Measuring Students' Flow Experience in a Multimodal Learning Environment: A Case Study

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Abstract. This research paper focuses on the relationship between flow experience and multimodal learning environments. Flow experience has been defined as the state in which an individual feels completely absorbed and fully engaged in an activity. This concentration and complete engagement can lead to optimal learning. Several scholars in the areas of distance learning [2] and game-based learning [3] highlighted the relationship between high levels of flow experience and the effectiveness of technology-enhanced learning environments. Yet, this theory has not been applied in the area of multimodal learning environments, were multiple forms of technologies are provided to collocated learners. The purpose of the present study was, by studying an HCI course, to explore learners' flow experience and to understand the affordances of that promote flow experience. Findings suggest that flow experience does exist in collaborative activities within a multimodal learning environments and that it offers a useful construct to understand the affordances of technology in similar learning environments.

Keywords: Flow experience, multimodal space, CSCL.

1 Introduction

Csikzsentmihalyi [1] defined flow experience as the state in which an individual feels completely absorbed and fully engaged in an activity. Flow experience (flow) is an extremely rewarding experience, balancing challenge and skill. It allows the individual to perform at an optimum level. It has been researched in many aspects of everyday life, from sports, to creative arts or work-related environments where this highly state of performance could be beneficial.

In the literature, one can find a large number of research projects which comment on experiencing flow during a learning activity. These investigations were based on the premise that such an experience can improve learners' motivation, interest and increase learning. More specifically, recent studies have investigated the relationship between flow and computer supported learning environments, in distance learning [2] and online game based learning [3]. Among their findings was the positive association between flow and effectiveness of these learning environments.

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Nowadays, a wider palette of information technologies becomes available on our fingertips, promoting the use of multiple devices to assist us during every task. Tablets, digital gadgets and interactive surfaces are blended together [4] offering fascinating spaces that could foster learning activities. Yet, limited attention has been paid in learners' experiences within collocated learning settings where students blend different interaction styles and move away from being focused in front of a single screen. How does a group occupying a shared space experience the multiple digital and physical tools around them? How do these technologies allow a group to experience flow? Is there a need for particular design principles that could foster flow experience in these environments?

This research's aim is two-fold. First, to explore students' flow experience during problem based learning activities within a multimodal learning environment with authentic users and settings. Second aim of this study is to improve the multimodal learning environment by understanding the affordances of the environment that promote or hinder students' flow experience. The paper starts with a description of the multimodal learning environment and then presents the findings of our study, in terms of flow experience and technology. Finally, we discuss the implications of these findings and provide design principles to support flow experience and improve such multimodal learning environments.

2 Background

Csikszentmihalyi [5] described flow as the optimal experience, "the state in which individuals are so involved in an activity that nothing else seems to matter". Csikszentmihalyi [1] further annotated flow as the optimal experience, the state in which people feel totally involved and effortlessly engaged in an act. First experiments on flow included activities as diverse as creative arts, chess playing, dancing, rock climbing. What these experiences had in common was that participants in each activity lost the sense of time and their self-consciousness. Summarizing up his investigations on flow, Csikszentmihalyi [5] indicated that this experience consists of multiple dimensions; the balance between challenge and skill, clear goals and immediate feedback, the intense concentration, an emergence of action and awareness, the loss of self-consciousness, a sense of control, a feeling of time distortion, and experiencing the activity as intrinsically rewarding.

Subsequent research has revealed several affordances of computer systems that are positively associated with an increase in users' flow experience and in part to the effectiveness of a computer system. In Sicilia, Ruiz and Tomaseti [6], researchers measured consumers' flow experience in order to evaluate and improve the effectiveness of a website influencing marketing opportunities. Higher levels of flow experience can enhance online visits and consumers' enjoyment. Additionally, among the factors that have been associated with flow in computer systems is the different type of technology provided each time and user's technology efficacy [7]. Furthermore, it can be correlated with particular features of the computer system, such as interactivity [8], modifiability, and flexibility [9]. Since flow encloses effective dimensions of

human behavior, it was revealed as an important aspect to be considered when designing effective computer systems.

From an educational perspective, the nature of flow experience as an intrinsically rewarding experience is what pushes people in flow to "higher levels of performance" [5], contributing to peak performance and learning. Researchers have largely invested their efforts in evaluating online learning systems and web-based instructional tools [2] [10]. Results by Liao [2] confirm that flow is a valuable element in distance learning environments and can support the engagement and commitment of students in the duration of an online course. In addition, identifying the importance of flow experience in game design, Kiili [11] used flow as a framework to facilitate positive user experience maximizing the impact of educational games. However, Pearce, Ainley and Howard [12] argue that the learning context raises new challenges in terms of producing highly engaged environments. We therefore understand that tested exemplars and design models are needed for particular technologies and specific learning activities.

As indicated by Csikszentmihalyi, Abuhamdeh and Nakamura [13], flow construct is a valuable strategy in technology-rich learning environments. Flow experience was able to assist in designing and improving the learning experience for online instructional tools and game based learning applications. Yet, limited attention has been paid in collocated learning contexts where students use multiple technologies, blending different interaction styles. As technology progresses, we are no longer limited within online systems and multimedia game environments. The vision Weiser [14] once described as ubiquitous computing is now partially a reality, with so many technologies available on our fingertips, such as smartphones, tablets, and interactive surfaces. There are much more possibilities of blending these technologies together into something unified instead of using them independently.

Therefore, the current study will approach the evaluation of a multimodal learning environment with everyday technologies by measuring learners' flow experience. More particularly the purpose of the present study is initially to explore students' flow experience within a multimodal learning environment, where their attention is no longer entirely focused on a single screen. Furthermore, we wish to understand the affordances of the multimodal learning environment that can promote or hinder learners' flow experience, based our evaluation with authentic users and settings.

3 Methods

3.1 Context

The study was part of a 13-week graduate-level course on Human Computer Interaction (HCI). The course aimed to provide to the students a comprehensive vision of the area and a hands-on experience of the user-centered design process. A Problem Based Learning (PBL) approach was employed, where groups of self-directed learners worked collaboratively to form a solution to an open-ended problem [15]. The 3 hour weekly sessions of the course, were organized in 1-hour mini-lectures and 2-hour

group activities on solving a design problem. Mini lectures served as a triggering point for learners' understanding towards particular issues of the user-centered design process. Group activities were situated in a multimodal learning environment to provide a collaborative work space for the design procedure.

3.2 Setting

In this section we will describe the design of the multimodal learning environment, which provides a set of physical and digital tools to support collaborative problem-based learning activities. This technology rich workspace was developed for co-located learners to work together towards the solution of a design problem, and also for them to be able to interact with each other between physical meetings [16].

A large horizontal table surface with a downward pointing projection was chosen as the central focal point for the group activities. This table projection surface was powered by a Mac mini and controlled by a wireless keyboard and mouse. It was intended to provide a focal point for fertile discussion and support various collaborative activities, such as the presentation of digital artifacts (e.g. images, notes).

However, using a single surface to support the multitasking nature of the group was considered problematic. Therefore, portable devices, such as tablets, iPods, infrared pen and pen readers (IPPR) and laptops were provided to be used as needed. These devices aimed to support multitasking in web-browsing as well as record-keeping but also provided higher flexibility in the environment [9]. Tutors also encouraged learners to enrich the multimodal learning environment with their own portable devices, such as tablets and smart-phones, whenever they felt it was appropriate.

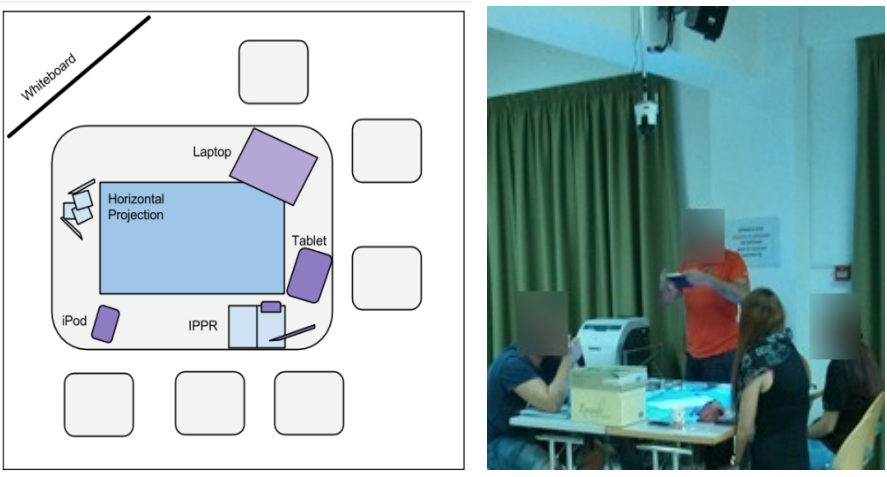

Fig. 1. Multimodal Learning Environment. Left: Space Layout. Right: An example set-up.

In addition to digital gadgets, a social network site[1] (SNS) was provided as a platform for sharing information, communication and coordination. The SNS was used with a two-fold purpose. Initially, the SNS provided a communication and sharing channel between the members of the group while away from the physical learning space. This was considered important to keep group members connected and with the ability to coordinate group progress. The second aim of the SNS was to support the communication and sharing of information between the devices available within the multimodal information space (e.g. handheld devices, horizontal projection). Finally, physical tools such as a whiteboard and stationery (e.g., pens, markers, post-it notes) were also provided for each group to use as appropriate. The aim was to provide materials used in traditional problem-based learning settings. The layout of the multimodal information space is demonstrated in Figure 1.

3.3 Participants

Two tutors and a total of 21 post-graduate students (8 male, 13 female) from varied backgrounds (e.g., computer science, graphic arts, multimedia, and education) participated in the study. Students were divided in 4 groups of 5 to 6 students each. For the allocation of students in groups, we kept in mind the aim of creating multidisciplinary groups thus the procedure of forming groups was in part based on each student's background. Therefore, each group was composed of members from different disciplines.

3.4 Data Collection

The ways to measure flow vary in literature based on the context and task under evaluation. For this study, we followed a mixed method approach to data collection and analysis to answer the questions posed. Both quantitative and qualitative data were gathered to measure student's flow experience, their perceptions of the multimodal learning environment, and the ways in which technology supported their flow experience.

At the end of each weekly laboratory session within the multimodal learning environment, the facilitators kept detailed notes and reflections of what students had encountered during the meetings. In addition, students were also requested to keep a reflection diary and submit it weekly. Students' reflective diaries were concerned with their overall learning experience but also referred to their experiences regarding flow. To support their reflections on flow as a holistic sensation we adapted a measure by Novak, Hoffman and Yung [17].

In order to understand flow experience as a process [12] during the 13-week course, a self-report questionnaire was administered three times during the course, at the beginning (Week 2), middle (Week 7) and end of the course (Week 12). This questionnaire aimed to assess students' flow experience within the multimodal learning environment and was adapted from Jackson and Marsh [18]. This measure

[1] In this case study the social network site in use was Facebook.

includes 36 Likert-type items with a 7-point agreement response scale (from 1: strongly disagree, to 7: strongly agree), designed to capture the nine dimensions of flow experience.

At the end of the course, four focus groups were conducted (one with each group) to explore student's flow experience within a multimodal learning environment and understand the affordances of this environment to promote students' flow experience. Each focus group lasted approximately 30 minutes and was facilitated by a researcher who aimed to uncover the opinions of the individual learners as well as the shared viewpoints of the group members.

4 Results

4.1 Questionnaire Results

A total of 20 students completed the questionnaire on flow during the three tasks. First the internal consistency for each subscale of flow was assessed using Cronbach's alpha; all 9 subscales had acceptable internal consistency (Cronbach's alphas > .60). Afterwards, all subscale mean scores were calculated and as demonstrated in Table 1 were all above the midpoint of the response scale suggesting that participants were in flow during their activities within the multimodal learning environment. More specifically, during the Task A participants were highly concentrated on the task at hand (M=4.12, SD=49) and felt that they lost track of time (M=3.98, SD=.68). During Task B, students reported increase in terms of the sense of control they had over the environment they were working (M=3.55, SD=.77) and the goals were clearer (M=3.48, SD=.65). Finally, towards Task C, participants reported clearer goals (M=3.98, SD=.65) and feedback (M=3.63, SD=.63), greater sense of control (M=3.87, SD=.70), while the balance between challenge and skills was higher (M=3.94, SD=.64).

Table 1. Subscales and Descriptive Statistics for Flow Questionnaires - (N=20)

Subscale	Items	Week 2 Means (SD)	Week 7 Means (SD)	Week 12 Means (SD)
1. Challenge-Skills Balance	4	3.65 (.61)	3.7 (.75)	3.94 (.64)
2. Action Awareness	4	3.21 (.81)	3.24 (.62)	3.88 (.67)
3. Clear Goals	4	3.21 (.81)	3.48 (.89)	3.98 (.65)
4. Unambiguous Feedback	4	3.07 (.68)	3.27 (.72)	3.63 (.63)
5. Concentration on task	4	4.12 (.49)	3.75 (.94)	3.99 (.86)
6. Sense of Control	4	3.38 (.80)	3.55 (.77)	3.87 (.70)
7. Loss of self-consciousness	4	3.46 (1.11)	3.56 (1.10)	3.98 (.87)
8. Transformation of time	4	3.98 (.68)	4 (.70)	3.60 (1.09)
9. Autotelic Experience	4	3.75 (.62)	3.43 (1.00)	3.55 (.99)

A graphical representation of the individual dimensions of flow per week is demonstrated in Figure 2. We can positively identify the change in all flow dimensions and can presume that the results from Week12 are slightly improved and more concise, compared to the sparse means from Week2.

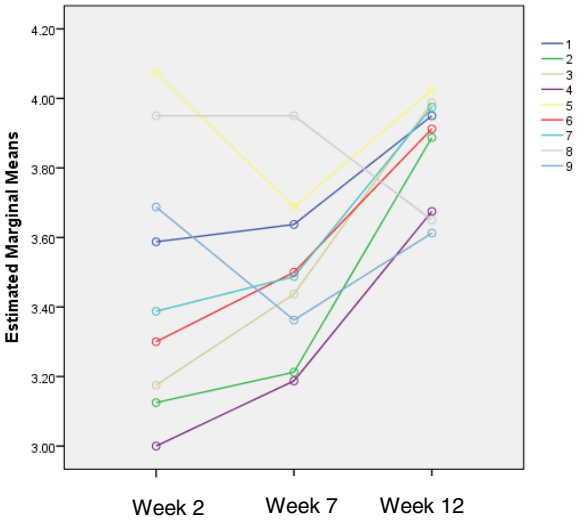

Fig. 1. Means of individual flow dimensions per week

4.2 Qualitative Data Analysis

The investigators conducted a thematic analysis of the focus group data to understand participants' flow experience within a multimodal learning environment and the affordances of this environment to promote students' flow experience. To improve the rigor and trustworthiness of the findings, the investigators used the observation field notes kept by the tutors and the reflective diaries kept by the students as a contrasting data source. The prominent themes found in learners' self-report were fully consistent with the impressions the tutors had gained and recorded through observation.

Next we discuss the core themes that emerged from the thematic analysis. Direct quotes are used throughout to provide evidence of the students' experiences and concerns raised during the focus groups.

Theme 1: Technology did not Enhance Flow, but Acted as a Supporting Role for Keeping us in Flow. This core theme revealed the supporting role of technology in flow experience and how the technological aspects of the multimodal learning environment affected their participation. Learners' reported that even though they experienced flow, technology did not play a significant role in their experience.

Group 1 participant: "I do believe that we could experience flow even without the technology. But I feel that technology was there to keep us in flow. We had too much information for record keeping that simple pen and paper would not be able to support us. The multimodal learning environment supported our activities."

Group 4 participant: "The whole atmosphere of the laboratory with the people working on the same tasks with the technology is something that helps experience this (flow). Technology gadgets and group work is a combination you cannot compete."

Group 3 participant: "We never felt interrupted because something was not there or it was at a distance place. I think that the proximity and immediate availability of the physical and digital items in the environment played an important role on keeping us in flow."

More specifically, participants reported that the downwards projection kept them closely together during the face to face sessions and provided a central focal point during their interactions. The shared surface was extensively used by all the groups brought the group members closer, keeping them all together in flow. For example,

Group 3 participant: "All my attention was focused around the projection on the table and nothing else seem to bother me outside the group activities. I was so focused on what we were doing that I could not even hear the rest of the class talking. It felt like we were the only team in the class."

Group1 participant: "The projection on the table was the most useful item within the environment […]. I do prefer having the downwards projection rather than a single computer screen."

In addition, the SNS that was used as a communication and sharing tool to support in between session group activities, was considered an ideal tool for keeping the group motivated and in continuous contact with the project, keeping them in flow.

Group 1 participant: "I think what made this all more realistic and kept us motivated was the constant communication with my team through technology, for example Facebook and Google documents. The familiarity we had with Facebook and the immediate communications – getting notification on my smartphone all the time – kept me up to date and in that amazing group mood."

Group 3 participant: "Facebook actually got fire! Due to our busy schedules this tool was the thing that kept us together focused on the project between the face-to-face sessions."

Theme 2: I Felt Focused but not in Strong Flow while Working within the Multimodal Learning Environment. This core theme was equally important and included responses relevant to whether flow experience existed and how strong was this experience within the multimodal learning environment. Students supported that they were focused during the collaborative activities and that the multimodal learning environment promoted learners' flow experience but not in high intensity. For example,

Group 4 participant: "I don't believe that I experienced high levels of flow. Sometimes, mostly during the design process, I felt more focused and immersed in the activity. I think that my interest towards design supported this feeling."

Group 1 participant: "I have felt this (flow experience) during our group work. During the course, I felt absorbed [...] but not intensively."

Yet, in contrary to the collective opinion of the group about the low level of flow experience, one participant argued,

Group 1 participant: "I think I have experienced this (flow) 100%. I find it astonishing the extent to which I became so immersed in the project work. The learning experience has been unparalleled."

Theme 3: Feeling the Transformation of Time Within the Multimodal Learning Environment. The theme emerged from students' responses on describing moments where they felt in flow within the multimodal learning environment. More particularly participants identified that they were fully concentrated on the activities and that they lost track of time.

Group 3 participant: "I actually realized I was in flow from the way time flies during our activities."

Group 4 participant: "All the group members were totally focused and connected to each other producing high quality work. During those moments we completely lost track of time, it seemed to us that time was going really fast."

5 Discussion

To this end, we analyze our findings in terms of how measuring flow experience assisted on understanding the affordances of the multimodal learning environment and whether the technology supported or hindered this experience.

5.1 Learners' Flow Experience

Our analysis of learners' flow experience within the multimodal learning environment shows how learners' levels of flow experience were above the mid-point of the response scale on average, indicating medium flow experience. This finding also emerged as a core theme from the thematic analysis of focus groups and diaries (Theme 2), since students felt highly focused during group activities and experienced a transformation of time (Theme 3). However, students reported that this experience was not intensive but was rather kept at a medium to low level during the activities within the multimodal learning environment, with few exceptions of students with higher intrinsic motivation.

5.2 Flow Experience as a Design Strategy

An important finding in this study is that even though technology did not initiated learners' flow experience, results indicate that technology successfully maintained flow. When learners described instances of flow experience within the multimodal learning environment, technology was not an important aspect of their experience. For instance, one participant argued that the team would be able to experience flow even outside the multimodal learning environment. Nonetheless, based on the thematic analysis, the role of technology was identified as supporting, acting on the background of collaborative activities (Theme 1). For example, the downward projection was indicated as a common focal point and managed to concentrate group's attention on a particular task. Another example was the use of an SNS as a communication and interaction medium keeping motivation levels high. Therefore, technology within the multimodal learning environment maintained learners' flow experience longer than a simple pen and paper environment would do.

As described earlier in the paper (Section 3.2), we enriched the learning environment with multiple digital tools and gadgets in order to support the multitasking of group work and flexibility of the workspace [9]. Having this multiplicity of devices, one of our considerations was to negatively affect the groups' focused attention, and instead spread it across multiple devices. However, questionnaires' results indicated medium to high levels of concentration on task at hand and focused attention towards the activity (M=3.87). Verifying the quantitative results, students argued that they felt completely focused and absorbed with the activities within the multimodal learning environment. Additionally, one group indicated that the proximity of objects within the space was an important element. Even though they choose to use them as appropriate having them immediately available "at hand" was considered a major advantage for the learning environment. Therefore, the multimodal character of the learning space was able to maintain attention of the learners and their concentration on the activities, especially when the proximity between the multiple elements was high.

Furthermore, what emerged from the analysis was the power of the table surface screen, rising as a "focal character" attribute [4] for the multimodal learning environment. The majority of the participants argued that the shared screen on the table was an extremely useful element within the learning space and was used during every session. The shared surface managed to provide a focus spot fostering the collaborative activities of the team and bring the team closer together. Therefore, the proximity that surface table provided to the team is a necessary attribute to take into consideration when designing similar learning environments.

In addition, the SNS successfully kept each group in touch and active within the project work. Our findings are in agreement with results from the area of distance learning [2] where high motivation levels are required to reduce the drop-out rate of students from online learning systems. What the particular selection of the SNS adds is the increased levels of familiarity with the tools and the immediate feedback that it provided. For example, one member would post a particular argument for consideration on the group page and even though he exited the application, a notification would be sent directly on his smartphone. Thus, we identify that clear feedback and immediacy are important attributes in the design of such complex systems.

5.3 Limitations and Future Directions

One of the limitations of this research is the subjectivity in terms of the collected data. We understand that the fact that only self-reported and subjective data were collected may weaken the results of this research study. However, the systematic investigation of such complex environments with real users does not allow the use of more objective measures such as physiometric and psychometric elements. Through this exploratory study though, we have pinpointed that focus groups and reflective diaries were the most valuable tools providing a more holistic perspective of the flow experience of students. More specifically, in order to better understand the factors that allowed the students to experience flow, and to comprehend the affordances of the environment to support flow, qualitative approaches were more suitable. Still though, the

mixed method approach to data collection was considered too intrusive, detecting the need for the development of new instruments to capture this new multimodal experience.

The literature would suggest that an increase in flow experience would positively affect learning and interaction within a learning environment [2]. In our investigation, this relationship was not explored within the multimodal learning environment to confirm previous findings. This association would be largely valuable for those teaching and designing a similar course. Therefore, we would further extend the current investigation of the multimodal learning environment by measuring and correlating flow experience to the learning performance of the participants or particular learning activities. Such an investigation is necessary to prove multimodal learning environments as successful learning spaces and provide further examples and cases on using such environments in real context.

Another issue identified in this research was the fluctuation of attention between weeks. Even though the multimodal character of the learning space was able to maintain their concentration on the activities, there was an unexplained fluctuation. This observation indicates that further investigation is needed towards understanding how is learners' attention scattered across elements in the learning environment and how are different tasks affecting their concentration on the activity.

6 Conclusion

As technology constantly becomes more affordable, students are now using their own smartphones, tablets and handheld devices serving all their needs. Each class now is becoming a multimodal learning environment on its own. The possibilities are countless. But the way to handle all this technology so that we keep focus on tasks and performance high is still unexplored. The importance of this research lies beneath this need. It is important that researchers that lead and support the design of educational environments have models to draw upon. In the context of educational games and online learning tools the concept of flow has been extensively researched to assist the design of such environments and several design principles and models have been proposed. However in multimodal learning environments there is lack of exemplars and models for educators to draw upon in their practice. Therefore, in this study we enriched a collaborative learning environment with multiple interactive, digital and physical items (e.g. projector, SNS, tablets and smartphones), to support collaborative PBL activities. Our aim was to understand students' flow experience and the affordances of the technology-rich learning environment. Our analysis of learners' flow experience within the multimodal learning environment provided important findings contributing to our understanding of learners' behavior within a multimodal learning environment, and importantly, to further improving the design of the multimodal learning environment.

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