FeetForward: On Blending New Classroom Technologies into Secondary School Teachers' Routines

Pengcheng An(✉), Saskia Bakker, and Berry Eggen

Department of Industrial Design, Eindhoven University of Technology, Eindhoven, The Netherlands
{p.an, s.bakker, j.h.eggen}@tue.nl

Abstract. Secondary school teachers have complex, intensive and dynamic routines in their classrooms, which makes their attentional resources limited for human-computer interaction. Leveraging principles of peripheral interaction can reduce attention demanded by technologies and interactions could blend more seamlessly into the everyday routine. We present the design and deployment of FeetForward - an open-ended, and foot-based peripheral interface to facilitate teachers' use of interactive whiteboards. FeetForward was used as a technology probe to explore the design of new classroom technologies which are to become peripheral and routine. The deployment took place with three teachers in their classrooms for five weeks. Based on in-depth and longitudinal interviews with the teachers, we discuss about how FeetForward integrated into teachers' routines, what its effects were on teaching and whether its foot-based interaction style was suitable for peripheral interaction. Subsequently, implications on design of peripheral classroom technologies were generalized.

Keywords: Peripheral interaction · Classroom technology · Foot-based interaction · Secondary school teacher · Calm technology · Interactive whiteboard

1 Introduction

With normally 30 or more students to serve and various tasks to fulfil, secondary school teachers have busy everyday routines, characterized by multitasking [1], unpredictability [2] and complexity [3]. While teaching, teachers need to constantly remain aware of students' progress, frequently confront interruptions, and reflect on their goals or plans for the lesson [1]. As such, they need to divide or shift their attention among different tasks, which consequently makes the teachers' attention a valuable yet limited resource in this context.

Nowadays, secondary schools in developed countries usually offer good access to technologies through well-built ICT infrastructures [4] and devices such as (laptop/tablet) computers, interactive whiteboards, smartphones. Various applications are available to support teachers to organize and track the class (e.g. Google Classroom [5]), to demonstrate and explain the content (e.g. SMART Notebook [6]), and to access relevant

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internet resources (e.g. Pocket [7]). However, such classroom technologies are designed for focused interaction [8]: users have to continuously pay attention to the graphical user interface to perform interactions successfully. As a result, such technologies unintentionally bring new complexity into teachers' work and the frequency of using technologies for educational purposes is relatively low [9, 10].

Classroom technologies could be more seamlessly blended into teachers' routines when they require less focused attention while still supporting teaching tasks [1]. We believe this can be achieved by leveraging the principles of peripheral interaction [11], a human-computer interaction paradigm which enables not only interaction with focused attention, but also interaction which takes place in the periphery of attention, and allows seamless shifts between the two.

With the purpose of exploring how new classroom technologies can be designed to become peripheral and routine for secondary school teachers, this paper presents the research-through-design [12] study of FeetForward, a foot-based peripheral interface to facilitate secondary school teachers' use of interactive whiteboards (See Fig. 1). We have deployed this simple yet new technology with three secondary school teachers in their classrooms for a period of five weeks. In this study, we used FeetForward as a technology probe [13] to gather implications for the design of peripheral classroom technologies. In particular, we aimed to study how FeetForward as a peripheral interaction design, could impact pedagogical activities, what may influence a new classroom technology to integrate into teacher's routines, and whether foot-based interaction styles were suitable for peripheral interaction.

Fig. 1. FeetForward: a foot-based peripheral interface to support teachers' use of interactive whiteboards. See [14] for a demo video. (Color figure online)

The remainder of this paper will discuss related work, theoretical background, the design process and rationale of FeetForward and the process of deployment and data gathering. Subsequently, we address the findings of the study and conclude generalized implications for design.

2 Related Work

In their renowned paper on calm technology, Weiser and Brown [15] envisioned that as computing devices become increasingly ubiquitous in our lives, users should be enabled to interact with these devices not only in the center but also in the periphery of their attention, and shift back and forth between the two. This vision inspired various related research areas. Peripheral displays [16] or ambient displays [17], for example, study how to present relevant information without requiring focused visual attention. More recently, the field of peripheral interaction [11] was introduced, studying how physical interactions with computing systems can shift to the periphery of attention.

In the context of education, a few examples of ambient displays are known. Lernanto [18] presents glanceable information about the real-time performance of students, to support differentiated instructions. Lantern [19] uses interactive lamps to display ambient information about work status of student teams to facilitate teacher-students communication. ClassSearch [20] aims to create ambient awareness of web search activities in the class, to facilitate social learning and teacher-led discourse. Similarly, Lamberty et al. [21] present an ambient display which shows each student's real-time design work, to improve peer awareness in learning. Sturm et al. [22] described an ambient display which gives feedback to a teacher about the attention and interest level of students being lectured.

While above mentioned ambient displays are helpful in providing relevant information during lessons, we believe teachers can be further supported in their daily routines if physical interactions would also become available in the periphery of attention. However, examples of peripheral interaction are mainly found in the office context. The unadorned desk [23], for example, uses gestures at the periphery of the workspace to trigger frequently used shortcuts in a desktop context. Probst et al. [24] explored subtle movements or gestures on a chair, such as tilting left and right, to trigger common web-browsing commands, such as next and previous webpage. Few related research explorations are known in educational settings. Notelet [25], is a bracelet interface, enabling a teacher to take a picture of the class through a camera mounted in a corner of the classroom to later remind the teacher about a certain behavior of a student. FireFlies [26] is an interactive system which allows teachers to quietly and unobtrusively communicate short messages to children using a tangible tool. Both these examples were explored in a primary school setting. This paper contributes an exploration of peripheral interaction for secondary school teachers, a target group that differs considerably in terms of teaching styles [27] and everyday routines.

Different from earlier explorations of peripheral classroom technologies, this paper particularly explores foot-based interaction as a style for peripheral interfaces. Foot-based interaction has been studied since the very beginning of the HCI realm [28], and has before that been used as a supportive or secondary modality to manual tasks of people such as potters, organists, or drivers. Because humans have highly developed abilities to manipulate artifacts by hand, feet are not often the first choice for performing human-computer interaction. However, foot-based interaction could be suitable in specific scenarios in which the hands are occupied [29].

Related to educational technology, Daiber et al. [30] explored foot navigation while interacting with geospatial data on a large display, and suggested the interaction style may be beneficial in "teacher-apprentice setting". In the area of peripheral interaction, Probst [31] explored foot kicking and rolling as interaction styles in the context of desktop computing (in sitting posture). Velloso et al. [28] presented a comprehensive review of foot based HCI, in which they also pointed out that since a lot of work of this area has been done in laboratory settings, more field deployments for extended periods of time are still needed. The work presented in this paper contributes a field deployment of a foot-based interface specifically aimed at shifting some of teachers' interactions with the interactive whiteboard to the periphery of attention.

3 Habituation and Peripherality

During their everyday routines, people frequently perform interactions with everyday objects in the periphery of their attention [32]. For example, when reading a newspaper, one could pick up a coffee cup and take a sip without consciously paying attention to it. Or when talking to a friend, you could still put something into your pocket, or straighten your jacket. The reason why these secondary activities can be performed peripherally is two-folded. On one hand, the cognitive or motor resources required by these tasks do not conflict with those required by the main tasks, which makes them possible to be performed in parallel with the main tasks (according to multiple resource theory [33]). On the other hand, these tasks have been repeated for many times in our familiar daily contexts, thus have become automatic to certain degree. The process of activities becoming automatic after repeatedly performing it, is also referred to as habituation [34].

As suggested by dual-process theories [35], our behaviors can be carried out along two competing pathways: a deliberative route, and an automatic route [36]. When we are performing novel activities, or when we are in unfamiliar contexts, our performance normally requires continuous attention in order to perceive new information and respond appropriately. Contrarily, when we are performing habitual activities in a familiar context, we do not have to pay continuous, or focused attention to our performance [34]. Along the automatic route, a behavior is performed peripherally, and therefore can save us cognitive resources for more focused or unfamiliar activities.

Habituation is a key determinant of automaticity [37–39]. New interactions also require a certain extent of habituation (learning and unlearning) before it can be performed in the periphery of attention [40]. In the domain of peripheral interaction, it is therefore valuable to investigate the habituation of interactions when evaluating designs, as it may indicate a design's integration into the personal contexts and existing routines of a user. In the study presented in this paper, we therefore use habituation (habit strength) as an indicator in the evaluation of peripheral interaction design.

4 Designing FeetForward

4.1 Understanding the Context

Secondary schools in developed countries are widely equipped with interactive whiteboards. they are generally seen as a useful tool for teaching and learning [41, 42].

However, various disadvantages restrict the use of interactive whiteboard. For example, effective use requires advanced skill training [42, 43], teachers often find using the interactive whiteboard time-consuming [43], and they argue that there is not enough customizable space [42].

The aim of the study presented in this paper is to explore how to shift some of the teachers' interactions with the interactive whiteboard to the periphery of attention. To better understand teachers' use of the interactive whiteboard, we observed two teachers while using the interactive whiteboard during a regular lesson, and we invited each of them to participate in an ideation session with several designers. While interacting with the board, both teachers were occasionally observed walking to their computer to fulfil operations such as opening an application, opening a webpage, resizing or moving a window, and pausing or replaying a video. Although such operations could also be done using touch or stylus interaction on the board, the teachers preferred using the mouse or keyboard of their computers, interactions to which they were more accustomed. From the observations and discussions with the teachers, it became clear that their operations on the interactive whiteboard or through computer required focused attention, even though these operations were considered secondary tasks. The ideation sessions therefore brought forward the idea to make such actions available through a peripheral interface, so that the tasks become easier to perform, and teachers do not have to walk to their computers that often.

Additionally, we observed that, while standing in front of the whiteboard, teachers' hands were often in use, holding tools such as (interactive) mark pen, textbook and paper documents. On the other hand, teachers' lower limbs were free to move. Unlike when sitting at a desk, while standing, foot movement can be observed through peripheral vision. This lead to the choice of exploring a foot based peripheral interface, and the design of FeetForward.

4.2 FeetForward Design

Peripheral behavior has a highly personal nature [40], new interactions usually become peripheral only when they are meaningful in the specific context to the specific user. Depending on factors such as teaching experience or subjects, teachers often have diverse teaching routines [1]; therefore, we designed FeetForward as an open-ended system. FeetForward consists of four pedals placed under the interactive whiteboard, which can be pressed using the foot, see Fig. 1. Each pedal can be connected to a personalized shortcut operation on the interactive whiteboard. Teachers can personalize the functions of the pedals to make them meaningful to their own contexts.

Each pedal of FeetForward can detect two states of foot operation: hovering and pressing (see [14] for a demonstrating video). When a foot is hovering above the pedal, an icon will pop up on the whiteboard indicating the function that is activated when the pedal is pressed. This augmented feedforward [44] was designed to help users remember or confirm the function before pressing the pedal. Additionally, the four pedals were tagged with different colors (yellow, red, green, and blue) to be differentiated from each other at a glance. These colors match the colors of the icons of the connected functionality. The FeetForward prototype deliberately involved straightforward functionality and relatively easy foot gestures (toe tapping [28, 29]), to ease the process of habituation and to enable interactions to shift to the periphery of attention.

The FeetForward design was developed into a functional prototype. Each pedal of the prototype contained a proximity sensor to detect hovering of a foot, and a tactile switch to detect pressing. Four pedals were connected to an Arduino microcontroller, which was connected to a teacher's laptop computer that ran a dedicated java-based program to achieve the personalized operations.

5 Methodology

The research presented in this paper was conducted using an approach inspired by research-through-design [12] and technology probes [13]. We designed and deployed our dedicated peripheral interface, FeetForward, with the purpose of expanding knowledge on the design of peripheral classroom technology. The aim of deploying this probe was to answer the following research questions: (1) What impacts may peripheral classroom technology have on teaching? (2) What may influence a new classroom technology to become peripheral and routine? (3) Can foot-based interaction be a possible style for peripheral interaction design?

A process of habituation is needed for any interaction to become peripheral [40]. We therefore deployed the FeetForward prototype in secondary school classrooms for a period of five weeks, which would also help obviate the novelty effect.

5.1 Study Setup

Two identical prototypes of FeetForward were implemented into two classrooms of different secondary schools. Three teachers (see Table 1) participated in the deployment. In the following parts of this paper we refer to these participants by their aliases: Peter, Sandy, and Mary. Peter and Mary taught mathematics at the same school. During the deployment, Peter taught 5 lessons per week in the classroom equipped with FeetForward, while Mary taught 2 lessons a week in that classroom. Sandy taught chemistry at a different school, and she taught 4 lessons a week in the equipped classroom. All three teachers had been using interactive whiteboards for teaching before this study.

A FeetForward prototype was installed in each classroom for around two months. Due to school holidays and examinations, the actual usage period for each teacher was five weeks. At the start of the deployment, we demonstrated the prototype with its four pedals assigned to functions we chose based on observations (opening a folder, opening a website, opening an application, and switching among opened application). Subsequently, we asked each participant to indicate what personalized functions they may want to use, and a researcher implemented these functions into the prototype. During the deployment, the researcher visited each participant once a week to see if they wished to change the personalized functions. These informal meet-ups also triggered conversations between teachers and the researcher, which could reveal additional insights into the use and experience of FeetForward.

Since FeetForward has four pedals, at most four functions could be assigned to it in each week. Table 1 lists the functions of FeetForward chosen by each participant during the whole deployment. As the table shows, we refer to the interactions with FeetForward to achieve teachers' personalized functions as **Fi,j**. Correspondingly, the interactions teachers had been doing before the study through interactive whiteboard or computer to achieve the same functions were referred to as **Fi,j'**.

During the deployment, each teacher joined four rounds of data gathering: (1) At the beginning of the deployment (we refer to it as **Week 0**), (2) after one week of using FeetForward (**Week 1**), (3) after three weeks of deployment (**Week 3**), and (4) at the end of the five weeks (**Week 5**). In each round, the teacher was asked to fill in a questionnaire, take an interview, and have one of his or her lessons video-recorded. The researcher was not present during these video-recording sessions. Questionnaires and interviews were conducted either in the teacher's classrooms or at the university.

Table 1. A list of personalized functions applied by each participant with their descriptions in the brackets. The weeks in which each function was implemented were also indicated.

Peter Function (description), week	Sandy Functions (description), week	Mary Functions (description), week
F1,1 (open folder), 1–5	F2,1 (switch webpages), 1–5	F3,1 (open webpage), 1–5
F1,2 (switch applications), 2–3	F2,2 (open webpages), 1–5	F3,2 (open "File" menu), 2–5
F1,3 (open webpage), 2–5	F2,3 (exit virtual desktop), 1–5	F3,3 (switch applications), 1–5
F1,4 (screen shot), 2–5	F2,4 (resize window), 2–5	F3,4 (open folder), 1–4
F1,5 (resize window), 4–5	F2,5 (open folder), 1	F3,5 (resize window), 5

5.2 Questionnaire Design

The questionnaire used in each round was designed to gather subjective quantitative data on the habituation of, and effort required for, interactions with FeetForward. In each data gathering round, the participants were asked to rate nine interactions on the Rating Scale Mental Effort (RSME) [45] and on the scale of the Self-Report Behavioral Automaticity Index (SRBAI) [46].

Measures of mental effort (using RSME [45]) have been adopted in related studies on peripheral interaction (e.g. [26]). Interactions which are experienced to demand less mental effort are assumed to require less attentional resources, which could indicate they may be performed in the periphery of attention. The SRBAI [46] was chosen to assess habituation of an interaction. When a behavior becomes more habitual, it uses cognitive resources more efficiently, and requires less attentional resources. Additionally, habituation may reveal how well a behavior is adopted into the everyday routine.

SRBAI is a streamlined version of Self-Report Habit Index (SRHI). SRHI was developed as a standardized and reliable scale of habit which contains 12 items. Four items of it were selected and validated to construct SRBAI to afford parsimonious measure of habit strength which especially focusing on the characteristic of automaticity [46]. Automaticity is the key effect led by habit which contributes to peripherality of an interaction, and parsimony is valuable for this study since multiple interactions were assessed over a period of time. As a result, SRBAI was used to evaluate interaction behaviors in this study.

In each session, up to nine interactions were given to a teacher to rate using RSME and SRBAI. These included the four functions connected to the four pedals of FeetForward, and the four interactions which would normally be used to trigger these functions. Both these interactions were included to enable comparison and evaluation of changes in habituation and effort over time. For example, Peter assigned the red pedal of FeetForward to the function of opening a frequently used folder. He was therefore asked to rate the interaction "opening my frequently used folder with the red pedal of FeetForward" and the interaction "opening my frequently used folder with my computer". Additional to these eight interactions, the teachers were asked to rate the activity of "turning on the lamps in my classroom" (which we refer to as **L**). We assumed that this behavior was relatively stable and habitual in teachers' everyday routines, and unlikely to change during the deployment. This interaction was used as a warm-up and as a reference when analyzing the data.

5.3 Qualitative Data Gathering and Analysis

We chose a phenomenological approach [47] to gather and analyze qualitative data. This approach is used to describe and explain lived experiences of several (1–10) individuals [47], which is particularly suitable for answering our qualitative research questions regarding the integration of peripheral interfaces in teachers' routines.

Qualitative data was collected using semi-structured interviews, as is conventional in the phenomenological approach [48]. As mentioned above, each participant was interviewed four times. Each interview was conducted with an individual participant and consisted of three parts, aimed to gain insights into (1) the users' general experience of using FeetForward including perceived advantages and disadvantages, (2) peripherality of the interactions including perceived effort and routineness, and (3) the users' experience of foot-based interaction, their experience in learning and practicing how to use the interface, and their allocation of attention to the pedals and visual feedforward. As each participant was interviewed four times, participants usually also reflected on changes in their experiences.

Using [49] as a reference, the transcribed qualitative interview data were analyzed using the following steps: (1) the first author read through the transcripts to gain an overall understanding of the data, (2) phrases or sentences which were considered relevant to a research question were highlighted, (3) these selected phrases were clustered into emerging topics under each research questions, and finally (4) these clusters were re-contextualized by adding concrete descriptions provided by the participants.

6 Quantitative Findings

Self-report Effort. Figure 2 shows the results of the Rating Scale Mental Effort (RSME), in which teachers rated the mental effort required for interactions with FeetForward, and for counterpart interactions with their laptop or interactive whiteboard to achieve the same functionalities. It is shown in Fig. 1 that all the interactions

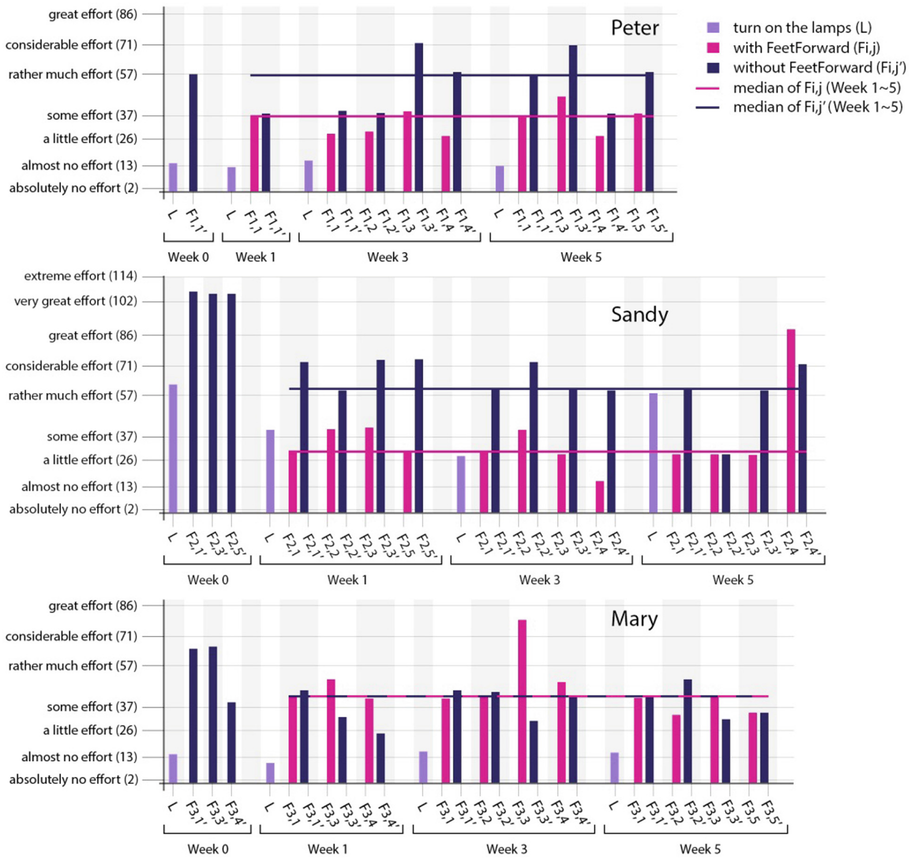

Fig. 2. Results of RSME. The rated value of RSME could range from 0 to 150: the higher an interaction is rated, the more effort a subject experiences. The medians of tasks with/without FeetForward during the five-week deployment were also shown.

with FeetForward were considered as more effortless than those without FeetForward for Peter. For sandy, FeetForward also took much less effort except F2,4 rated in the last week. Mary found interaction F3,1 and F3,2 are a bit more effortless; But F3,3 and F3,4 were felt more difficult than F3,3' and F3,4'. As the comparisons of the medians in Fig. 1 shows, using FeetForward was generally considered no more effortful than performing previously practiced interactions. And it was especially considered as more effortless than previous interactions for Peter and Sandy.

Self-report Automaticity. Figure 3 shows the results of the Self-Report Behavioral Automaticity Index (SRBAI), the four-item rating scales participants used to indicate the perceived automaticity of interactions to achieve the personalized functions, with and without use of FeetForward. The higher the rating, the more habitual/automatic the behavior is experienced. The results in Fig. 3 indicate that after the deployment, the perceived automaticity of most tasks with FeetForward (F1,2, F1,5, F2,3, F2,4, F2,5,

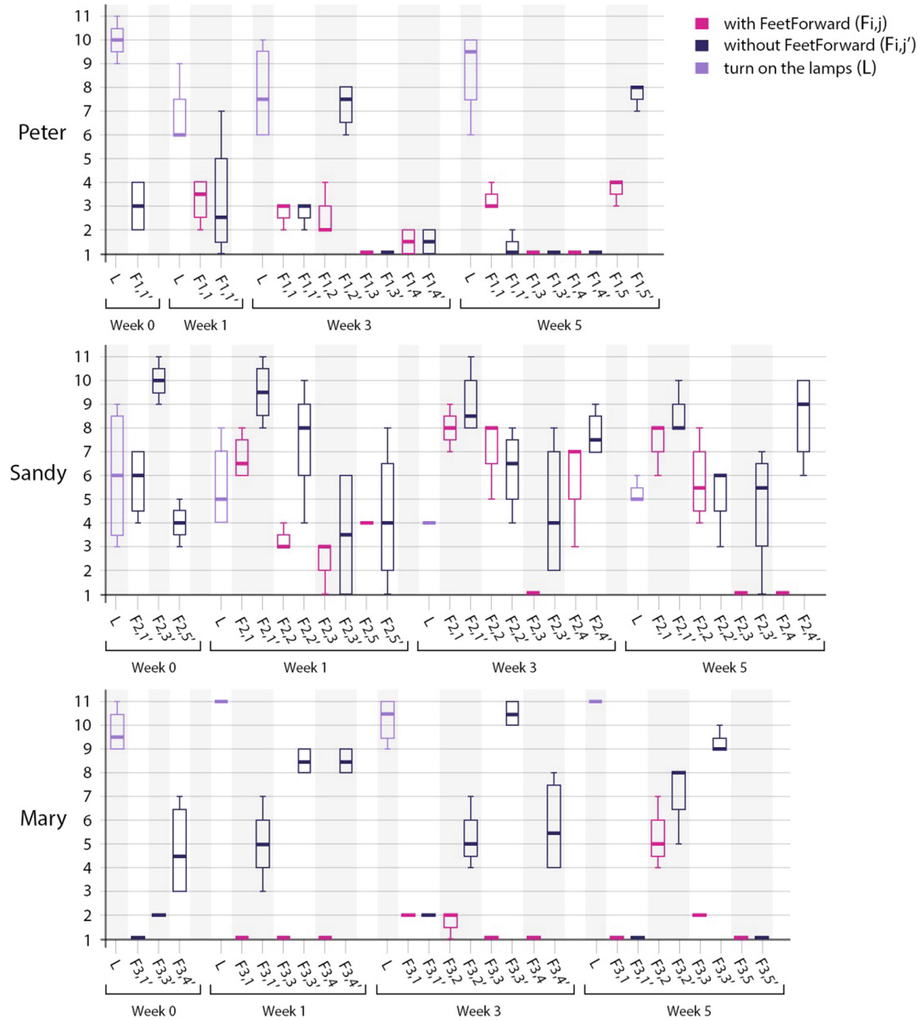

Fig. 3. Results of SRBAI gathered using eleven-point Likert scales, where 1 stands for 'strongly disagree', 6 stands for neutral attitude, and 11 stands for 'strongly agree' to statements of SRBAI (e.g., "Behavior X is something I do without thinking."). The results are represented by box-and-whisker plots (indicating median, quartiles, and max/min values).

F3,3, and F3,4) had not increased, even though some of them (F1,5, F2,3, F2,5) were experienced as considerably more effortless than their counterparts (see Fig. 2), and some of them (F2,3, F3,3, F3,4) had been implemented for four or five weeks (see Table 1). There were also some tasks to be found not automatic at all both with or without using FeetForward (F1,3, F1,4, F3,1, F3,5, and their counterparts). However, as shown in Fig. 3, there were also a few of interactions (F1,1, F1,5, F2,1, F2,2, F3,2) with FeetForward that had clearly gained self-report automaticity. For example, data from Week 1 and Week 3 show that the automaticity levels of F1,1 and F1,1' were about the same, but in Week 5, F1,1 had become more automatic than F1,1'. F2,2 was evidently less automatic than F2,2' in Week 1, but they had become comparably automatic in Week 3 and Week 5. The same change happened to F3,2 from Week 3 to Week 5. Additionally, while F2,1' is quite automatic to Sandy, F2,1 had quickly become automatic (since Week 1), and remained the level which is quite close to F2,1'. In general, for most of the interactions with FeetForward, the five-week deployment might be too short to see an evident increase of behavior automaticity, or a replacement to a previously practiced interaction; However, a few of operations with FeetForward did show a clear rise of self-report automaticity.

Interaction Duration. In order to gain insights into the routineness of the interactions with FeetForward, we video-recorded one lesson of each teacher during each data gathering session. Additionally, the prototype logged interactions during the deployment. These data were used to interpret the duration of each interaction with FeetForward. We defined this interaction duration as the duration between the moment the user started to glance down at the pedals, and the moment that the user pressed the pedal. This total interaction duration consists of two sub-durations: *glancing down* (from starting to look down at the pedals to moving the foot above the pedal and an icon appearing) and *foot hovering* (from the moment the foot hovers above a pedal until the pedal is pressed). These two sub-durations were measured separately. Foot hovering was measured by the prototype, using the proximity sensor and tactile button. The numbers of interactions logged by the system were 26 from Peter, 26 from Sandy, and 23 from Mary. Glancing down was measured through video analysis, in which the number of frames within the sub-duration was measured as the original value, and converted into seconds (The framerate of the analyzed videos was 30f/s). The numbers of interactions which were captured by video and analyzed were 7 for Peter, 11 for Sandy, and12 for Mary. The mean values and standard deviations of interaction durations of each participant are presented in Table 2. As the table shows, the total durations of Peter and Mary were below 4 s, while Sandy's duration was 2.68 with the standard deviation of 1.64 (1.04 – 4.32), which is generally below 4 s. Therefore we can conclude that interactions with FeetForward were mostly performed in less than 4 s. This is within the duration range of microinteractions [50], which considered a minimal interruption of primary tasks according to the Resource Competition Framework [51].

7 Qualitative Findings and Discussion

In this section, corresponding to each of our three research questions, we address and discuss in-depth qualitative findings from longitudinal interviews with the participating teachers, while also including some discussion about the quantitative findings presented in previous section.

Table 2. The results of interaction duration (in seconds), which are formatted as: mean ± SD.

Subject	Glancing down	Foot hovering	Total duration
Peter	1.56 ± 0.51	0.54 ± 0.33	2.1 ± 0.84
Sandy	1.85 ± 0.93	0.83 ± 0.71	2.68 ± 1.64
Mary	1.3 ± 0.5	0.97 ± 1.01	2.27 ± 1.51

7.1 What Impacts May Peripheral Classroom Technology Have on Teaching?

Saving Effort. As RSME and interaction duration data shows (see Fig. 2 and Table 2), interactions with FeetForward were generally perceived to demand no more effort than the existing interactions, and were mostly performed within 4 s. The interviews also revealed that all participants agreed that FeetForward saved them time and effort to achieve certain functions. For example, Peter thought the pedal connected to the function of resizing a window (F1, 5) made the task much easier, "*because it's hardest to do* [with the stylus on the interactive whiteboard]". Sandy indicated that when she was interacting with her computer, "*I have to walk* [to the desk from the whiteboard] *and I have to look at the small screen, I have to bend over… and it takes a while.*" She thought with the task simplified by FeetForward, that "[I] *don't have to walk always from computer to board back and forth. It's much quicker.*" and that she could "*keep on talking to my class while I'm doing it*". Mary agreed: "*It saves me walking to the computer. It helps me not concentrating at the computer screen. I look at the pedals and I can also pay attention to the pupils.*" In summary, by reducing effort, and enacting minimal interruption to the main task, FeetForward can possibly enable some side tasks to be performed quasi-parallel with other tasks. These experiences therefore echo the core intention of peripheral classroom technology.

Fulfilling Personal Needs. Freedom of function personalization of FeetForward triggered conversations between the participants and researchers, revealing the teachers' diverse routines and needs. For example, the pedal that had become most habitual to Mary with FeetForward was connected to the function of calling the "File" menu to open recently used files (F3, 2, see Fig. 3). She used this function frequently, but the problem she faced without using FeetForward, was that the 'open' button is located at the top area of the interactive whiteboard, and she could not easily reach it. "*I am not going to jump in front of students*". Therefore, she had to go to her computer to fulfil the task. Sandy shared this difficulty with her, "*I cannot reach the top button*". Besides, she used different web pages in her lessons, therefore she chose for a pedal to switch between opened tabs whose buttons are on the top area of the internet browser (F2,1). This pedal also had gained the most automaticity among the four (See Fig. 3). Peter's "*most useful*" pedal connected to opening a folder which stores resources relevant to the current lesson topics (F1, 1), and it had become more automatic than the previously practiced interaction (using computer). Although Peter considered that pedal most useful, the other participants did not find this function very relevant. These findings show that different functions of FeetForward blended into different routines, which was supported by the open-ended nature of the peripheral interface. Furthermore, we found that this open-endedness motivated teachers to think about more possibilities of the classroom technology which fit to their own contexts. Sandy reported that after she got more used to FeetForward, *"I started to more and more think about possibilities of pedals… you want make use of it. I haven't tried the possibilities. …I can think about a hundred things to do"*.

Improved Integration of Technology. By making side tasks more effortless, and satisfying diverse personal needs, peripheral classroom technology may also lead to improved integration of technology into classrooms. FeetForward made our participants use certain functions more often. Before Peter had the pedal connected to a frequently used folder, he already put relevant pictures into that folder with the intention to use them during his lesson. However, "*I didn't use it often* […]. *Maybe with FeetForward it's easier for me to access, and I will use it more often*". Sandy talked about the pedal to switch webpages: "*because I think it's convenient to switch* [using] *the pedal, it makes me use the web browser more*". That also made her use online exercises more often. "*I can switch more easily, so that made me search for web-based applications I could use with the students… Instead of assigning them as homework, I can use these exercises in the class*". Additionally, effortless access may lead to more flexible use of technology. Peter, for example, found the function of resizing and repositioning a window helpful when two applications needed to be shown or used at the same time. Due to the effort required to do this with the stylus, he usually did this before the lesson with the computer. "*It's something I do mostly when preparing my lesson… But sometimes I have to do when I am in front of the classroom*". Using the pedal, the task became easier, especially in unexpected situations. This also held for the frequently used folder; he normally tried to "*foresee*" which pictures might be used in the lesson, and collected them in one document beforehand. But with FeetForward, "*when the students ask about their homework, and I didn't anticipate,* […] *at that moment we could retrieve the picture from the folder with FeetForward*". The flexibility offered by FeetForward may thus enable teachers to interact with technologies more extemporaneously during teaching activities, possibly enhancing their use of digital resources.

7.2 What May Influence a New Classroom Technology to Become Peripheral and Routine?

Although FeetForward facilitated or simplified teachers' individually relevant side tasks in relatively short interaction durations without requiring much mental effort, we had not seen that all the new interactions completely became more automatic than previously practiced interactions during the five weeks. The study results indicated that it requires a relatively long period of time for designed peripheral interaction to really become peripheral, and many factors could have an influence on this process. In this sub-section, user's experiences about factors that may influence a new technology to become peripheral and routine will be addressed and discussed.

Consistent Accessibility. Throughout each week, each of our participants taught in different classrooms of which only one was equipped with FeetForward. Mary for example, used two classrooms. She thought it would be "*really helpful*" if prototypes were equipped in all classrooms. She spent more time in the classroom in which no FeetForward was available. She indicated that, since the two classrooms "*look alike,* [..] *I perceive they* [the two classrooms] *are the same,* [..] *so I have to remember they* [pedals of the prototype] *are here to actually use them*". Likewise, Sandy emphasized the importance for the classrooms to have consistent settings for a new technology; "*not* [teaching] *in the same classroom takes long time for me to get used to it* [FeetFordward]". To explain this further, she indicated that "*working in different classrooms is like cooking in different kitchens …it takes me a while to adjust …*". The inconsistency of the settings demanded extra mental effort to adapt to, as Sandy said, it "*requires thinking*", which made it difficult to adopt the new technology. In Mary's thought, if FeetForward would only be available one classroom, "*most of the teachers will just use the whiteboard* [not the pedals]". As experienced by our participants, consistent accessibility is important for a new technology to blend into a teacher's routines.

Existing Habits. Due to the function of FeetForward, we were able to compare effort and automaticity of interactions with the pedals to those of interactions teachers had been previously doing, to achieve the same operations. As seen in respectively Figs. 2 and 3, we found that although some interactions with FeetForward were rated as more effortless than the existing interactions, perceived automaticity of these interactions had not exceeded the existing ones during the deployment. All participants reported several times in interviews that they sometimes forgot to use the pedals, but automatically used their computers or whiteboards. For example, "*Afterwards…* [I noticed] *Oh I could have used FeetForward*" (Peter), or "*When I want to open my frequently used folder, first thought is to go to the computer. [..] Sometimes on my way to the desk and I think oh wait I can use the pedal*" (Mary). Sandy indicated that she forgot to use FeetForward especially when experiencing high mental load or stress, for example when "*the lesson isn't going as I planned*". She furthermore mentioned "*When something happened, you have to switch to your automatic pilot*". Although walking to the computer to operate the interactive whiteboard may objectively be less economical compared to using FeetForward, it seems to be strongly habitual. Given the attention demanding nature of teacher's main tasks, it seems that side tasks are prone to be performed in a habitual way. Such strong existing habits seem difficult to be replaced by a new habit; the period of five weeks may not have been enough to completely achieve this.

Frequency of Practice. Repetitive performance in certain context gradually raises the automaticity of a certain behavior [34]. Although using the pedals did not replace existing habits during the deployment, all participants agreed that their frequency of usage effected how they got used to FeetForward. "*The less I used it, the less automatic it is*" (Mary). Mary believed that using the prototype "*continuously*" and "*repetitively"* would help it to become part of her routines more quickly. The deployment of FeetForward was conducted in the last two months of a semester. Therefore the three teachers had fewer lessons to teach than earlier in that semester. As Peter experienced, "*teaching frequency is at low point*", and "*if I had more lessons, the more quickly I will adjust to FeetForward*". Besides lesson schedule and perceived usefulness, it was also pointed out by the teachers that physical presence of a new technology may have influence on frequency of its usage. As mentioned in the previous sub-subsection, participants sometimes forgot to use FeetForward. However, the visibility of the prototype reminded our participants to use the new technology, when they came into the classroom. "*It's visible because it's on the floor*" (Sandy). "*When I come in I see them* [the pedals], *when I switch on the board the pedals are under it*" (Mary). Additionally, Peter thought the physicality of FeetForward had benefits "*because it's a physical button, it's not part of the smart board*". When he was using the interactive whiteboard, "*actual computer functions, they are more in the back of my head… maybe the physical buttons make me use some computer functions more often*". This could indicate that, because the pedals offer users physical affordance, or inherent feedforward [44] to some functions which were previously hidden behind the interface of interactive whiteboard, these functions might be more frequently used.

Learnability. As an open-ended system, FeetForward required participants to map the four pedals to four customized functions. It took longer than expected for teachers to remember these functionalities. "*Four pedals are quite a lot*", Peter experienced, "*it will take time for us to remember which pedal does what*". Sandy indicated "*I still have to think about the color. I made mistakes… I have to remember* [the colors]". During the deployment, we found that the position and order of the pedals were remembered by the teachers earlier compared to the colors. Peter indicated that when he was glancing down at the pedals, what he focused was "*positions of the four pedals mostly, not onto colors*". In Sandy's classroom, she located the green and the yellow pedal at the left and right ends under the board. And for her, "*the green and yellow ones are first to remember… The left the right, they are at the ends, easy to locate*". Similarly, Mary indicated that it was easier for her to remember "*Positions, not the colors… If you change the color to all yellow, I don't think it will make a difference to me*". Clearly, the functions of pedals were first remembered by the teachers using spatial memory.

7.3 Can Foot-Based Interaction Be a Possible Style for Peripheral Interaction Design?

Challenges. Foot-based interaction was new to our participants, and may be new to many users. This seems to have made it more difficult to habituate to it. "*If the pedals would have been here when the smart board have been, then I would probably use them equally, I guess*" (Peter). At a standing posture, users' lower limbs have to support their body weight. This makes foot-based interaction limited when teaching. Peter told us that it was not convenient for him to switch from pedals close by to the pedal far away; "[I] *have to move my supporting foot*". Mary experienced that it is more difficult to interact with pedals when wearing high heels; "*I am afraid to lose my balance. High heels are not practical in classrooms*". Mary also pointed out that if a foot task is performed with a manual task at the same time, switching eyesight between the board and the ground will be "*effortful*", "*because you have to move you eyesight and mind*".

Benefits. Despite these issues might be solved with a more sophisticated prototype, for which the foot does not have to be tilted very high and the pedals are more perceivable to peripheral vision. We believe that foot-based interaction seems promising for peripheral interfaces. Mary thought that foot-based interaction was supportive to the main tasks she performed on the interactive whiteboard. "*I think it adds something, adds some more options*". It was especially helpful when her hands were occupied, or when she had to operate the top area of the display. "*I use my pen to interact with whiteboard, and I am right handed, when I want to click on it I have to give the pen to the left hand… Top part, I have to jump toward it*". Similarly, Sandy described specific moments in which she experienced foot-based interaction as supportive; "*I had four test tubes, I was holding them, and they* [students] *had questions, and I had to go to different slides* [to explain the question]." Moreover, since the feet are within the user's eye-sight, the teachers could easily get used to the interface, as also evidenced by the observation that interactions were often preceded by briefly looking down at the pedals (See Table 2).

8 Discussion and Implications

Used as a technology probe, FeetForward gathered rich contextual information to answer our research questions. Based on discussed findings, we generalize implications to inform the design of peripheral classroom technology.

Towards Seamless Integration of Technology. In current classrooms, in which no peripheral interaction designs are installed, teachers tend to perform many computer-related tasks during lesson preparation. For example, Peter prepared pictures for students, or opened and resized the windows of applications, and Sandy opened webpages she wanted to use before the lesson. This often made them feel pressured at the start of lessons (as also found in [1]). However, such preparations are convenient because conducting these operations ad-hoc during lessons demands effort and attention away from the main task of teaching. In our field study with FeetForward, we have replaced some of these attention-demanding focused interactions by more readily available foot-operations. Our findings show that although teachers need to get used to these new interactions, they seem to demand less time and effort and therefore potentially shift to the periphery of attention where they can be performed in parallel to main tasks. Additionally, we found that the open-endedness of the peripheral interface made it easy for the teachers to blend it into their own routines. As we discussed, the personalized functions with FeetForward which were found to have perceivably gained automaticity seemed also to be especially relevant to teachers. Furthermore, when the interactions got more effortless, teachers were triggered to use the technology more frequently and more extemporaneously. Given these promising findings, it seems that peripheral classroom technology is meaningful to enact a more seamless integration of technology into this context.

Design for Habituation. Interactions that are capable to perform peripherally are meaningful for users whose attentional resources are occupied by multiple tasks. However habituation, or automatization, is needed before their peripherality could be leveraged. It is not easy for users to add new interactions into their flow of routines, and it is especially difficult if the new interactions compete with a previously practiced interactions, as revealed by our study. It has also been found that perceived relevance, consistency and learnability of the interface and frequency of use could have effects on the habituation of new interactions. These factors need to be considered while designing for habituation. Through the deployment we found that flexibility of personalization of the new technology helped itself to identify individually relevant function and make its way to blend in differentiated routines of the teachers. Consistency may be important for any interface, but they are especially crucial for peripheral interfaces, since peripheral, or automatic behaviors only involve limited attentional resources and therefore are less sensitive to changes in the context. For example, in our study, teachers experienced that if all of their classrooms were equipped with FeetForward, they would get habituated to it more quickly. It is also very important for a designed peripheral interaction to be easy to learn and practice [40]. By inquiry into how the teachers remembered the functions of FeetForward, it has been found that spatial memory may play an important role in getting habituated to a new interface, which can be further exploited in the design of peripheral interaction (as also explored by related work such as [23]). It was also found that the physical presence of FeetForward served as an intuitive cue for the users to practice using it, and it also provided affordances for some computer functions that are otherwise "hidden" in the interactive whiteboard. Inspired by this we believe that more functions could be derived from the current centralized interfaces (such as computer, interactive whiteboard), and distributed into physical objects (such as a pedal, a pen, or a wearable) around teachers to make these functions more visible and accessible and therefore easier to be practiced and used ad-hoc. Additionally, our study also implied that although some interactions were considered effortless, it didn't necessarily mean that they were at the moment with enough peripherality to be performed automatically by the users. Therefore, behavior habituation, or automatization could be used as additional assessments in longitudinal evaluations of peripheral interactions.

Leveraging Foot-based Interaction. The study presented in this paper explored foot-based interaction as a means to peripherally interact with large displays while in standing posture. Based on the experiences of our participants, we have seen that foot-based operations can help users to interact with components which are far to reach (e.g. the top area of the display). Furthermore, with feet leveraged for supportive or secondary tasks, users could utilize their hands for more relevant or elaborate tasks, which may enhance quasi-parallel task performance (e.g. using stylus, or holding demonstration materials). However, our study also revealed challenges, which should be considered when designing foot-based peripheral interaction. While the fact that our participants could visually see the interface made it easier to get used to the interactions (possibly using peripheral vision), such foot operations should not demand focused visual attention, since the eyesight switch from the display to the foot area can result in unwanted interruptions. Therefore it could be helpful to consider how to make the foot interface easy to locate and to operate through user's peripheral vision. Additionally, we found that, with the interface designed for a standing posture, it can be challenging for users to keep balance, for example when the user has to frequently move the supporting foot to reach a certain part of the interface. These challenges could be addressed by decreasing the height of the foot-pedals, or by attaching sensors to the user's shoes, such that smaller foot movements are required to trigger the needed operations.

9 Conclusion

In this paper, we presented FeetForward, a foot-based peripheral interface aimed to support teachers' secondary tasks when using the interactive whiteboard. Designed as a peripheral foot-based interface, FeetForward was considered to facilitate side tasks for teachers, and was operated in short periods of time with minimal interruptions to the main tasks. It was experienced to support multiple-task situations as well as ad hoc and extemporaneous use of technology while teaching. However, it was also shown that a field deployment lasting five weeks was not long enough for interactions with FeetForward to exceed the previously practiced interactions in terms of behavior automaticity. Although using FeetForward was objectively economical, occasionally, previous interactions were subconsciously performed especially while the users are with relatively high mental-load. This indicates that a prolonged deployment will be needed in order to see FeetForward being fully integrated into the users' habitual task flow. Nonetheless, a few tasks with FeetForward which are especially individually meaningful to the users had gained perceivable automaticity during the deployment, showing the potential of FeetForward to blend into different routines of the teachers. Based on our findings, we discussed the possible impact peripheral technology may have on teaching, and the factors that may influence a new technology to become peripheral and routine, as well as the opportunities and challenges of employing foot-based interaction into peripheral interaction design. Subsequently, based on the discussions, we generalized the implications for design. By presenting FeetForward as a novel peripheral classroom technology, and evaluating it in the real context of use, this paper contributes insights into the design of interfaces that can help integrate classroom technologies more seamlessly into teacher's everyday routines.

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