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Ownership of learning in monitoring technology: Design case of self-monitoring tech in independent study

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Abstract. Psychological ownership has been connected to agency, engagement and control. In technology-enhanced learning, this means that the technology design aids learners to get involved, make choices and feel responsible for their learning. In this paper we present a design case in which we explore how self-monitoring tools might support ownership of learning from two perspectives: from the technology design and from the learners' experiences when using a prototype that uses self-monitoring technology. We describe the design process of a prototype that incorporates self-monitoring of physiological data and analyze the results of the tests conducted with the version 2.0 of the prototype in order to assess to what extent the prototype supports different dimensions of self-regulated learning. Based on the research results, we claim that ownership should be regarded as a process that can be fostered through participatory design approaches and by supporting reflection when using the tools.

Keywords: ownership, technology-enhanced learning, Participatory design, self-regulated learning

1 Introduction

The concept of psychological ownership has been described as a cognitive-affective state in which individuals develop a sense of property and psychological connection over a specific object, whether it is tangible or not [1]. As [1] pointed out, psychological ownership emerges by becoming knowledgeable, exercising control or feeling personally involved with the target of ownership.

In contemporary digital societies, knowledge and control are strongly dependent on data collection practices [2], [3]. Thus, techno-monitoring practices that enable the collection of data have been deployed in a myriad of sectors ranging from health and wellbeing, economics, sports, to self-management. Such intensive use has made data collection through monitoring technologies instrumental for decision making, as well as an integral part of people's experiences.

The increasing affordability of monitoring systems has popularized these tools and academic institutions have started to adopt them. For instance, monitoring technologies like learning analytics have been widely adopted in academic institutions. Since 2017 influential technology forecasts [4], [5], [6], [7] have estimated that monitoring technologies will be more and more popular in formal education. In this context, analytics are considered a valuable tool for decision making and personalizing learning by discovering, interpreting and disclosing patterns [8], [9], [10].

A particular type of monitoring is the one performed by the self. In recent years, there has been increasing interest in digital technologies that are able to automatically collect data about an individual. Scholars exploring digital technologies based on automatic data collection agree that such technologies can support self-monitoring by allowing ubiquitous and accurate data collection [11], [12]. Personal informatics, personal analytics and Quantified Self (QS) are approaches to self-monitoring that focus on individual endeavors for gathering data about one's own behaviors, biological factors, states, impressions or thoughts. In learning, self-monitoring technologies like personal informatics and QS have focused on providing learners' feedback on their actions in areas like sports learning [13], music [14] or communication [15].

In education, self-monitoring means that students are the ones who observe, reflect and plan their learning in order to gain higher control of the process. Previous research has established that the ability to exercise control over the learning process is strongly connected to the self-regulation of learning [16], [17]. In this regard, a well-accepted definition of self-regulated learning (SRL) highlights students' metacognitive, motivational and behavioral involvement in their learning processes [18]. From this perspective, self-regulated learners are highly involved in directing and taking responsibility for their own learning, which can be regarded as a sign of psychological ownership of learning.

While self-monitoring has been recognized as a key part of SRL, there has been little research on how self-monitoring tools might support the students' psychological ownership of their learning process. We consider this important because technology mediates and influences the way people act and perceive the world [19]. Thus, we consider it necessary to openly discuss the values and the impact of self-monitoring technologies in learning since they also have an influence on how students understand and develop ownership of their learning processes.

In this paper, we critically explore ownership of learning through self-monitoring technology. In the following sections, we elaborate on process-based approaches to ownership, from the perspective of the technology design and the learning experiences using self-monitoring tech. We present a design case consisting in the design and the evaluation of a critical design prototype based on the self-monitoring of physiological data in independent study. We discuss the findings from the case and highlight some implications for the design of technology-enhanced learning (TEL) with a focus on psychological ownership.

2 Theoretical Background

2.1 Ownership in Technology Design

In recent years, authors and scholars from diverse fields have raised concerns about issues related to ownership and data privacy in monitoring technologies. In education, scholars have warned that the use of monitoring tools like learning analytics might foster student passivity and dependency, disempowerment as well as practices based on managerialism and surveillance [3], [20], [21], [22].

In the case of self-monitoring technologies, the lack of transparency in the algorithms used, as well as regarding further uses of the data makes it very challenging for students using these technologies to understand and have control over their data. As noticed in previous research, such lack of attention to human aspects when using information technology systems might provoke alienation and under-use, as those who are expected to use the systems feel ignorant or threatened [23], [24]. In a similar line of thinking, [25] have also warned that delegating decision making to computer systems could challenge human agency. In this regard, the inequalities in agency between humans and technological systems opens questions regarding who or what is empowered to act in socio-technical systems [26].

The effects of technology on human agency have been widely discussed in science and technology studies. While deterministic theories and social constructivist studies have been considered insufficient to explain the complex and mutual constitution of technology and culture [27], it has been accepted that technology impacts the way people perceive the world [19], [28]. From this perspective, several voices have claimed for the democratization of technology design processes in order to allow people with little or no technological expertise to discuss and influence the design of tools that would impact their lives [29], [30].

The democratization of the technology design process constitutes an effort to ensure people’s agency and ownership of the technological solutions. Approaches like participatory design (PD), co-design and co-creation seek for the active participation of the people who would be affected by the design solution and foster their ownership over the problem and the solutions generated [31].

Participatory design has already been adopted in TEL to support innovation [32], [33], research [34], as well as the design of tools [35], [36] and resources [37]. However, to the best of our knowledge, when it comes to the design of monitoring technologies learners have not been involved that much. Considering the prominent role and the controversy of learners’ data collection through monitoring technologies, we consider it critical to discuss how the technology design process impacts learner ownership.

2.2 Ownership of Learning through Self-Monitoring

Learners’ ownership over their learning process has been considered key for reaching high levels of engagement and achieving their goals [38], [39], [40], [41]. Psychological ownership of learning has been connected to SRL since self-regulated learners are highly involved and able to direct their learning efforts by controlling their thoughts, emotions and motivations in order to adapt and undertake actions that help them reach their goals [18].

Self-regulation and self-direction have also been connected to agency since learners need to take responsibility and control of their own learning [42]. To date, the main models of self-regulation identify three phases in which learners need to be highly involved and responsible for their learning actions: preparation, performance and evaluation. The different phases are interconnected and dependent on each other. Thus, the feedback from evaluation affects the preparatory actions of the next self-regulatory actions, which in turn would be also evaluated [43].

When self-regulating their learning, learners also engage in other procedures in which metacognitive, motivational and behavioral factors come into play [44]. From a social cognitive perspective, interventions seeking to support SRL need to tackle these three dimensions of learning [44]. Metacognition has been considered important in the self-regulation of learning as it has been linked to motivation. Procedures like planning, goal setting, organization, self-monitoring and self-evaluation have been related to the metacognitive dimension [44], [45]. Several studies have shown that individuals can learn to control their motivation by managing different metacognitive procedures [46], [47].

Learning strategies consist of actions that learners implement to aid them in their learning and improve their performance. By selecting appropriate learning strategies, learners can also affect aspects that impact their motivation, such as their self-efficacy perceptions and attributional beliefs [48]. Being aware of the relation between the selected strategies and the thought patterns is an important quality of self-regulated learners and contributes to increased feelings of self-control and efficacy. As noted by [49], the successful use of strategies reinforces learners' motivation to self-regulate learning.

Self-regulated learners control their learning by monitoring their activity. Previous studies have considered self-monitoring as a key element of the self-regulation cycle [16], [43]. Thus, diverse TEL environments aiming at supporting learners' self-regulation skills automatically collect data about learners' behavior, while encouraging them to self-monitor their activity (see for instance iClass [50], the Responsive Open Learning Environment [51] and Just4me [52]).

Recently, self-monitoring technologies have been considered promising for supporting the self-regulation of inner states like attention and relaxation [53], emotions [54], activity [55], as well as other behaviors that impact learning like sleep habits [56]. While self-monitoring might support learners to take control and ownership of their learning, the datafication practices associated with techno-monitoring have been strongly questioned [3], [57]. In education, main concerns regarding the adoption of QS and personal informatics tools point at effects like limiting the understanding of what constitutes learning and creativity, impacting learners' self-concepts and narrowing down the range of opportunities and pathways in education [58]. Considering that all these concerns are strongly related to the potential of self-monitoring tools to support learners' agency and ownership of learning, we consider that critical explorations of self-monitoring tools in learning and education are needed.

In the following section we present a design case that explores self-monitoring of physiological states in independent study.

3 Design Case

In this section, we present a critical design exploration of self-monitoring technology in learning using research-based design, which is a methodological approach to the design of learning tools. Research-based design draws from the participatory design and the human-centered design traditions and is strongly influenced by constructive design [60]. From this perspective, the construction of artifacts is inherent to the research activity [61] as artifacts are considered important research outcomes, which embody knowledge [62]. Research-based design aims to bring design thinking to the design of tools for learning and therefore differs from educational research approaches, such as design-based research, in which the focus is on designing interventions to investigate learning in real-world situations [63].

In order to explore the potential of self-monitoring tools to support ownership of learning we have developed a design prototype - Feeler - that uses physiological data self-monitoring to foster SRL. The Feeler prototype presented in this study is an effort to envision scenarios of use and implications of emerging technologies based on the monitoring of physiological data, such as Electroencephalographic (EEG), from a critical perspective. Next, we describe the design process of the Feeler which led to version 2.0 and present the evaluation tests of version 2.0.

3.1 Design Process

The research-based design process identifies four phases: Contextual Inquiry, Participatory Design, Product Design and Designing a Prototype as a Hypothesis. Iterations are a central element and happen throughout the whole process. The distinction of phases in the model indicate different emphases on the design activity but should not be understood as a linear sequence. [60]

The Contextual Inquiry consists of an exploration of the socio-cultural context of the design. During the Feeler Contextual Inquiry phase, we adopted rapid ethnographic methods, such as participant observation and user interviews, to explore design situations and define the design challenges. The findings informed the Participatory Design phase where stories, scenarios and personas were created and presented to the research participants through a co-design game that portrayed a journey using self-monitoring technologies (see [64]). During this phase, lightweight prototypes were also used to actively involve end-users in the design process.

The analysis of the co-design workshops data served as a basis for the Product Design phase with the creation of mock-ups and prototypes of the Feeler tool. During this phase, the requirements and design functionalities were revised before moving to the Designing a Prototype as Hypothesis phase. At this point, the first functional version of the prototype (Feeler v.1.0) was ready to be tested with graduate students. Based on the students' feedback, a second version of the prototype (Feeler v.2.0) was developed.

Table 1 shows the design research instruments used during the design of the Feeler prototype.

Table 1. Description of the Research Design process in the Feeler Prototypes.

Research phase	Research design instruments	Outcomes
Contextual Inquiry	10 semi-structured interviews (six with graduate students and five with subject experts). Four days of observation and field note-taking in an environment intended for independent study. Literature review. Three focus groups (n=15) conducted with graduate students. Pre- and post-questionnaires distributed to 15 graduate students during the participatory design sessions.	Self-awareness and meditation as skills that create opportunities for learning and well-being. Constant access to social media challenges focus and reflection on academic tasks. Positive perceptions on self-monitoring. Challenges to apply research on physiological data in real-life learning contexts.
Participatory Design	Three participatory design workshops (n=15) with graduate students. Three presentations and feedback sessions on the first 2 lightweight prototypes made of cardboard and plywood during the lab's open-door event.	Participants' inputs and contributions shared: - Concerns on data ownership and privacy. - Interest in diversity of forms of self-monitoring and data types. - Willingness to engage in reflection at the end of the self-monitoring process.
Product Design	Four mock-ups and prototypes, two of which are functional, results of the design studio work.	Several design concepts. Proto-personas. Several design scenarios and use cases. Feeler non-functional prototypes, one made with paper and another one with plywood.

Prototype as Hypothesis	Production of two functional prototypes (Feeler v.1.0 and v.2.0) in a Fab Lab (hardware) and design studio (software). Feeler v.1.0 proof-of-concept test with graduate students (n=6).	Feeler functional prototypes: v.1.0 and v.2.0.

3.2 Prototype Description

Feeler is a prototype that consists of a software (current version running on macOS) and a set of box-shaped computing objects that guide learners' actions during an independent study session. When using the Feeler set, the system collects data about the user's mental states. The data is obtained through a self-monitoring device that captures EEG data and transforms them into attention and relaxation levels. Furthermore, the software prompts the user to report their own impressions about their mental states in different phases of using the Feeler.

In Feeler, a study situation is divided in three stages: before, during and after the independent study session (see Table 2). Before starting a session, learners are expected to set up the equipment and log into the software. Then, Feeler divides learners' performance during independent study into three phases: (1) meditation, (2) study and (3) play, each of which is associated with a computing object (a box). The division of a study session in three phases aims to foster learners' self-awareness, and self-control skills. In particular, each box introduces learners to strategies that research has shown to be beneficial for learning and self-regulation, such as meditation, time-management and self-rewards.

The boxes provide learners a tangible interface to interact with, allowing them to minimize the need to pay attention to the software application and therefore, fully engage with the task at hand (see Fig. 1). For instance, when the time allotted for an activity ends, a gentle vibration in the box indicates that the time period is over. To move onto the next phase, learners connect the following box by placing the boxes next to each other. The magnets placed at the sides of the boxes help learners connect the boxes in the right order. Once the boxes have been connected, the following phase activates.

Table 2. List of learners' actions when using Feeler.

Stages	Learners' actions	Feeler Software actions
Before the independent study session	Learners wear the EEG device and log in the Feeler software application to start a new session.	A new session is created. The system starts monitoring and recording the learners' EEG data.
During the independent study session	Learners interact with the boxes, which provide feedback and guidance.	

- Meditation	Learners perform a five minutes calm breathing exercise using the meditation box.	The meditation box provides guidance on the breathing rhythm through a pulsating light. It also indicates the learner when the time for the task is over.
- Study	Once the study phase is activated, learners start working on their academic assignments on their computers during 20 minutes.	The Feeler system takes a screenshot of the learners' digital activity based on their attention and relaxation levels. The study box gives visual feedback about the pass of time. When the time has expired, the box vibrates.
- Play	Learners play a memory game consisting in repeating a light and audio sequence as many times as they can do it correctly.	The memory game activates in the play box. The box displays a light and sound sequence that adds one step more every time the player repeats the sequence successfully.
After the independent study session	Learners interact with the Feeler software application.	
- Self-assessment	Learners fill a personal experience questionnaire where they indicate their level of satisfaction (satisfied, neutral, dissatisfied) and estimate their attention and relaxation levels (in a scale from 0 to 100%) during the session.	The software displays two questionnaires: one on satisfaction, and the other one on attention and relaxation levels. Learners must answer all the questions in order to access the visualization of the session data.
- Review	Learners can explore the data of the session they just terminated.	Data about learners' attention and relaxation levels, as well as their personal experience are displayed in a multi-layered visual dashboard.

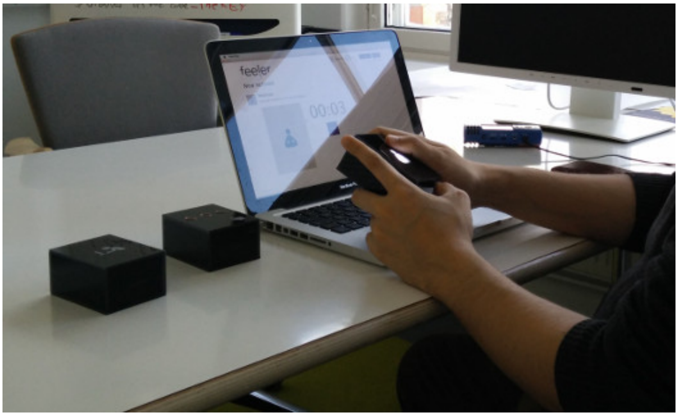

Fig. 1. Learner performing calm breathing by following the light rhythm of the meditation box.

At the end of the session, learners can access the visualization of their attention and relaxation data captured through the monitoring of their EEG activity, as well as through the personal impressions questionnaires they answered at the end of the session in the software application. The learners' data is displayed through a visual dashboard that structures the data in several levels. For instance, the first-level data visualizations enable learners to examine their attention and relaxation values based on the EEG readings and on their personal impressions. In the third-level data visualizations, learners can also visualize the changes captured by the EEG monitoring device in their attention and relaxation levels in relation with the screenshots of their digital activity when working on their academic assignments (see Fig. 2).

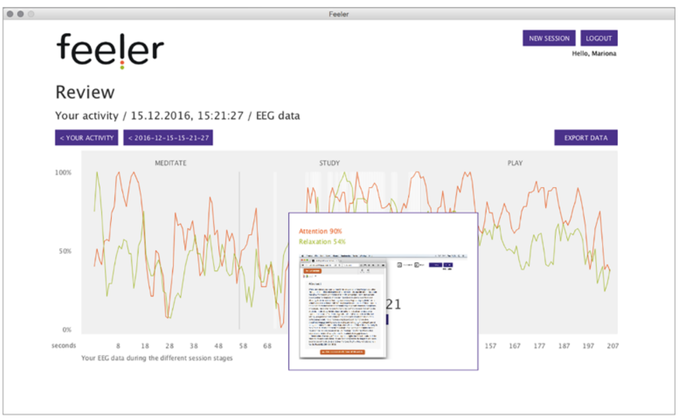

Fig. 2. Visualization of the learner's attention and relaxation levels based on the EEG data and the screen capture the learner was accessing at a particular moment of the study phase.

4 Prototype Evaluation

4.1 Selection of participants and set up

This exploratory study analyzed to what extent self-monitoring tools, like the Feeler prototype, support fundamental dimensions of SRL connected to metacognitive, motivational and behavioral aspects and thus, help learners take ownership of their learning processes.

In this study, six university graduate students voluntarily participated in the research and conducted independent study activities with the Feeler prototype (v.2.0). The participants were between 25 and 33 years old and were from Finland, India, Colombia and Poland. All the participants were fluent in English. Before using the Feeler, the students answered an online questionnaire in which they provided information about their background and study habits. None stated they had extreme difficulty focusing on their study work, and they reported that they were highly motivated to work on their independent study projects. Most of the participants were familiar with self-monitoring and QS tools.

Each participant used Feeler once a week over three consecutive weeks at the university Learning Hub. In each session, the participants' tool use lasted for 30 minutes. During the study time, participants worked on their master thesis dissertations.

4.2 Data collection and analysis

The research data was collected from the participants' individual, semi-structured interviews conducted after each session. In the interviews, the participants were asked to express their thoughts aloud while they reviewed their data. During the conversations, participants discussed matters related to self-knowledge, self-control, discovery and inquiry, as well as their trust of the data. Each interview lasted between 30 and 40 minutes. In addition to individual reflections and interviews, one week after the participants' last session using the Feeler, we organized a focus group interview with all of them. During the focus group the participants discussed and shared the feelings they experienced during the sessions, the impact the Feeler prototype had on their study practices and the relationship between relaxation and attention, as well as productivity and procrastination.

The analysis of the audio recordings (11.5 hours in total) followed a qualitative research approach. We conducted a thematic analysis [65] in order to identify the presence of key themes connected to the self-regulation of learning in participants' speeches. For this, we built on a previously tested SRL model based on social-cognitive theory [17] to define a coding scheme for analyzing the data collected during the research using the qualitative analysis software Atlas.ti (v. 8.1.3). In order to ensure the external validity of the coding scheme, two independent SRL experts reviewed the description of the categories. The external reviewers' comments were used to refine the coding scheme and to inform another revision round.

This research followed [66] recommendations to code semi-structured interview data. As [66] suggest, two independent coders deployed the coding scheme with some of the research data (40%) in several rounds of analysis. After each analysis, the coders reviewed the categories assigned to all units of analysis and discussed coding disagreements together. When the coders disagreed on the fragments, they unanimously decided to re-code the fragments. The coding process was repeated twice, until the coding errors reduced to an acceptable point (intercoder agreement=.97). After this, the PI coded the rest of the research material with the final version of the coding scheme.

Stages of analysis

The codification of the audio recordings of the sessions involved two stages of analysis. During the first stage, the behaviors identified in participants' speeches were quantified (n=1004). This quantification informed a second stage of analysis, which consisted of thematic analysis of the predominant behaviors.

Self-reflection behaviors accounted for 46% (n=466) of the total number of participants' comments (n=1004), while behaviors identified as part of forethought ("task analysis" and "self-motivation beliefs") corresponded to 11% (n=110), and performance behaviors ("self-control" and "self-observation") represented 20% (n=202).

The second stage of analysis investigated the significant themes present in "self-reflection". These themes consisted in "self-judgment" (28%, n=280) and "self-reaction" (18%, n=186) and they were the most common behaviors in the first round of analysis.

4.3 Results from analysis of the self-reflection behaviors

The high number of comments coded as self-reflection made us consider in what ways the prototype supported behaviors associated with self-reflection, which is key for the self-regulation of learning. Therefore, the results from the qualitative analysis focused on the "self-reflection phase". During the analysis, this category was divided into "self-judgment" and "self-reaction" (see Table 3). In turn, "self-judgement" was subdivided into "self-evaluation" and "causal attributions". "Self-reaction" was broken down into "adaptive behaviors", "resistant behaviors" and "changed behaviors".

Table 3. Categories used in the qualitative analysis of the comments associated to the self-reflection phase.

Category	Theme	Subtheme
Self-reflection phase	Self-judgement	Self-evaluation
		Causal attributions
	Self-reaction	Adaptive behaviors
		Resistant behaviors
		Changed behaviors

Self-judgment

Self-judgment behaviors are subdivided into self-evaluation and causal attributions (see Table 3). The following subsections present the main themes related to the self-evaluation and causal attributions behaviors identified during the analysis.

Self-evaluation

Self-evaluation refers to comparisons between one's own performance and a standard. In the sessions, participants' self-evaluation behaviors focused on comparing their own performance with the EEG data, with their past performance and with other participants' performance.

When reviewing the data collected by the EEG device during a single session, the participants tried to identify the moments when they were the most and least attentive or relaxed. Once the participants identified the distinctive moments of a session, they reconstructed what they had been doing and compared this information to their own impressions. At the beginning of the study, the participants were solely focused on the EEG values of a single session. Visually scanning the session data helped the participants spot distinctive moments around which they built explanations. As the participants took part in more test sessions, Feeler collected more data about their activity, and they were able to compare their attention and relaxation within the sessions: "Definitely, the first session was probably my worst because I was all over the place that day (...). I feel that today session I was the most focused on the task and I was able to do it properly" (participant 2, session 3).

Causal attributions

Causal attributions refer to participants' efforts to identify the causes of their performance. When trying to define the causes of a particular mental state, participants reconstructed their activity through the screen captures taken by the Feeler: "For me, because it took the screenshots it was clear that some of the attention peaks were that I found something interesting, so when the interest is higher the frontal globe reacts and then you get the peaks" (participant 6, focus group interview).

Participants did not always manage to explain why their attention and relaxation levels behaved in a particular way. In some cases, it was hard to understand the relation between attention and relaxation and how one affected the other. A participant stated, "I found it very contradictory because I thought, maybe if I pay more attention, I would be more stressed, but in some instances, it was just the opposite. So, I'm not even sure how these two terms are even related to each other. It may be mutually dependent or not, so that's something that one can find out" (participant 1, focus group interview).

The contradiction between participants' experiences and the values provided by the system caused confusion. Such contradictions encouraged participants to reflect on how attention and relaxation were defined and calculated through EEG data. "But sometimes [it] is quite difficult even to separate both of them [attention and relaxation] when doing a skilled activity (...), so just defining it, this is relaxation state, this is attention state entirely is quite a bit tricky" (participant 3, focus group interview).

While reflecting on attention and relaxation, the participants questioned their assumptions and started developing new understandings based on their personal experiences. By problematizing tacit definitions of attention and relaxation, participants developed a more critical attitude toward how these constructs affect learning.

Self-reaction

After self-judging their performance, the participants reacted in different ways. Participants' eagerness to use Feeler again and their intention to try new strategies were considered part of their self-reactions (n=188), which included adaptive (n=110) or resistant (n=53) behaviors. The analysis dedicated special attention to those cases in which the participants changed their study habits, inspired by the Feeler (n=14) (see Table 3).

Adaptive behaviors

Participants self-reacted to their judgments and showed intention to adapt their behavior. For five of the six participants, this type of reaction was the most common. The revision of adaptive behaviors brought to light a set of key themes: 1) willingness to try new practices when engaging in independent study work, 2) reconsideration of their current study habits, 3) interest in finding out how certain behaviors affect their learning, 4) acknowledgment of a positive impact of Feeler on learning and 5) a favorable disposition toward using Feeler again.

Throughout the sessions, five participants recognized their willingness to try new practices when engaging in independent study work. For instance, participants expressed their willingness to meditate before a study session, use different task strategies and play games as a self-reward after working.

In some cases, trying new practices made participants reconsider some of their current study habits, such as task switching or impulsive behaviors. After observing how meditation, study and play affected relaxation and attention, participants were curious about the impact of certain actions on their mental states and, therefore, their ability to learn: "If I, on the next time, I can get as relaxed, then it would be nice to see if there are differences in the study or if it's similar in the study, because that would really support the fact that relaxing before is good to do" (participant 6, session 2).

In general, the participants acknowledged that the prototype had a positive impact on learning. Some of the aspects that participants mentioned were how Feeler helped them to meditate and increase their relaxation. In this regard, all participants considered meditation beneficial for their study activity.

Five of the six participants had a favorable disposition toward using Feeler again. In some cases, participants were interested in collecting more data about themselves in order to develop better insights. In other cases, the participants recognized that they may use Feeler occasionally to test a hypothesis and help them gain focus. These participants also wanted to explore the long-term effects of using Feeler for their study activity.

Resistant behaviors

Self-reaction behaviors were connected to participants' resistance to modifying their strategies and to using Feeler again. Participants' reluctance to adopt Feeler as part of their learning environments was based on 1) doubts regarding the EEG data, 2) resistance to modify certain behaviors, 3) not considering the use of Feeler as necessary, 4) difficulty analyzing the data and 5) dislike of certain aspects of the prototype.

On many occasions, participants' self-reports about their attention and relaxation levels during the session did not match the data calculated by the EEG device. When facing this discrepancy, some participants distrusted the EEG data because they could not understand the reasons for such a mismatch.

Despite recognizing the positive effects of Feeler, some participants did not necessarily modify their habits. For instance, although meditation was considered beneficial, participants did not practice it outside the test environment. The participants reported that they had not modified their behavior because of a lack of time or because they simply got carried away by their routine and did not consider doing things differently.

Changed behaviors

The reported changes consisted of practicing meditation, gaining self-awareness and increasing reflection about participants' own practices. Four of the six participants reported some sort of change in their study practice after taking part in the exploratory study: “I tested the meditation, and I feel that it helps when I'm writing my thesis or when I study for an exam” (participant 6, session 3) and “I thought a lot more about the meditation aspect of it, so in my five minutes break between sessions I don't tend to go to social media so much (...) so that's one small shift that has happened” (participant 2, session 3).

Although they did not have access to the prototype, participants felt inspired by the different strategies they experimented with during the test sessions and decided to adapt them to their own situation: “For me somehow informed the way I behave and during those weeks I also, when I was about to read something, I took this sort of pause and started with this meditation thing before focus” (participant 4, focus group interview).

5 Discussion

From a technological mediation perspective, technologies shape the relations between people and the world. Thus, to understand how a particular learning technology supports ownership, we consider it necessary to look at the technology design process, as well as people's behaviors and experiences when using that specific technology.

In this section, we discuss to what extent Feeler might have contributed to the development of psychological ownership through the technology design process and through the students' learning experiences when using the tool in independent study. The discussion of the findings is an important step to identify implications for practice that can inform further TEL endeavors aiming to promote students' ownership of learning.

5.1 Nurturing Ownership During the Design Process

Design approaches like PD have claimed that in order to design meaningful technologies, the people who would be affected by the design should have the opportunity to express their views during the design process [67], [68]. Recognizing people as experts of their own life, who have the right to exercise personal agency and control when using technology are important aspects of the PD agenda, which are also linked to the concept of ownership [69]. For these reasons, the adoption of a design methodology aligned with PD, like research-based design, was considered key to explore how self-monitoring technology can support ownership of learning.

Design approaches based on participation acknowledge that people's agency and sense of ownership over a technology design is a process that needs to be cultivated. This cultivation happens by encouraging people to engage in contexts for action that enable them to exercise agency [70]. Therefore, in Feeler design special attention was dedicated to engage learners in contexts, like co-design workshops, in which they felt comfortable to discuss, share their views on self-monitoring and influence the prototype design. In particular, some of the participants' contributions to the participatory workshops determined certain design decisions in the Feeler prototypes. For instance, the decision of developing a desktop application instead of opting for a cloud-based solution responded to the learners' concerns regarding their data privacy. In this line, the data collected through Feeler was not shared with other users by default, not even in an anonymized format as many self-monitoring tools do. Supporting learners to become agents, with the capacity of making choices in the prototype design, was considered important for helping them develop a sense of ownership.

As [71] highlight, the key aspects that trigger users' ownership of the design results and the process can be instrumental, perceptive and symbolic. In Feeler design, we used some of the strategies suggested by the authors to foster users' involvement during the design process like encouraging users' self-expression through different means and including users' contributions in the results.

Throughout the Feeler design process, the use of design methods like inspiration cards, concept mapping, 3D prototyping, design games and mockups supported participants to explore the impact of self-monitoring on their life enabling them to express their views and wishes in different ways. Also, providing learners opportunities to influence Feeler design at different points of the process was considered important for supporting a sense of ownership and control. For this reason, the learners who accepted to participate received follow-ups of the design progress and were invited to engage in further workshops and tests of the prototypes. In this regard, it is worth noting that some of the learners who gave feedback to the version 1.0 of the Feeler prototype, also took part in the tests conducted with the version 2.0. We believe that this continuous involvement might be connected to the learners' feelings of ownership in the design process.

As it has been suggested in previous research, ownership should be regarded as a set of rights through which people have the opportunity to express their opinions and engage in decision making [1]. In learning design, scholars have warned that excluding the learners from the process might lead to behaviors and feelings opposite to learning ownership like alienation [24]. For this reason, we consider that the exploration of the emergent technologies in learning and teaching should support the participation and critical reflection of those whose experiences would be shaped by the technology.

Previous research has pointed at reflection as a strategy to support individuals becoming more agentic [70]. Feeler design is influenced by approaches focused on supporting critical reflection on the values and agendas driving technology design like reflective design [72], critical design, and speculative design [73], [74]. These approaches build on critical theory and seek to support reflection on technology by the people who use the technology. Through the Feeler design process, we have encouraged learners to imagine how the self-monitoring of their mental states would shape their experience of learning. In a way, Feeler was an extreme case of self-monitoring since it poses many challenges regarding the privacy of the data, but also the interpretation of the data collected. Feeler v.2.0 is the result of the questions and reflections of the people who participated throughout the design process and it also triggers reflection [75]. We consider that without reflection it is not possible to “know” something and develop ownership, as [1] suggested.

5.2 Supporting Ownership of Learning through Self-Regulation

Building on the analysis of the participants’ speeches using the Feeler, we establish that the Feeler prototype supported metacognitive, motivational and behavioral dimensions of SRL and thus, it may have helped learners gain ownership of their learning.

First, from a metacognitive perspective the study showed that the Feeler prototype supported self-awareness, self-monitoring and self-assessment. Behaviors like self-monitoring and self-assessment require involvement and contribute to the development of self-awareness, which has been considered important for self-regulation [76]. Also, previous studies have highlighted awareness and involvement in learning as key for taking ownership of learning [39].

During the sessions, participants started to pay attention to aspects that affected their independent study work, such as their emotions and the strategies they chose to perform a task. We might say that the automatic monitoring performed by the Feeler system encouraged learners to become self-aware and start self-monitoring their own states and behaviors. The collection and visualization of data may have helped participants self-assess by developing deeper understandings of how certain states and strategies affected their learning. As previous research has shown, self-awareness, self-monitoring and self-assessment contribute to self-knowledge, which, in turn, is required for effective self-regulation.

Because Feeler design focused on supporting self-knowledge through personal inquiry, the tool did not provide recommendations to improve performance. This design decision led learners to engage in decision-making regarding what to do next, which required them to self-reflect and assess how well the learning strategies embedded in the boxes had worked for them. As [77] state, involving learners in decision-making and supporting them to acquire self-monitoring skills contributes to the self-regulation and ownership of learning.

Secondly, the elevated proportion of adaptive decisions, which are a type of self-reaction, can be taken as an indicator of participants’ motivation to use the strategies embedded in the prototype design. Feeler may have positively affected aspects related to self-motivation, such as self-efficacy perceptions, by enabling participants to experience different strategies and determining how well they worked for them. In addition to the immediate effects, learning a new strategy may have contributed to changing participants' self-beliefs about their ability to control some of their behaviors like, for instance, procrastination.

These findings relate to [78] observations regarding positive effects derived from effective strategy use. After using Feeler, the participants realized that they could control their attention and relaxation and were willing to adopt new practices in order to regulate their mental states. As [39] acknowledge, developing a sense of control is important for achieving ownership of learning. The effective use of learning skills can support learners gain control over their learning. In the tests with Feeler, participants felt they could control their attention by using strategies effectively, and establish a state of involvement when studying [79].

The exploratory study results confirmed the existence of a self-oriented feedback loop in SRL [18]. The feedback loop explains how self-reactions affect forethought processes, such as task analysis and motivational beliefs, in a cyclical manner [80]. For instance, when self-reacting to one's own judgments, the participants made hypotheses about the aspects they would like to test in future sessions. These hypotheses were coded as adaptive decisions, but they could have been also considered as goals for the next time they would use the prototype. Thus, drawing on [78] observations on positive effects derived from effective strategy use, we may consider participants' eagerness to try new practices and set new goals for subsequent sessions as an indicator of motivation, which in turn shows ownership of learning.

Thirdly, the findings from the exploratory study suggest that the automatic recording of participants' digital activity may have contributed to the self-regulation of their behavior. The participants frequently referred to the screenshots captured by Feeler in order to reconstruct their experience. These screen captures, which visually described the participants' attention and relaxation levels, can be considered attributional feedback since they allowed the participants to identify the consequences of certain behaviors. According to [78], attributional feedback facilitates self-regulation.

To a large extent, the screen captures helped participants develop causal explanations of their performance, which is necessary for informing self-reactions. The high proportion of adaptive decisions among participants' comments, as well as the behavior changes reported outside the exploratory study, suggest that Feeler provided feedback that influenced participants' self-regulative behavior contributing to engaging them in activities that helped them develop ownership of learning.

6 Conclusions and Implications for Practice

In this study we have discussed the concept of psychological ownership in self-monitoring technologies from two perspectives: the technology design and in relation to SRL dimensions. The design exploration presented described the research-based design process of a self-monitoring tool, Feeler v.2.0, and the insights gained through the analysis of the tests conducted with the prototype during a period of time. In this section, we summarize the key findings and highlight some implications for further research and innovation in TEL aiming to support learners' sense of ownership.

First, we want to highlight that ownership and agency should be regarded as a process, rather than as a result. In Feeler, by looking at the design process, as well as the learners' experiences when using the tool, we have been able to point at different aspects that support ownership. The emphasis on the procedural aspect is important because it helps understanding how technology mediates peoples' perceptions. In TEL this means acknowledging that technology mediates peoples' understanding of learning. We consider that if the people who use a technology do not understand such a process of mediation it is very hard that they develop authentic ownership.

Second, since the definition of what counts as learning has a strong impact on students' experiences, we claim they should have the opportunity to influence the technology design, as well as the implementation of a particular technology, in a learning environment. For this, design approaches that align with the participatory design tradition like research-based design can foster learners' ownership by supporting their involvement at different stages of the design process of the learning tools. Also, critical and speculative design are valuable strategies to support awareness and reflection on technology values, which are also necessary for developing agency.

Third, ownership of learning requires learners' agency and control over their learning actions. Self-direction and self-regulation models tackle different aspects that point at skills learners need to develop such a sense of ownership. We want to highlight that main models of SRL stress the value of reflection and monitoring - self-monitoring in particular. Thus, we consider that self-monitoring tools, like the Feeler prototype, have great potential for helping learners become owners of their learning process. While the number of people who participated in the Feeler v.2.0 is small, we consider that the insights gained through the qualitative understanding of their experiences using the Feeler prototype point at key aspects of self-monitoring tools related to the metacognitive, emotional and behavioral dimensions of SRL. We think that these findings can inspire and inform future developments in TEL that use self-monitoring tools.

Finally, we want to remind that the concept of ownership should be understood from a systemic perspective [69], [81]. As [81] indicated, the interaction between the diverse parts of the learning system - the students, the teachers, the curriculum and the technology - are also responsible for a sense of ownership. In this study, we aim to contribute to this issue by exploring how ownership can be supported in the technology design process and in the learners' experiences. This is a timely and relevant debate for TEL research since it is deeply connected to the question of how to support democratic synergies in learning and education.

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[1] An earlier version of the study was attached in the doctoral dissertation of the first author: Durall, E.: Reflection and self-regulation using monitoring tools in learning. Critical design

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