FireFlies: Physical Peripheral Interaction Design for the Everyday Routine of Primary School Teachers

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ABSTRACT
This paper presents a research-through-design study into interactive systems for a primary school setting to support teachers' everyday tasks. We developed an open-ended interactive system called FireFlies, which is intended to be interacted with in the periphery of the teacher's attention and thereby become an integral part of everyday routines. FireFlies uses light-objects and audio as a (background) information display. Furthermore, teachers can manipulate the light and audio through physical interaction. A working prototype of FireFlies was deployed in four different classrooms for six weeks. Qualitative results reveal that all teachers found a relevant way of working with FireFlies, which they applied every day of the evaluation. After the study had ended and the systems were removed from the schools, the teachers kept reaching for the devices and mentioned they missed FireFlies, which shows that it had become part of their everyday routine.

Author Keywords
Peripheral Interaction, Design, User Exploration, Everyday Routine, Calm Technology, Physical Interaction, Audio.

ACM Classification Keywords
H5.2. Information interfaces and presentation: Auditory (non-speech) feedback, Evaluation/methodology, Interaction styles, Prototyping, User-centered design. K.3.1. Computers and Education: Computer Uses in Education.

General Terms
Design, Experimentation.

INTRODUCTION
The everyday routine of primary school teachers is usually characterized by a large number of small activities. Apart from their primary tasks such as explaining lessons to the class and giving instructions individually or in groups, several secondary tasks have to be performed as well. For example, teachers need to observe how the children are doing, keep track of time and prepare the next lesson. These secondary tasks usually have to be performed alongside primary tasks.

TEI 2013, Feb 10-13, 2013, Barcelona, Spain.

In recent years, digital technologies have become ubiquitous in everyday life. This also holds for classrooms, which are now equipped with interactive whiteboards as well as (shared)desktop computers. These technologies are mainly meant to support the teacher's primary task of explaining the teaching material. The earlier mentioned secondary tasks are less easily supported by these technologies. A reason for this may be that focused attention is required to interact with these technologies, whereas secondary activities are usually performed alongside a different main activity.

In the everyday physical world, several activities are performed outside the focus of our attention. For example we are aware of what the weather is like or what time of the day it is, without actively thinking about it. Also we can tie our shoelaces, wash our hands or walk our usual route home without focused attention. These perceptions and actions take place in the background or *periphery* of our attention, while they may easily shift to the center of our attention when this is relevant. Based on these observations, we have proposed the concept of *peripheral interaction* [4]: interaction with technology designed to easily shift between the center and periphery of the attention and thereby potentially better fit into people's everyday routines. This direction is highly related to *calm technology* [17] and *ambient information systems* [13], but distinguishes itself by not only focusing on the *perception* of information in the periphery, but also to include physical *interaction* in the periphery of the attention.

From previous research we learned that peripheral awareness of information is often acquired through auditory perception [3]. Furthermore, most actions performed in the periphery during our everyday routines, involve the manipulation of physical artifacts [2]. In this paper, we present a peripheral interaction design called *FireFlies* which combines tangible interaction [14, 16] and audio to enable both interaction and perception to shift easily between the center and periphery of the attention. FireFlies is designed to support primary school teachers in peripherally performing secondary tasks during their everyday routines. Though developed for a specific, user-driven purpose, the main intention of FireFlies is to study how interaction with technology can fluently blend into people's everyday routines, similar to the way in which interactions with the physical world are a part of routines.

In this paper, we present FireFlies and the related design process, as well as discuss the preliminary, qualitative results of a six week deployment of FireFlies in four classrooms.

RELATED DESIGN-RESEARCH

This paper explores the design of interactive technologies that employ the periphery of the attention and therefore easily embed in everyday routines. Early work in this area, introduced the term *calm technology*, which "engages both the center and periphery of the attention and in fact moves back and forth between the two" [17, p.74]. Examples of calm technology include the Dangling String [17], a physical string which rotates to create a visual and auditory display that subtly represents the network activity in an office; and AmbientRoom [11], which uses light and sound to subtly present information to office workers. Elaborating on calm technology, Tolmie et al. [15] build on the importance of everyday routines when presenting the concept of *unremarkable computing*, which aims to make interactive technology unremarkably embedded in everyday routines.

Although most related work focuses on *perceiving* information in the periphery of the attention, some examples are designed for physical peripheral *interaction*. Edge and Blackwell [6] present *peripheral tangible interaction*, artifacts located on the side of the office workspace, available for short episodes of interaction. Whack Gestures [13] allows users to react to cues on their mobile phones through gestures, that require minimal attention. StaTube [8] enables users to peripherally set their instant messaging status, while the status of contacts is subtly presented through light. Apart from these interaction design examples, this paper builds on a large body of work on multitasking in human-computer interaction (e.g. [18])

Although no specific peripheral interaction design is known for the classroom, several interactive technologies have been developed for this context. Examples of this large area of related work include vSked [10], an interactive visual scheduling system to support elementary school children with autism in working independently; Subtle Stone [5], which allows high-school students to communicate their emotional state to the teacher, by changing the color of a personal device; Student feedback orb [9], which presents university students' feedback to the teacher during instructions; and Lantern [1] is a light-object located on university students' desks during instructions, which students can manipulate to indicate which exercise they are working on or to call for help.

Different from these related classroom technologies, we are interested in developing a *peripheral interaction design* for primary school teachers. We believe this approach is relevant given the many secondary tasks teachers perform in their everyday work. These tasks may be supported by interactive systems that reside in the periphery of their attention, where they do not burden or hinder the ongoing everyday routine.

PERIPHERAL INTERACTION DESIGN PROCESS

The design and research presented in this paper builds on earlier work in the classroom context. In a previous exploration of peripheral interaction, we developed and evaluated two interactive prototypes; CawClock and NoteLet [4]. *CawClock* is a clock which used background nature- and animal-sounds to subtly display time-related information. In the evaluation of CawClock, the audio provided relevant information without attracting the attention and therefor seemed a suitable medium for peripheral information display in classrooms. *NoteLet* explored physical peripheral interactions. NoteLet enables teachers to take a picture of the classroom and store it on her computer along with a child's name, by touching a name on a bracelet. To easily select the right name, fabrics with different tactile qualities were used for children in different grades. Evaluation of NoteLet revealed that selecting a name was quick and simple as well as that the tangible aspects of the bracelet (e.g. the different fabrics) contributed to this. The design seemed promising for a peripheral interaction. Although one teacher mentioned that looking at the pictures after school hours required too much time, two others saw an added value of NoteLet over just remembering observations. (See [4] for more information).

Building on our experience with CawClock and NoteLet, we were interested in developing an interactive system for primary school teachers which combined audio as a peripheral display with physical interaction designed to shift to the periphery of the attention. A combination of peripheral perception and action would, in our view, enable a design to more fluently embed in the everyday routine of the teacher.

When evaluating NoteLet, some teachers saw no added value in using the design. It is unlikely that activities which are not relevant to a teacher will fluently become embedded in her everyday routine (also see [2]). In order to come to a relevant design for our target group, we conducted a creative workshop in which a primary school teacher, four experts on innovative educational technology development and two design-researchers participated. In this workshop, we introduced the concept of peripheral interaction, and the participants brainstormed about tasks of teachers which could be supported by technology. This resulted in a range of relevant tasks, such as giving turns, keeping track of children's development or emotions, counting the frequency of certain behavior and rewarding or warning children. These tasks were later discussed in groups to develop peripheral interaction concepts.

Resulting from this workshop we realized that mainly the teacher's small tasks, such as those mentioned above, could be supported. We therefore decided that it would be interesting to develop an open-ended system that could be used for multiple goals, which would increase the likelihood that teachers can use it for a purpose that is personally relevant to them. This led to the development of FireFlies.

FIREFLIES DESIGN

FireFlies is an open-ended design which can be used to support several secondary tasks of primary school teachers. The design consists of three separate parts: the *light-objects* (one for each child), which are intended to be a visual

Figure 1. FireFlies light-objects lit in different colors (left), and light-object in a classroom as a distributed display(right).

(peripheral) display of information, the *soundscape*, which provides generic peripheral information, and the *teacher-tool,* which allows the teacher to manipulate the light-objects and the soundscape through simple physical interactions which can potentially shift to the periphery of the attention.

Each child has a small *light-object* on his desk, see Figure 1. This light-object can have one of four different colors: red, green, blue or yellow, or the light can be off. Each light-object is a small display that provides information to or about the child in question. Furthermore, all light-objects together form a visual display that is distributed over the classroom, providing information about the class as a whole.

While one or more light-objects are on, an ongoing background *soundscape* is played in the classroom. Based on our earlier CawClock design [4], the soundscape is constructed of four specific nature-sounds, each connected to a color of the light-objects; bird-sounds (yellow), ocean-sounds (blue), cricket-sounds (green) and owl-sounds (red). The sound that is played depends on the current colors of the light-objects. When all of them are red, the soundscape consists only of owl-sounds. When some are red and some are green, both owl-sounds and cricket-sounds are played. When one light is then set to yellow, bird-sounds are added to the soundscape. The number of light-objects that have a certain color is represented in the frequency in which the corresponding sound is present in the soundscape; when only one light-object is blue, an occasional ocean sound is heard, whereas continuous ocean-sounds are heard when all light-objects are blue. The soundscape is meant to provide an overview of which colors are being used at the moment as well as approximately how many light-objects have those colors. As the soundscape is present in the background, the teachers can obtain general peripheral awareness of the current state of the FireFlies system without having to look at the light-objects themselves. The strategy of combining specific visual information (about each individual child) and generic auditory information (about the class as a whole), was chosen after it was successfully applied in the design of CawClock [4].

The *teacher-tool* is a device with which the teacher can set the colors of the light-objects and thereby influence the soundscape, see Figure 2. The teacher first selects a color by moving the slider on the top of the tool to the intended color. Each child is represented by a bead attached to a string on the bottom of the tool, see Figure 2. When squeezing one of these beads, the color of the light-object of that particular child is set to the selected color. The top part of the teacher-tool furthermore contains a button labeled ‘everyone’, which can be used to set all light-objects to the same color at once.

Although the basic functionality (selecting a child’s name) of the teacher-tool is similar to the earlier NoteLet design [4], we decided to move away from the bracelet design. Evaluation revealed that the bracelet limited the use of the design; teachers only chose certain moments at which they put on the bracelet. The system was therefore not used often, as it was not as accessible. For a design to become part of the teacher’s everyday routine, it must thus be flexible in use. The teacher-tool can be used while it lies on a table, while held in the hand or while worn on the teacher’s clothing using the clip on the back. This clip allows the teacher to easily carry it around the classroom without having to hold it continuously.

The interactions with the teacher-tool are intended to be quick and straightforward so that they can easily integrate in the everyday routine and potentially shift to the periphery of the attention. To make sure that minimal attention is needed,

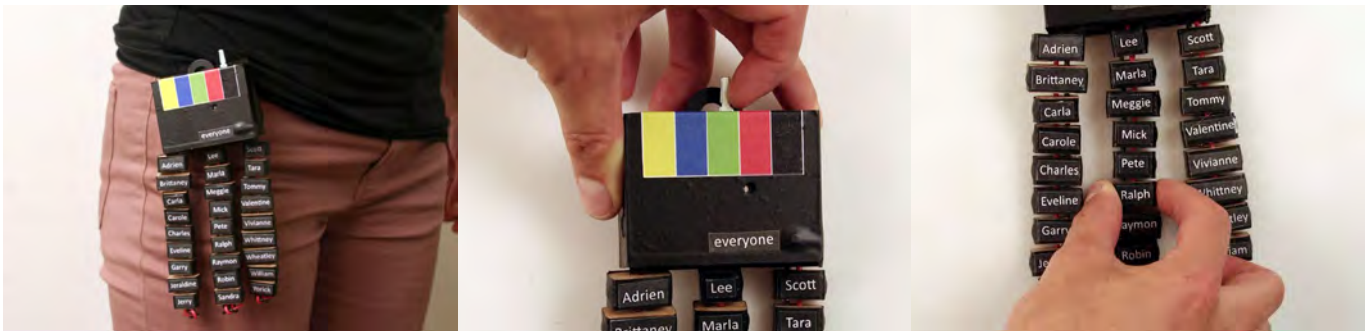

Figure 2. FireFlies Teacher-Tool: clipped to the user’s clothes (left), selecting a color (middle) and selecting a child’s name (right).

NoteLet used two kinds of fabric to enable distinguishing children in different grades. Although this made it easier to find a name, it did not enable distinguishing each individual child. On the teacher-tool we decided to differ the size of the beads relative to the names of the children. This way each individual child is represented by a unique bead-size. The beads are ordered alphabetically by first name. Since teachers likely have automated knowledge of the children's names, we hoped that, after getting experienced with using the teacher-tool, feeling the size and location of the bead would allow them to easily select the right name.

To support quick interaction, the teacher-tool also includes audio feedback. When a color is selected, a short cue is played that corresponds to the soundscape's audio representing that color. Furthermore, when squeezing a bead, a short piano-tone is played. Each name is connected to a different pitch; low pitches for names in the beginning of the alphabet and higher tones for names at the end of the alphabet. A short cue of a low piano tone followed by a high piano tone is played when the button 'everyone' is used. Although these latter audio cues are played when the interaction has already affected the color of the light-objects, they may be useful for the teacher to check whether they selected the right name.

FireFlies is an *open-ended design*; the teacher can decide for which purpose he or she will use it. We believe we can gain new insights in the kinds of tasks that are relevant for peripheral interaction design by observing how teachers decide to use FireFlies. To enable evaluating FireFlies in the context of a primary school, an interactive prototype was developed. Both the light-objects and the teacher-tool use a JeeNode module [12] for wireless communication and data processing and run on batteries to ensure that they can be located anywhere in the classroom. The soundscape is played from speakers located in the back of the room. See [7] for a video demonstration of the FireFlies prototype.

USER EVALUATION

This paper presents a research-through-design study on interactive technologies that can be used in the periphery of people's attention. Since the intention of the FireFlies design is to become an integrated part of the everyday routine of the classroom, we found it important to evaluate it in the context of real classrooms for a longer period of time, which is also recommended in the area of ambient information systems [9]. This way, teachers and children can extensively experience FireFlies during numerous classroom situations.

To evaluate FireFlies, we implemented our interactive prototype in four different classrooms for six weeks each. These classes were recruited from two different primary schools; two classes of the same school participated simultaneously with two sets of FireFlies. Other than the differences in children's names and thus sizes of the beads on the teacher-tool, these two sets of FireFlies were identical.

Of the four participating classes, two had a full-time teacher while two others were taught by two part-time teachers (e.g one working Mondays and Tuesdays and the other on Wednesdays, Thursdays and Fridays). This means that in total six different teachers and 102 children worked with FireFlies for six weeks. Obviously, the full-time teachers used it during more school days compared to the part-time teachers. See Table 1 for an overview of the six female participants.

In the beginning of the six weeks, we gave the teachers the FireFlies prototype, explained how the teacher-tool could be manipulated and what the results of these interactions were on the light-objects and the soundscape. We furthermore explained that they could choose in which way and at which moments they would use the system, although we encouraged them to use it regularly, preferably at least once every day.

During the six week period, a researcher frequently visited the participating teachers before or after school hours to charge the prototypes' batteries and informally talk about the teacher's experiences. We conducted two open interviews with each teacher; once in the third week and once in the sixth week of the study. Furthermore, we held 10-minute group interviews with the participating children in the sixth week of the study. We also captured questionnaire and video data, but these are outside the scope of this paper. Our present discussion focuses on how FireFlies was used and the extent to which it became part of the everyday routine based on the above mentioned formal and informal, qualitative discussions with the teachers and children.

FINDINGS: USING FIREFLIES IN CONTEXT

In this section, we will discuss how FireFlies was used in the four participating classrooms, as well as which lessons we learned regarding the design. As FireFlies is an open-ended design, the participants had to decide how they would use it. The part-time teachers (P3-P6) decided on this in discussion with their professional partner before the start of the deployment, whereas the full-time teachers (P1 and P2) discussed it with the children in class on the first day of the

Table 1. Overview of the teachers participating in user study.

Teacher	Appointment	Age	Teaching experience in years	School	Class	No. of students	Grade	Student age
P1	Full-time	26	3	A	1	25	4th	7 to 8
P2	Full-time	24	4	A	2	27	5th	8 to 9
P3	Part-time	51	23	B	3	27	3rd	6 to 7
P4	Part-time	26	3					
P5	Part-time	46	16	B	4	23	4th	7 to 8
P6	Part-time	54	32					

Table 2. Overview of the meanings of the colors of FireFlies in each participating class.

Class	Red	Green	Blue	Yellow
1	Work independently in silence	You can work together / discuss	You are working well	Teacher is explaining
2	Work independently in silence	You are working well	Come to the teacher	Work on the computer
3	You are not working well	You are working well	It is your turn	Work on the computer
4	Work independently in silence	You can work together / discuss	Come to the teacher	End of lesson, clean up

deployment. In all classrooms, a specific meaning was linked to each color; see Table 2 for an overview.

Each participating teacher used FireFlies every working day during the six weeks of the study. In class 1, the light-objects were always on; the colors indicated a certain way of working and accompanying set of rules, one of which always applied. In the other classrooms, FireFlies were used in regular lessons, which involved whole-class instructions, independent work and/or individual or group instructions. These lessons took place multiple times per day. In classrooms 2, 3 and 4, FireFlies was not used during group discussion, nor during creative lessons such as crafts, arts and music.

We will now illustrate how FireFlies was used by giving four usage examples, one of each classroom. These observational examples are chosen to give an impression of usage and to feed our discussion about the design of FireFlies, rather than to provide an exhaustive overview of all the ways in which FireFlies was used during the study.

Example 1: FireFlies as a Medium for Communication

The children of classroom 1 are making a drawing during the arts lesson. All light-objects are green; the children are allowed to discuss. The lesson is about to end, they will continue with spelling. The teacher changes all light-objects to yellow: all children need to pay attention to her as she explains the lesson. After the explanation, all light-objects are turned red and the children start to work independently. The teacher sits in front of the room and observes if the children are doing well, for example if they are silent. She turns the light-objects of the children who are working well to blue, giving them a compliment. After ten minutes, she takes the teacher-tool and walks around the room to help children individually. Children who are doing well get a blue light, while the light-objects of children who are no longer working well are turned back to red. As the teacher passes a child with a blue light, she softly mentions 'you have a blue light, because you are working very silently, well done!'

In this example, the colors green, yellow and red are used to indicate what the children are (allowed) to do at that moment, e.g. 'you are allowed to discuss', 'listen to the teacher' or 'work in silence'. Similar to other participating classrooms, the meanings of red and green were chosen based on a method they used before working with FireFlies; a visual red or green traffic light on the whiteboard to indicate when the children were or were not allowed to discuss. Comparing to this traffic-light method, the teachers indicated that, with FireFlies, the children seemed more aware of the fact that they had to be silent when the red light was on. The teachers reasoned that this was caused by the fact that the light-object is a personal object, rather than one meant for the whole class; a red light, with their name on it, standing right in front of them, reminds the children continuously of the rules.

The fact that the light-objects are personal objects was also utilized by several teachers to differentiate between the children. For example, P5 frequently gave a group of children permission to work together while another group had to work in silence, which was not possible with the traffic light. The fact that FireFlies provides a personal display for each child was therefore seen as a major advantage of the design.

As presented in the example, P1 used FireFlies to compliment children by giving them a blue light. Though other teachers used green for this purpose, this method was applied in other classrooms as well. The participating teachers mentioned they particularly liked the fact that this communication was done silently. Normally they would be hesitant to compliment children aloud during independent work, since that would break the silence. In classroom 3, the color green was used to give compliments, while they used red for the opposite purpose: as a warning when children were not working well. In this case we noticed that, although the children did not like getting a red light, they preferred it over being verbally warned. One girl mentioned "if the teacher says that I am not working well, I get very sad, but when the light says it to me, I change my behavior and I am not so sad".

After choosing how work with FireFlies, none of the teachers changed the meaning of the colors. We did see however that these meanings became more elaborate over time. For example, in classroom 1, yellow meant 'the teacher is explaining' and was initially used during whole-class teaching. In later weeks of the study however, the teacher also made individual light-objects yellow when children received individual instructions either at their own desks or at the teacher's desk. Similarly, in class 2, blue initially meant 'come to the teacher', while it was later used when the teacher was walking around the classroom to indicate which child she would visit next. In both cases, the original meaning of the colors blue and yellow did not really change, but simply expanded, for example from 'the teacher is explaining' to 'work with the teacher'. The children understood what they had to do from the context in which their light-object turned to blue or yellow.

Example 2: FireFlies as a Distributed Display

A reading lesson is starting in classroom 3. In the beginning of the lesson all light-objects are off. The teacher sits in

front of the room and points out which text they will read. She makes the light-object of one child blue and he/she reads one sentence aloud. After finishing the sentence, the teacher makes another light-object blue and this child reads the next sentence, and so forth. The light-objects of children who had their turn remain blue. By looking into the classroom, the teacher has an immediate overview of which children still need to get their turns. When all children have read, the teacher turns all light-objects off and starts again.

As evident from this example, using FireFlies to give turns was not only useful in communicating relevant information to the children, it also supported the teacher in knowing who already had their turns. This information is locally visualized as a distributed display in the classroom. The teacher does not need to keep track, the information is to some extent offloaded in the environment. We noticed a similar effect in situations where FireFlies was used to give compliments. P1 for example mentioned noticing that a group of children in the back of the room were not working well, they were chatting. But when looking into the room, she saw blue lights on their desks (they had received a compliment earlier in the lesson). This immediately reminded her to set these lights back to red and 'undo' the earlier compliment.

Example 3: FireFlies as an Auditory Display

The children of classroom 4 are working on individual mathematics assignments. 10 children, who have strong mathematical skills, work on more advanced tasks and are allowed to work together. Their light-objects are therefore green, while the remaining lights are red. The speakers in the back of the classroom softly play cricket and owl-sounds representing the green and red lights in the classroom. After a while, a child raises his hand to ask a question. The teacher sets the light-object of this child to blue and the child walks to the teacher and asks his question. Soft ocean-sounds are added to the soundscape. As the child walks back to his desk, another child raises his hand. The teacher makes his light-object blue, he walks to the teacher and returns after his question is answered. A few minutes later, the teacher notices hearing ocean-sounds, and realizes the lights of the two children are still blue. She turns them back to red. At the end of the lesson, the teacher turns all lights to yellow. Bird-sounds are played and children realize it is time to clean up.

While the teachers were rather positive about using the light-objects, the soundscape was used much less often. Teachers could adjust the volume themselves as well as turn the speakers off in case they found it inappropriate. Although we encouraged them to try it out, P1, P2 and P4 used it only once in the beginning of the six weeks. They mentioned that they used FireFlies mostly when the class needed to work in silence, and that a soundscape would make it difficult to concentrate. Although P3 and P5 used it regularly, they had the same concerns and minimized the volume. They also mentioned that particularly the cricket-sound (connected to green) and the owl-sound (connected to red) were unsuitable. However, these two colors were used often during independent work. P3 and P5 mentioned that the ocean sounds connected to blue were suitable as a background sound as they provided a relaxing atmosphere. Blue however, was most often used alongside other colors, as a result of which multiple sounds were played simultaneously. Different from the other teachers, P6 was positive about the soundscapes and indicated that it had an added value by providing information when children were focused visually on their work, as well as by creating a positive atmosphere in the classroom. For example, hearing the bird sounds firstly made children realize that the lesson had ended if they did not see the color change yet and secondly it provided a pleasant atmosphere which turned cleaning up into an enjoyable activity.

All teachers chose their way of using FireFlies based on the colors rather than based on the audio. Most teachers indicated that, if they were to choose, they would link the sounds and colors differently. They would prefer ocean-sounds to be linked to red, as the activity that is performed under the red light (working in silence) is better supported by a gentle background sound of the ocean, than by discreet owl-sounds.

The FireFlies design builds on earlier work [4], in which we concluded that the audio of CawClock was a suitable medium for background information display in classrooms. Although the audio design of FireFlies was largely based on that of CawClock, it was not suitable for most of the purposes for which FireFlies was used. The major difference between the current and previous study, is the grades in which we deployed our system; grade 1 and 2 for CawClock and grade 3 to 5 for FireFlies. This was decided in the earlier described workshop with educational experts, who saw more opportunities for innovation in higher grades. During the deployment of FireFlies, we discovered that children who are 'working in silence' in earlier grades, are much less silent than those in higher grades, which makes background soundscapes more outstanding in higher grades. The soundscapes of FireFlies were therefore less suitable indeed.

Example 4: Physical Interactions with the Teacher-Tool

All light-objects in classroom 2 are red; the children are silently reading a book. The teacher stands in front of the room, the teacher-tool clipped to her belt, and turns all light-objects off while saying 'please take your mathematics books'. The children start working on their mathematics assignments. The teacher turns all light-objects to red and takes place at a table in front of the room (the instruction table). She lays the teacher-tool on the table and makes two light-objects blue and three yellow. Two children then come to the instruction table and three others go sit at the computers. After giving instructions to these two children, she turns their lights back to red and makes two others blue. After all children had been at the instruction table, the teacher starts walking around the classroom, holding the teacher-tool in her hands. She helps children who need extra explanation and makes the light-objects of children who are working well green.

As evident from this example, P2 used the teacher-tool in multiple ways and at different locations in the classroom. Most teachers, however, used it while sitting in front of the room. When operating the teacher-tool, it was lying on the table or held in the hands in the majority of cases. P2 operated the tool while attached to her belt, but only when all lights were set to the same color, not to change individual lights.

None of the teachers had difficulty understanding how to operate the teacher-tool. In the beginning of the study, it took them a while to find the right name on the tool. However, at the end of the study, they indicated to automatically know approximately where each name was located; they quickly found most names. When discussing what had caused this interaction to become quicker, most teachers indicated that they had gotten used to it. They noted that particular names, e.g. those who needed to be called to the teacher a lot, could almost automatically be found as they were used frequently.

The beads of the teacher-tool, each representing one child, differed in length based on the number of characters in the child's first name. The teachers indicated that this helped them mainly to find the names that were frequently used, or the names that were extraordinarily long or short. The majority of the names, however, were located through the alphabetical order in which they were listed.

When discussing the design of the teacher-tool, about half of the teachers indicated that they would have liked the names to be ordered in the way that the children are seated in the classroom. This would enable them to visually link the locations of the children in the room to their locations on the teacher-tool. They mentioned they are visually or spatially oriented and would prefer using that ability to operate the tool. Other teachers, however, indicated that they would not prefer this, as they would then need to 'relearn' how to use the teacher-tool after the locations of children's desks have changed, which happens around five times per year. These teachers indicated to have very good knowledge of the names of the children and preferred using this rather than location to find the names. It seems that there is no perfect interaction design of the teacher-tool which works best for all these six teachers. Peripheral interaction designs may therefore benefit from interaction design which can be adjusted by the user.

Apart from the physical design, the teacher-tool also incorporated audio feedback. Although the teachers said they understood that the audio indicating the color selection could enable selecting it without looking, none of them actually applied this. Since they all looked at the design when operating it, the sound did not have an added value to them.

DISCUSSION

In this paper, we presented FireFlies, a peripheral interaction design for primary schools, as well as the qualitative results of a 6 week deployment of FireFlies in four classrooms. In this section we will discuss the implications of these findings as well as reflect on the setup of our study.

In order to evaluate the extent to which a design blends into the user's everyday routine, it is essential to evaluate it in the context of use for a period of time [9]. In our study we visited the participants every day before or after school hours. This was done to charge the prototype's batteries, but also to enable an informal evaluation moment. We believe this was worth the time and effort. Practical questions about using FireFlies (e.g. 'will the light-objects survive falling on the floor?') could quickly be answered positively, which caused the teachers to use it in the way they wanted without hesitation. Additionally, numerous examples regarding the use of FireFlies were collected in these informal encounters, such as the ones presented in this paper. Additionally, we believe that our presence functioned as a reminder to use FireFlies, especially in the beginning of the study.

A more general motive to perform longitudinal studies is to overcome what we call 'first-time enthusiasm': high levels of enthusiasm when a new technology is used for the first time. In the first week of the study, we observed first-time enthusiasm particularly among the children, who were very engaged with their light-objects and, according to the teachers, easily 'obeyed' them. Toward the end of the study however, their enthusiasm decreased as FireFlies became more part of their routines. The children also reported that in the beginning they thought the light-objects were 'really cool' while at the end they were 'just normal'. Six weeks deployment was clearly enough to overcome first-time enthusiasm; its influence on our results seems reduced to a minimum.

As became clear from our observational examples, using FireFlies in many cases replaced other ways of working (e.g. giving compliments and turns verbally). Several teachers indicated that in the beginning of the study, they had to consciously think about using FireFlies for these purposes. Actions such as giving a turn seemed highly embedded in their routines, they sometimes automatically performed them and forgot that they planned to do it with FireFlies. The children often reminded the teachers to use FireFlies in those cases. Toward the end of the study however, almost all teachers indicated that using FireFlies had become an automated part of their everyday actions. When they wanted to call a child to the instruction table or give a compliment, they automatically thought of grabbing the teacher-tool and changing a light. Also, they reported to have automatic knowledge of which color to use in which case. Further evidence for this automatic behavior was found after the study had stopped. Teachers reported that they missed using FireFlies as well as that there were moments in which they were about to start using it and then realized this was no longer possible. We believe this indicates that using FireFlies was relevant to our participants as well as that it, some extend, became a routine activity.

FireFlies is an open-ended design: it was up to the teachers to decide for which purpose to use it. This approach was taken to increase the likelihood of individual users finding a personally relevant use of FireFlies. Although the usage differed among

participants, all participants found a relevant purpose for using FireFlies. We believe this shows that the open-ended approach was successful. Relatedly, we found that teachers were interested in adjusting the mapping between audio and color (e.g. connect ocean-sounds to red rather than to blue). Furthermore, it seemed that the interaction design of the teacher-tool might have been most suitable in one way for one teacher and in another way for another teacher. Enabling users to flexibly adjust such parameters of the design to their own liking could be an interesting approach to make peripheral interaction designs more open-ended. This could be an interesting direction for future research.

CONCLUSIONS

In this paper we have presented FireFlies, an open-ended peripheral interaction design aimed to support primary school teachers in performing secondary tasks while teaching. FireFlies combines physical interaction and auditory feedback and can be seen as a research instrument to study the concept of peripheral interaction design in context. An interactive prototype of FireFlies has been deployed in four different classrooms for six weeks each. Preliminary results reveal that FireFlies was used every day during the study. All teachers found relevant uses for the system, even though the way they used it differed. Teachers evidently needed time to incorporate the use of FireFlies in their everyday routines. However, the fact that they missed its functionality and sometimes automatically grabbed for the teacher-tool after the study had finished, indicates that using FireFlies became part of their everyday routines to some extent.

FireFlies seemed most beneficial as a visual information display to both children and teachers, the audio aspect was less successful. Evaluation of the physical interaction design revealed that teachers were quickly able to operate the teacher-tool during other activities. However, we also realized that the preferred interaction design, which may anticipate for example the user's spatial knowledge or the user's abstract knowledge of children's names, differs per teacher.

This paper presents new insights in the design and evaluation of interactive systems that are to be embedded in everyday routines. Despite our specific target group, we believe this knowledge is also relevant for those with similar aims in other contexts of use. Additionally, our work contributes to research on classroom technology, by showing an example of how teachers may benefit from peripheral interaction design.

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