Addressing social skills: Playground architect*

The investigation into the potential of the TagTiles console in the domain of social skills started with identifying the main problems that children face in this domain by interviewing teachers. One of the issues the teachers described was the lack of assertive-

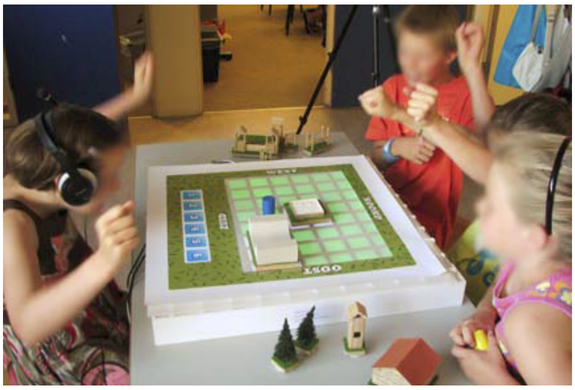

Fig. 2. Playground Architect on an earlier version of the TagTiles console. A play session is in progress. The board lights up to show that all objects have been placed correctly so far.

ness and confidence that hinder many children in certain situations. Therefore we decided to create a game that promotes assertive behavior. Several game concepts were created and eventually ‘Playground Architect’ was selected for further development.

In Playground Architect (see Fig. 2), 3 to 5 children can participate. One of them takes the role of Architect. The other players are Builders. The Architect’s role is specifically intended for a shy child. He or she receives the Architect’s pawn, and the Builders have all the playground objects, which they have to place onto the board according to the instructions of the Architect.

The Architect is the only one who can access a set of narrative instructions (by using the pawn) that describe the client’s wishes. These instructions are played back via the Architect’s headphones. The instructions involve choices that are to be made by the Architect or by all players together, depending on the Architect’s preference. If the Architect makes the decision alone, this can be seen as a sign of assertiveness or self confidence. But in any case it is the decision of the Architect how to proceed, placing the shy child in a leadership position. The main task of the Architect is to communicate the client’s wishes to the Builders, as the Architect himself is not allowed to build.

Forty children (mean age 9.5 years) participated in an evaluation of the game that took place at their school. Before the evaluation, they were all tested for Dominance/Shyness via a teacher questionnaire, based on which the shyest children were placed in the Architect’s role.

The analysis of speech during the recorded play sessions showed that the shy children (the Architects) talked at least as much as the less shy children (the Builders). Peer acceptance was also measured and in many cases this increased already after only a single round of play. Reviewing the play sessions with the children’s teachers gave overall very positive reactions (see [13] for complete results).

2.2. Integral skill development with the TagTiles console

The developed game applications demonstrate that you can use one skill set in optimizing the development of another. For example, the original TagTiles game [11] aimed at cognitive skills, employs fine motor skills and a social component (competition) to increase motivation. The games aimed at fine motor skills [12], use a cognitive challenge to tune the overall challenge of the game. The Playground Architect game, aimed at social skills, also uses a tunable cognitive challenge.

We therefore argue that the TagTiles console is useful for an integral approach towards skill development. Based on our evaluations, we can readily see that fine motor skills will be improved by the TagTiles game aimed at cognitive skills. We can also readily see that the spatial skills of children improve with the games aimed at fine motor skills. Furthermore, collaborative games like Playground Architect can easily be augmented to add linguistic or math challenges. As an example, the TagTiles console illustrates that electronic tangible interfaces can deliver both the fun and the educational yield required, which we described before. And that its applications fit the AmI characteristics.

2.3. Sample application

For many children in the age group 3–5, it is a challenge to make the transition from free play that takes place on the floor or outdoors, to sitting at a desk and completing a task as instructed by a teacher. Typically, pre-school learning environments allow both. The latter requires children to adhere to instructions, and to sustain attention for a task that usually has a more serious nature than freely playing with toys. The TagTiles console can make this transition much easier, as it can make the transition more gradual by using tasks that feel like play, but also introduce the children to sitting at a desk and completing a task.

We will illustrate our vision with an example of a game with which letter recognition can be trained for children aged 3–4 years. In this application, children are literally taken from play throughout the classroom to playing at a desk. We chose to focus on the training of letter-sound associations. This skill typically develops during the age of 3–5 years. It is also prerequisite for learning to read and write, which is usually part of the school curricula starting when children are about 6 years old. As such, the application also serves as a test, because children that are not yet able to recognize letters can be identified at an early stage and if desired provided with extra training. Similarly, children that are ahead of the curriculum can be identified and offered more challenging tasks to keep them engaged.

The game is played as follows. As a preparation the teacher has hidden tagged cuddly toy animals and letter cards throughout the classroom. The children are gathered in small teams (2–3 children). With their team they first need to find one of the animals. Once they found a toy animal, they go to the TagTiles console and place the animal on top of it. The console senses the animal and pronounces its name.

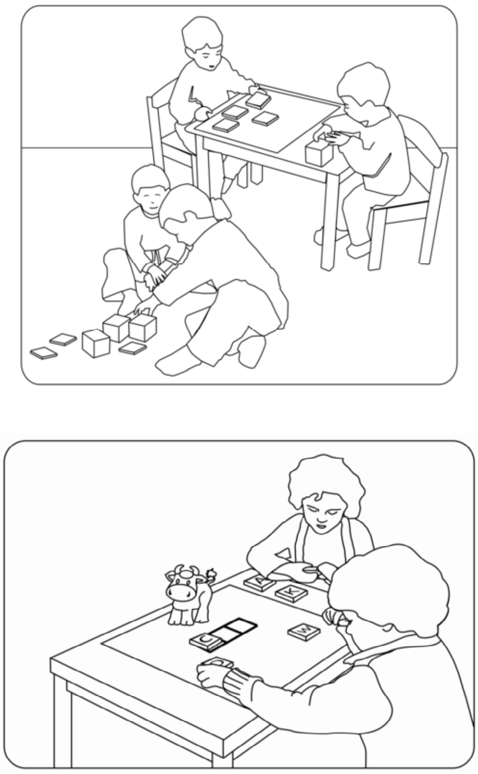

Fig. 3. Sketches of children in classroom environment including ground- and desk-play options (top) and of children testing the letters of the name of the cuddly animal on the interactive tabletop (bottom).

Then, the children need to search the classroom again to find the letter cards that form the name of the animal. This can be a structured process when the children can already recognize letters and know what they are looking for, but it can also be done in a trial and error fashion, by just trying a letter on the console and then listen to the response of the console which will pronounce its sound (see Fig. 3).

When the task is too difficult for the children, the system will notice this and help them by pronouncing and/or displaying the letters that are missing. This will train the children in making the connection between a letter symbol and its sound.

To add a game element, the teams may play in competition to be the fastest to gather the letters of the animal and place them in the right order onto the tabletop.

Once they have done this successfully, there can be a next phase in the game in which the children need to find additional objects. Now they can place objects together on the tabletop, with which the system may provide simple sentences (via audio output) about the objects, e.g. 'the cow is next to the duck'. The children may even bring or create their own objects to develop a more elaborate or just different story.

3. Validation

As AmI is people centric it is important that the primary carriers of the current development process of children buy into the proposition. To test our ideas and concepts with teachers and parents we conducted a series of group sessions and interviews, of which we will describe the results below. We also discussed our ideas with other domain experts and the most important findings are also described.

3.1. Validation with parents

In most cases the parents are primarily responsible for the development of their children and they typically decide which play- and learning materials their child is exposed to at home, hence the importance of validating the concept with them. The study with parents was set up as a broad assessment of what is important to parents when it comes to child development, whether they feel a need to support the development of their children in addition to existing means and to assess which solutions they think are most suitable.

The study included parents of children aged 4–8 years old in the Netherlands, in the United Kingdom and in China. In the Netherlands and the UK 21 parents in groups of 7 participated in focus groups and 8 were interviewed individually. In China 16 parents were interviewed individually and 30 parents participated in focus group sessions in groups of 6.

In more detail, the research objectives were to explore parents' attitudes, motives and needs with respect to the upbringing of their child(ren) and developmental aspects in cognitive, social and physical domains. Also the possible effects of cultural backgrounds were taken into account. In addition, the parents' behavior with respect to issues related to their child's behavior and how to deal with these was explored. The possible role of serious games or learning aids was discussed in relation to developmental issues. A general insight had been formulated beforehand (Table 1), to be tested in the study. The parents were confronted with a set of more specific (predefined) statements to learn about their attitude towards these statements. Subsequently, the parents in the Dutch and British groups were presented with a video prototype of TagTiles, to gauge their reactions to this concept.

Table 1

Predefined insight tested in the user study with parents

Situation
Parents want to have learning tools which aid the child's development (cognitive, social, physical) during leisure time, i.e. while the child is playing and having fun.
Dilemma
Children go for fun. They do not want to feel that games have educational purposes. So fun and learning are difficult to combine from a child's perspective.
Solution
Toys that are convincing for children and parents; the child should see it as a real toy and the parents should be able to see the educational value.

We present a selection of the statements discussed and we describe the parents' reactions to the presented video prototype of TagTiles. The most important statements that were tested with these parents are the following:

1. The ideal toy is a combination of fun and development, without putting pressure on the child.
2. Toys that do not include a screen are to be preferred over past times that do.
3. Supporting the development of motor skills should receive attention in general, and not only when a problem has been identified.

Parents in all three countries responded very positively to the first insight. In the Netherlands and the UK many toys on the market are labeled as such already. In China this was not the case. In the Chinese market most toys were either categorized as fun or as educational.

The second statement also strongly resonated with most parents in the study. The physicality of the TagTiles console was seen as a great benefit, because most parents would be happy to give toys to their children that will keep them from (continuously) playing screen-based games. Toys that have no screen trigger more active play. The parents welcomed toys without a screen especially when they are as attractive for children as computer games can be. A remark added was that these toys could become addictive (as well).

The third statement was less well recognized by most parents. Only parents that had a child with known issues regarding motor skills recognized that it would be beneficial if 1) the development of fine motor skills received proper attention from the start and not just when a deficiency was detected, and 2) if (potential) deficiencies were detected much earlier. There was also a cultural aspect to this. Chinese parents take it as a given that intensive motor training is beneficial for the total development of a child's brain. However, in the Netherlands and the UK this aspect is not recognized at all by parents.

The video prototype of TagTiles was well-received. The parents were shown a video where TagTiles was played by two children, and they were only shown the original version of a pattern-copying game. TagTiles was seen as a game on an attractive high tech board that constituted a credible device for educational purposes. The fun part was sometimes questioned. This was not very surprising to us as previous experiences of demonstrating the game had taught us that this specific TagTiles game has to be actually played to readily recognize the fun of it.

3.2. Validation with teachers

Next to parents, teachers typically play the second most important role in the personal development of children. They need to decide almost on a daily basis what each individual child needs in order to support its skill development in the most effective manner. Therefore we also involved teachers in evaluating our ideas and concepts.

Ten teachers from a range of different types of schools (different religions and different types of education) in the northern part of the Netherlands participated in a workshop. The workshop consisted of two parts. In the first part the teachers were asked about their general ideas on learning materials for the cognitive development of children. What do they find important aspects of learning materials? What are their wishes with respect to new learning applications? The following aspects were described by the teachers as important:

- Autonomous use. Children should be able to use educational materials independently. Also self-assessment of the performances was mentioned.
- Attractiveness. The materials should look inviting to use, challenging, attractive and they should be interactive.
- Versatility of use. Multiple functionalities, options for extension of applications and addressing multiple skills at different levels were seen as beneficial.
- Didactics. The materials should be very accessible for pupils and teachers. Language use should be clear and the tasks should be well-structured.
- Supporting collaboration. Children should be able to play together with the materials as well as individually.
- Registration of the user. Identification of the user and registration of performance was desired, allowing integration in existing performance-monitoring programs.
- Practical aspects. The materials should not be too small, they should be easy to handle and robust, easy to clean and easy to store.

In the second part of the workshop a concept was introduced to the teachers by means of a video prototype. The video showed a concept similar to the TagTiles console, demonstrating how it could be used to train color recognition and spatial skills, while guiding the child in a puzzle task with audio instructions (through headphones).

The teachers were asked to respond to this video and identify the strong points, but also to share concerns and questions this video might have raised. The teachers' responses revealed that the wishes described above were all recognized in this concept. The benefits most often mentioned were: the autonomous use, versatility of tasks and didactics/easy accessibility. In addition, the registration of the pupils' work was seen as a strong benefit.

In the video, a rather monotonous voice guided the children through the tasks. This sounded too boring to the teachers. Also the physical aspects concerned some of them, as they thought headphones are often too vulnerable for classroom use. How the console could be self-assessing was one of the questions of the teachers. And one of them also asked if the system would be able to identify task solutions that were almost correct. In addition they wondered if the system could support remedial teaching and help to indicate when children would need this.

3.3. Validation with other domain experts

The previous sections focused on the normal development of children. To complete the picture we also want to present some other related aspects that arose from discussions with other domain experts such as therapists and remedial teachers. It demonstrates that our development support bubble goes beyond the support for 'mainstream' children and can in fact be applied to most children. Below we mention two additional domains which we believe the development support bubble can also include. These domains are both about early detection and remediation of deficiencies. Research has shown that early detection and treatment greatly enhances the success of treating deficiencies [16].

One group of children with specific needs in their development includes children that have impairments related to motor control, such as spasms. The training of fine motor skills can be very frustrating for these children [12]. They are often required to repeat monotonous movements. Tangible electronics can be used to incorporate the specific physical exercises a child has to perform into a game by using special objects or by making the moves to be made in the game coincide with the moves required in the training. This can make the training much more enjoyable for children, and it can motivate them to continue their training at home. In addition, as all activities can be logged, the therapist can receive feedback on the progress made at home.

Another domain relevant here is the assessment of young children. It has become more common to test children at early ages to detect if remediation is needed [16]. However, the assessment of children in the ages of 3–5 has some issues. Current testing practice includes interviewing children and their caregivers, which is very labor intensive, and paper and pencil based tests administered to children, which require at least rudimentary writing skills. In general experts agree that both methods are less suited for broad application to the very young.

Using tangible electronics like the TagTiles console for training and assessment has some clear benefits. By embedding the test in a game like application it becomes very accessible, more engaging and less threatening to the child. This will lead to more reliable and consistent results. In addition, as the child can play the test game independently, it is not labor intensive. Also, using tangible electronics adds the ability to assess basic motor skills. Finally, in conjunction the characteristics of tangible electronics mentioned above enable the early detection of potential problems with the development of children.

In a correlation study [14] we showed that very specific basic cognitive skills can be addressed by a game on the TagTiles console. Thus we can both assess and train these basic skills. When a developmental lag in some of these skills is identified, they may be recognized as early indicators of specific conditions that may play a role in the development of the child. For example, when fundamental skills such as attention or memory are not well developed, this may hamper the development of more complex skills such as reading and writing e.g. [15].

4. Discussion and conclusions

In this paper we presented a possible future class room. The adaptive use of tangible computing presented, allows us to put the child at the center and still increase educational yield. It can address cognitive, social and fine motor skills in an integrated manner. Furthermore, it enhances the normal educational process, but also signals and treats shortfalls in development. The environment is flexible and allows for intrinsically motivating educational applications with which the child can work both independently and collaboratively. At the same time the objects used are familiar to the children and connects to their natural way of play, thus creating a natural transition from playing at home through playing in a school environment to focused learning at school.

Therefore we conclude that, in the hands of the appropriate domain experts, electronic tangible interaction consoles, like the TagTiles console, are very powerful tools indeed for the integral and personalized development of children in the areas of cognitive, fine motor and social skills for assessment, education and therapy. Furthermore, as the exercises can be presented in the form of attractive games, the children are intrinsically motivated to use them. Finally, as professionals in the field like teachers and occupational therapists pointed out, such tools can be used by the children unsupervised and hence as easily at home as in a more formal setting.

We assert that the ability to deliver this combined set of benefits in an integral manner is unique to tangible electronics.

As an example, the TagTiles console illustrates that electronic tangible interfaces fit the AmI characteristics. It is easy to use, easy to learn to use and offers great opportunities for personalization and contextualization of the developmental process. Next to showing that these benefits are real we have shown that these benefits in particular are of importance to both parents and teachers and that both also recognize that electronic learning aids based on physical computing, like the TagTiles console, deliver on these benefits. In addition, we have pointed out the opportunities that are envisioned in the domains of assessment and training of particular skills, for children with specific needs.

As with such a console the requirements of teachers, parents and children are aligned, the parts of the development process taking place at home and at school can be aligned also, and even be integrated. This allows for the introduction of concepts like a personalized development support bubble for children that spans both contexts and can optimize the development process from pre-school throughout the school life of a child.

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