



Investigating STEM Students' First-Time Experience with Smart Glasses

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Abstract. We study how STEM students experience the use of smart glasses for the first time. We evaluate the glasses' usability, degree of technological acceptance, experience, and elicited emotional response. To this end, we resort to several quantitative instruments and semi-structured interviews. We found that students greatly appreciate the potential and current support that smart glasses and AR provide as educational tools. We discuss our findings and identify opportunities for further research with these devices to support educational activities.

Keywords: HCI · UX · Usability · Smart glasses · STEM education

1 Introduction

Smart glasses can be particularly useful in educational settings, as they can become active tools in the classroom, enhancing instruction and new forms of student engagement [1]. Components such as sensors, mounted displays, and controllers have led to a myriad of domain-specific educational applications [2–4]. This has also extended the use of Augmented Reality (AR), a technology that enables combining, in the user's field of vision, virtual information with objects from the physical environment [5]. AR brings numerous benefits when smart glasses are used in educational settings, and several research studies have exploited AR-based tools to facilitate and enhance learning [6]. In such settings, assessing the user experience (UX) is key to properly take advantage of the support that smart glasses and AR-based tools can provide [7,8].

The approaches used to investigate and measure specific aspects of UX include qualitative or quantitative methods, as well as attitudinal or behavioral ones [9]. Several types of instruments can be used in each of these experimental

settings [10]: observations, interviews, expert evaluations, and questionnaires. Such methods have been used extensively to investigate people’s perspectives on smart glasses in educational contexts (e.g., [11,12]). Most of these efforts, however, focus on independent UX dimensions. That is, the vast majority of work that has been done in this area, has focused, for instance, on investigating either the degree to which people are willing to accept this type of devices or, **independently**, on people’s emotional response. Both dimensions, however, have rarely been investigated **together**. We seek to redress this gap by exploring university students’ first experience with smart glasses in a learning environment. More specifically, we seek to provide a holistic description of the students’ first experience with smart glasses by answering the following research questions:

RQ1: How satisfied do students feel after using smart glasses for the first time?

RQ2: What is the degree of technological acceptance students report?

RQ3: What levels of workload do students perceive?

RQ4: What emotions do students exhibit after the experience?

We explore these questions within a STEM (Science, Technology Engineering, and Mathematics) educational setting. Our study expands previous research in this area by assessing how the functionalities and capabilities of smart glasses are perceived by students when they first interact with these devices in an educational environment. Our observations can inform further deployments of smart glasses and related technology in educational settings.

2 Related Work

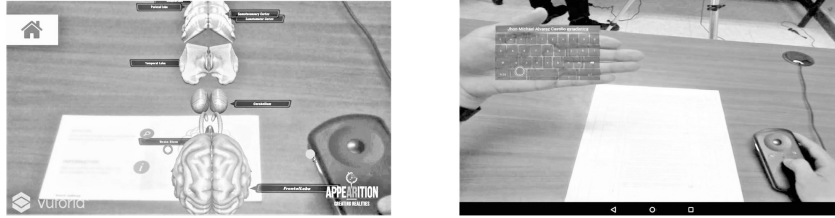
In this section, we review prior work on UX with wearable devices, smart glasses in educational settings, and education-oriented AR apps.

2.1 UX and Wearable Devices

Several authors have investigated UX with wearable devices in a variety of contexts. Xue et al. [13] found that, regardless of the users’ gender, age, and educational level, satisfaction with Microsoft HoloLens increases when people have computer skills. Tung et al. [14] explored interaction based on mid-air gestures and found that users preferred non-tactile interaction rather than providing input through portable devices when using smart glasses in public spaces. Wang et al. [15] investigated how people used the palm of their hand to project and interact with a keyboard from smart glasses. This allowed them to increase their typing speed and improved their overall UX. We build upon these observations with a particular focus on UX and usability of smart glasses in STEM educational settings. Our research is motivated by previous findings by Santana et al. that identified little use of smart glasses in areas related to STEM education [6].

2.2 Smart Glasses in Educational Settings

Smart glasses have been extensively used in educational settings. Silva et al. [16] presented the *Glassist*, an application for Google Glass that allows elementary school teachers to create individual portfolios for students [17]. At the high school level, Kuhn et al. [18] developed an application to perform physical experiments. The authors found that students had a higher cognitive load when working with Google Glass in comparison to other devices.



(a) Brain exploration with (b) Augumenta Virtual keyboard
pARTum

Fig. 1. Two commercial apps for the Epson BT-300 smart glasses

2.3 Education-Oriented AR Apps

Many AR applications with educational purposes have been proposed both as commercial products as well as research prototypes. Examples include gPhysics, and Glassware. We study the use of two freely available commercial apps for the Epson Moverio smart glasses: pARTum¹ and Augumenta Virtual Surface.² We describe their functionality, as it is relevant for our experiment:

pARTum enables the creation of immersive classroom environments to promote autonomous learning. It enables interaction with the physical world through AR markers. Figure 1a shows how this app can be used to enable the interactive exploration of the different parts of the human brain.

Augumenta Virtual Surface allows the creation of virtual keyboards, sliders and other widgets. It capitalizes on natural interaction (e.g., gestures) in scenarios where touchpads and voice control are not feasible. Figure 1b shows a virtual keyboard produced with this app superimposed on the user's palm.

3 Experimental Design

We explored the use of pARTum and Augumenta Virtual Surface with STEM students. This section describes our experimental protocol.

¹ <https://www.appearition.com>.

² <http://augumenta.com>.

3.1 Participants

We invited 24 STEM undergraduate students from a local engineering-oriented university. We recruited six students from four different academic programs: Chemical engineering, Computer Science, Statistics, and Mechatronics. From each program, three participants identified as female and three as male. Ages ranged from 19 to 22 ($\mu = 20$, $\sigma = 1.04$). None of the participants had previously used smart glasses. 3 stated having no knowledge of AR concepts. 14 participants were aware of AR, but did not have any practical experience. 7 were aware of AR and had limited practical experience with it but only on mobile devices.

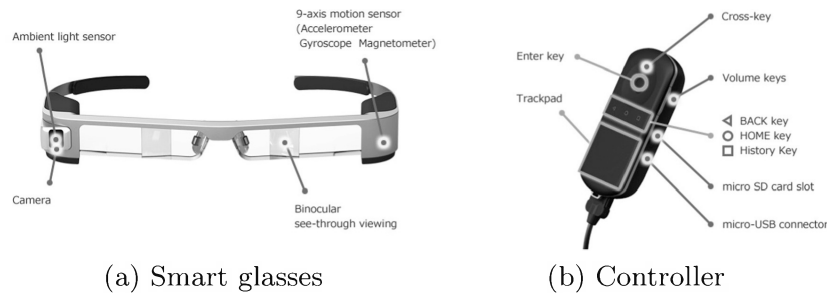


Fig. 2. Epson Moverio BT-300 smart glasses

3.2 Apparatus

We addressed our research questions with the Epson Moverio BT-300 smart glasses (Fig. 2a). This device's display has a binocular see-through viewing and supports projection of 3D content (resolution of 1280×720 pixels). It has a camera with ambient light and motion sensors and include a wired external controller (Fig. 2b) that enables tangible user input through a touchpad with buttons to navigate around what is projected in front of the user's eyes.

3.3 Procedure

Our participants engaged in the following activities:

Familiarization with the Smart Glasses. After signing the consent form and filling out the demographic questionnaire, each participant watched a 3-min video explaining how to use the smart glasses. Participants were then asked to: 1) take photos with the camera, and 2) navigate a map with a web browser. This stage ensured that all participants knew how to interact with the device.

Using the Commercial Apps. Participants then proceeded to interact with the two commercial apps we chose. Each participant was given a printed instruction sheet on how to use the apps, and we provided an explanation on the activities to be performed. In the first activity, they had to use **pARtum** to visualize and analyze interactive 3D objects using some AR markers. In the second activity, participants first configured the **Augumenta Virtual Surface**

app through the smart glasses. This required using the device's camera and some hand gestures. Upon configuring the app, participants were able to superimpose a virtual keyboard onto their palm by closing and opening their fist. They used this keyboard to take brief notes, simulating an in-class note taking activity.

Participants spent about 15 min to complete these activities.

Closing Interview and Questionnaires. Participants were then asked to share their impressions in a semi-structured interview. They also filled questionnaires on different aspects of their experience (e.g., workload, emotions).

3.4 Data Collection

We used questionnaires to collect participants' perceived: a) usability, b) technological acceptance, c) overall experience, and d) emotions. To this end, we adapted four standardized questionnaires: a) the **Post-Study System Usability Questionnaire (PSSUQ)** that measures usability through three dimensions: system usefulness, information quality, and interface quality; b) the **Unified Theory of Acceptance and Use of Technology (UTAUT)** questionnaire, that measures technological acceptance through six dimensions: performance expectation, effort expectation, social influence, facilitation condition, behavioral intention, and attitude; c) the **Nasa Task Load Index (NASA-TLX)** questionnaire, that assesses the user's experience through six dimensions: mental demand, physical demand, temporal demand, performance, effort, and frustration; and d) an **Emotions Questionnaire**, that measures people's emotional response focusing on the six basic emotions proposed by Ekman [19].

We modified some of the statements of these questionnaires to fit the purposes of our study. For example, we removed the statement "*The device gave error messages that clearly indicated how to solve the problem*" from the PSSUQ because no error messages were displayed during our experiment.

4 Findings

In this section we first discuss the quantitative analysis of the questionnaire data we collected. This is followed by the qualitative analysis of the interviews.

4.1 Quantitative Analysis

In the range [1 – 7], the average ratings across all participants for the dimensions of the **PSSUQ** were: 5.50 for *System usefulness*, 5.60 for *Information quality*, and 5.88 for *Interface quality* (see Fig. 3a). The lowest scores were given to *ease of use* and the perceived *comfort*. The overall averages for the dimensions of the **NASA-TLX** questionnaire are depicted in Fig. 3b. In the range [1 – 20], *Physical demand* had the lowest perceived workload (5.00). This was followed by *Performance* (6.50) and *Mental demand* (9.00). Both *Frustration* and *Temporal demand* were rated at 10.00, and *Effort* reached the highest score (11.00).

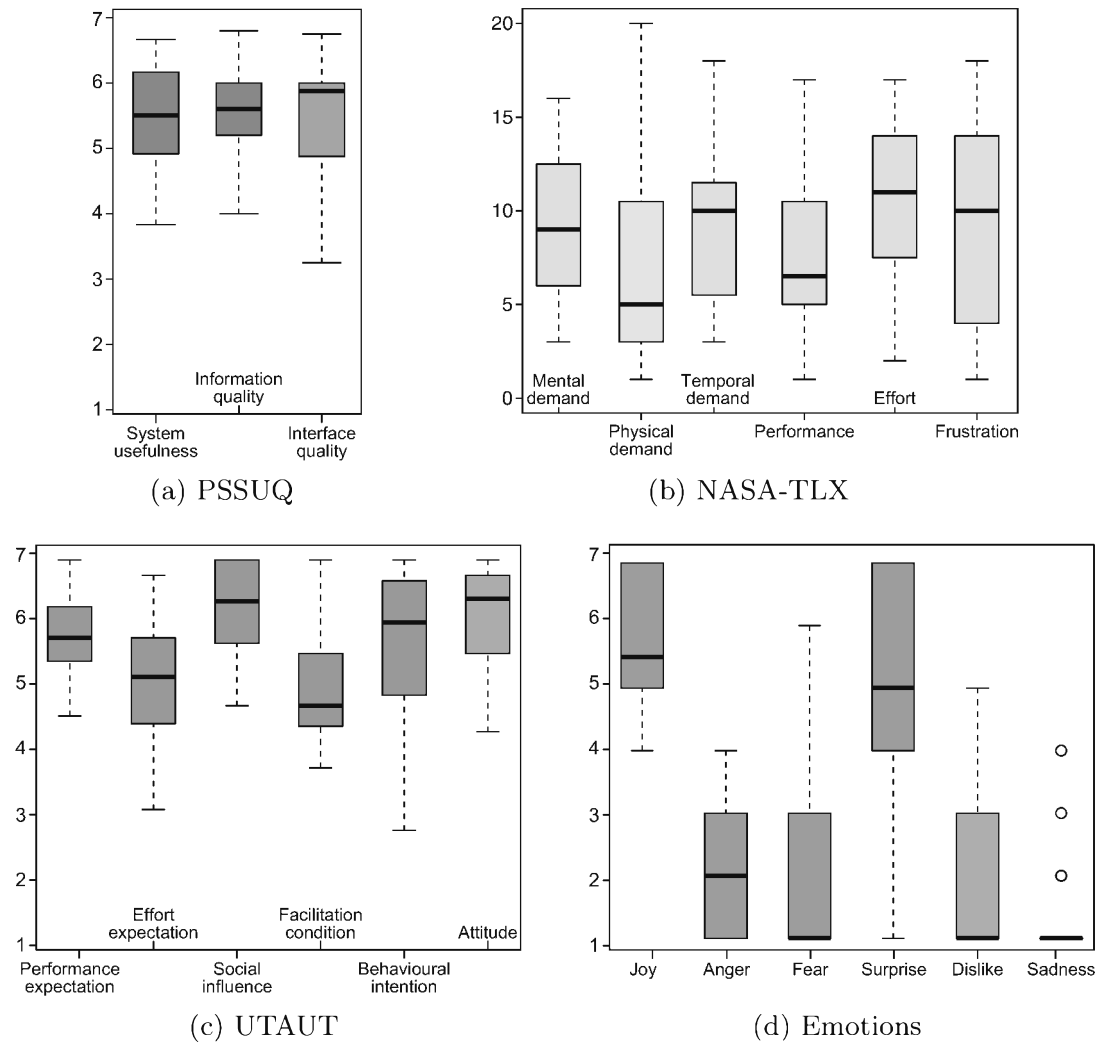


Fig. 3. Participants' average ratings for the questionnaires' dimensions

We applied the Shapiro-Wilk test to the data of this questionnaire and did not find statistical evidence that the observations were not normal ($W = 0.96$, $p = 0.42$). Our data indicates that 17% of the mental workload corresponds to a low level and 83% to a medium level. No scores were found for higher levels. These results suggest that, overall, participants experienced a medium-level workload. The participants' ratings for the **UTAUT** questionnaire (Fig. 3c) were collected using a [1 – 7] Likert scale. The lowest average scores correspond to *Facilitation condition* (4.67), *Effort expectation* (5.12), and *Performance expectation* (5.75). The other dimensions were rated at the upper end of the range: *Behavioural intention* (6.00), *Social influence* (6.33), and *Attitude* (6.38). Finally, the average scores for the participants' **emotional responses** are shown in Fig. 3d. The six basic emotions of the questionnaire, rated with a [1 – 7] scale, defined two groups. Negative emotions received low scores: *Anger* (2.00), *Fear* (1.00), *Dislike* (1.00) and *Sadness* (1.00). The opposite is true for the positive emotions: *Joy*

(5.50) and *Surprise* (5.00). These scores suggest that the smart glasses induced a mostly positive emotional response in our participants.

We also analyzed the internal consistency (or reliability) of each questionnaire's items through the Cronbach's alpha [20]. This coefficient measures how closely related a set of items are as a group in multiple-question Likert scale surveys. The results of the reliability test were as follows: 0.85 for the PSSUQ, 0.58 for the NASA-TLX, and 0.90 for the UTAUT questionnaire. The Emotions instrument received a reliability score of 0.45. In most social sciences, a reliability coefficient equals to or higher than 0.70 suggests that the questionnaire items have relatively high internal consistency. In our study, this is true for the PSSUQ and the UTAUT questionnaires. We finally analyzed the correlations between the dimensions of the different questionnaires we used. To this end, we carried out a principal component analysis (PCA). We used this statistical method to test how the data of pair-wise questionnaire combinations cluster together and to which extent the resulting clusters explain our observations.

The two first principal components (PCs) that result from considering the dimensions of the **PSSUQ** & the **UTAUT** questionnaire explain 63.81% of the total variance of the data on usability and technological acceptance (Fig. 4a). Two clusters emerge from this analysis: C1 (*Effort expectation, Information quality, Performance expectation and Facilitation condition*) and C2 (*Attitude, System usefulness, Interface quality, Behavioral intention, and Social influence*). The dimensions of these clusters have a strong positive correlation.

The two first PCs of the **PSSUQ** & **NASA-TLX** questionnaires explain 55.72% of the total variance (Fig. 4b). This data refers to usability of the device and the participants' perceived workload. These components lead to three clusters: C1 (*Temporal, Physical, and Mental demand*), C2 (*System usefulness, Interface, and Information quality*), and C3 (*Performance, Frustration, and Effort*). The dimensions of C1 and C2 have a strong positive correlation, while those of C3 are negatively correlated. These results suggest that participants had difficulties in performing certain activities, which led to a more negative experience.

The two PCs that result from the **NASA-TLX** & the **Emotions** questionnaires data explain 50.43% of the total variance (Fig. 4c). This data refers to participants' perceived workload and their emotions. Two clusters emerge:

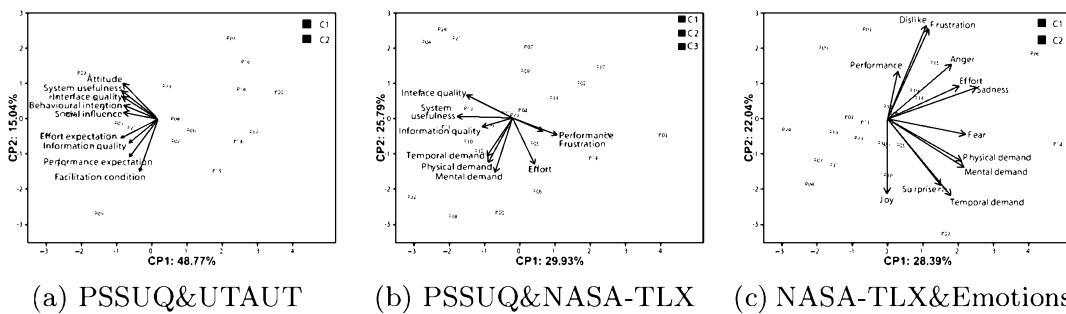


Fig. 4. Clusters emerging from our PCA. Participants' IDs appear in gray.

C1 (*Performance, Dislike, Frustration, Anger, Effort, and Sadness*) and C2 (*Joy, Surprise, Temporal, Mental, Physical demand, and Fear*). This data shows that participants maintained a positive emotional response with an average workload while performing the activities of our experiment.

4.2 Qualitative Analysis

As shown by the questionnaires data, participants had an overall positive attitude toward the smart glasses. Their comments confirm their ratings: “*Having a 3D object that you can move was incredible.*” [P01]; “*I found very interesting [...] using my body and the cards to explore the brain.*” [P04]; “*Navigating the streets of another city without physically moving was very interesting.*” [P22]; “*It was an incredible experience because I could see everything in 3D.*” [P12].

Some participants explicitly referred to the ease use of the smart glasses: “*Interacting with it was very quick; I learned how to use them quickly.*” [P02]; “*I liked that they were quite interactive and easy to use since the commands were similar to my mobile phone’s.*” [P17]; “*It was easy to understand what to do with it.*” [P24]. However, a few comments also highlighted unexpected behavior: “*Sometimes it did not react as I expected.*” [P14]. Negative comments were also made in relation to the ergonomics of the device. In five instances, participants commented on the discomfort produced by having to hold the device’s controller with one hand and the device itself with the other: “*It was frustrating because the glasses didn’t fit me.*” [P03]; “*I had to do everything with one hand, because I had to hold the glasses with the other.*” [P17]; “*The glasses were too big for me; they had the wrong size. As I had to hold them, I was unable to use the applications properly.*” [P21].

Regarding the apps, participants enjoyed using the AR markers with pARtum. On the contrary, in most cases, the interaction with Augmenta Visual Surface was problematic. Due to the gestures it required, our participants’ interaction with the virtual keyboard was mainly a trial and error exercise, as illustrated in this exemplary statement: “*I could not even write my name. It would just end whatever task I was working on.*” [P19].

5 Discussion

By considering our qualitative observations together with our quantitative results, we can see that the form factor, ergonomics, and some unexpected behavior negatively impacted participants’ experience with the smart glasses. This likely explains the somewhat high scores for the *mental* and *temporal demand, effort, and frustration* dimensions of the **NASA-TLX** questionnaire. Likewise, it may explain the low average scores for the *effort expectation* and the *facilitation condition* dimensions of the **UTAUT** questionnaire.

The measures from the **PSSUQ** suggest that participants were overall satisfied after using the smart glasses for the first time (**RQ1**). The data from the **UTAUT** questionnaire indicates a good level of acceptance (**RQ2**) but it also suggests that the smart glasses' features associated to the *Effort expectation* and the *Facilitation condition* should be improved. Nevertheless, we note that the participants' interactions with the Augmenta virtual keyboard could have had a large negative impact in the scores reported. Our findings also show that our participants experienced an average workload (**RQ3**) during their interaction with the smart glasses. These results, provided by the **NASA-TLX** questionnaire, are consistent with previous investigations with smart glasses first-timers (e.g., [21]). In general, the quantitative observations of the preceding questionnaires align with the participants' statements reported in our qualitative analysis.

Finally, the vast majority of students showed positive emotions after their first experience with smart glasses (**RQ4**). Despite some comments on the device's form factor and ergonomics (specially by students who wore eyeglasses), the scores associated to negative emotions were not significant. Our qualitative analysis corroborates this observation. It should be noted, however, that we used a specific model of smart glasses. The results may vary with other devices.

6 Conclusion and Future Work

This paper investigated STEM students' first experience with smart glasses in an educational context. We evaluated several aspects of the smart glasses: usability, technological acceptance, user experience, and emotional response. Each of these aspects was investigated through a different quantitative instrument. We also conducted semi structured interviews to elicit students' additional reactions.

Our results show that participants had a mostly positive attitude toward this type of technology. However, we also identified problematic interactions (e.g., virtual keyboards) and ergonomic aspects that should be improved in the design of the smart glasses. These observations represent opportunities for further studies that investigate how smart glasses can be used in educational contexts.

Our future plans include to carry out experiments with more diverse groups of students and other types of devices. These investigations would enable us to build a more objective characterization of the user experience students undergo when interacting with smart glasses in educational contexts.

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