SmartFeedback: Augmented Audience Response System for Intelligent Feedback

Ramón Hervás, Iván González-Díaz, Jesús Fontecha, Ana I. Molina, Manuel A. Serrano, Carmen Lacave
Technologies and Information Systems Department
University of Castilla-La Mancha
Ciudad Real, España
{Ramon.HLucas, Ivan.GDiaz, Jesus.Fontecha, AnaIsabel.Molina, Manuel.Serrano, Carmen.Lacave}@uclm.es

Tania Mondéjar
Psychology Department
University of Castilla-La Mancha
Ciudad Real, España
Tania.Mondejar@uclm.es

***Abstract*—Active participation in classroom is a critical teaching tool to achieve significant learning, which encourages critical thinking and, ultimately, makes possible to improve academic results. In recent years, innovative strategies have been developed, such as the use of devices to support participation, known as Audience Response systems (ARS) or informally, clickers. The present work proposes the development and initial validation of a system based on an augmented ARS device, with three types of functionalities (a) Programmed, the teacher can pose questions or surveys to the students, who will be able to participate through the ARS; (b) Spontaneous, an innovative functionality that allows the affective, improvised and natural participation of the audience, so that it will be possible to provide emotional feedback about any event produced in the class; (c) Implicit, the mere presence of the device and its position with respect to the rest of the devices will provide valuable data to study social behaviors and habits. The aim of all this is not only to make teaching activities more dynamic, but it is also a valuable and new source of information for the teacher, including permanent feedback of learning, opinions, emotions and social behavior, which can be used for studying their relationship with academic results. This paper describes the ARS prototype developed, whose functionalities have been tested through a trial with 19 users that helps to answer design questions for this type of devices.**

Keywords— Dynamization, Active Participation, Clicker, Academic Results, Emotions, Social Behavior.

I. Introduction

The Audience Response Devices (ARS), also known as clickers, provide an interactive voting/answering system, consisting of a software platform for managing the questions asked by the teacher, and typically a simple hardware, consisting of a radio-frequency receiver and several transmitter nodes that are distributed among the audience (students). The emitting nodes have a simple button panel that allows the participating audience to select and emit their answers, after each question has been shown (previously set). ARSs contribute to active participation in the classroom, a fundamental teaching tool for achieving significant learning [1], which encourages critical thinking and, ultimately, favors improved academic results [2].

In recent years, innovative strategies have been developed in order to empower students in the classroom and increase their engagement in the teaching-learning process. Just-in-Time teaching [3] or inverted class [4] are some well-known examples. These strategies aim at reducing traditional master classes, replacing them with guided self-learning, dedicating the classroom hours to more participatory and reflective activities. To this end, it is common to use ARS devices [5], as well as software versions of this concept, such as Kahoot! (https://kahoot.com/), which are very useful for implementing gamification techniques in the classroom [6]. The interest in the use of this type of tools, which allows the application of active learning strategies is growing considerably [7]. Its incorporation to the classrooms has been, in general, well received, as much by the students [8] as by the teachers [9]; which is related to the benefits that have been demonstrated to contribute [10]: instantaneous feedback, improvement in the performance of the students [11]; promotion of the attendance and the participation [12], attention and motivation [13] and group-based learning [14].

This paper describes a relevant part of the design and development process of a dedicated audience response device that incorporates certain innovative functionalities. These features are intended to provide feedback to the teacher, during the teaching-learning process, explicitly collecting the spontaneous emotional interactions of the students. In addition, the proposal goes further, providing the hardware device with sensor-based mechanisms and implicit monitoring functions that would allow, in future works, to analyze aspects related to the social behavior of students, as well as to check if there is any relationship between them and their academic results.

As a key part of the design and development of the final prototype of the augmented ARS, this contribution also describes the preliminary evaluation (proof of concept) carried out on the potential use of the device in the classroom, as well as its possible impact on teaching practice. The starting point was a prototype of virtual ARS (emulated by software in a web environment), provided to students, which incorporates the ordinary functionalities of a traditional ARS, along with other functions that enable spontaneous interactions and allow them to collect their opinions and / or emotions at any time of the class.

The evaluation, carried out with the participation of a pilot group of student volunteers, allow to analyze and discuss the results obtained and to validate whether the proposal of innovative functionalities to incorporate in the increased ARS is positive and enriching for the learning.

This proposal is a valuable and new source of information for the teacher since the data collected (always ensuring the privacy of the student) will be used in the future to analyze, among other aspects, the relationship between the augmented ARS with the level of academic results. This information can be very useful for the schools, serving as a support for decision making that ensures continuous quality improvement; hence the name *SmartFeedback*.

Consequently, the aim of this work is to establish the functionalities that the final prototype of the augmented ARS will have, to determine the design and development principles, both of the dedicated hardware device and the associated software, and to analyze, in a preliminary way, its pedagogical impact. The article presents the proposal of the SmartFeedback system in section 2, the experience carried out and its results, in section 3, and the conclusions of this evaluation, in section 4.

II. Proposed System

A. Motivation

The use in class of the standard clickers usually requires a simple deployment and set-up, so the functionality they offer is limited to a simple survey of the responses provided by students at predetermined times. This limitation is what has motivated the work presented here, since the objective is to analyze the information provided to teachers during the development of the class, the impact of teaching activities on students, as well as their behavior, both individual and collectively. The prototype of the augmented ARS has a low-cost profile in terms of the necessary hardware (less than 20$ per unit), and it provides a range of future uses of the incorporated functionalities, as well as of the collected data, which are not contemplated in the traditional commercial clickers.

B. General View

In the proposed teaching-learning scenario, based on active participation and enriched by the use of augmented ARS devices, three types of activities are allowed:

- *Programmed:* is the supported functionality by traditional clickers, in which the teacher can propose questions or polls (surveys) to students, who can participate through the response buttons of the ARS device in pre-set/programmed moments.

- *Spontaneous:* students can interact with the device at any time during the session by pressing a specific button to express a positive feeling about what is happening in class (equivalent to the "Like" used in the context of social networks). This is an innovative feature that allows for the affective, improvised and natural participation of the audience, and provides feedback on any event produced in the class, similar to what happens in social networks.

- *Implicit*: the device allows services that do not require any interaction from the students. Specifically, the presence of the augmented clicker in the classroom and its proximity to the teacher's device, as well as to the rest of the devices carried by the students, provides valuable data to study social habits and behaviors. The presence and proximity data are obtained by analyzing the power of the signals emitted by the ARS devices themselves, incorporating embedded Bluetooth Low Energy (BLE) and Wi-Fi wireless transceivers. This functionality is one of the main reasons for developing dedicated hardware for the ARS device.

These functionalities are shown in the general scheme of the *SmartFeedback* system, presented in Figure 1. Spontaneous emotional interactions can occur during a programmed activity, while the implicit functionalities must take place at all times, independently of the other functionalities.

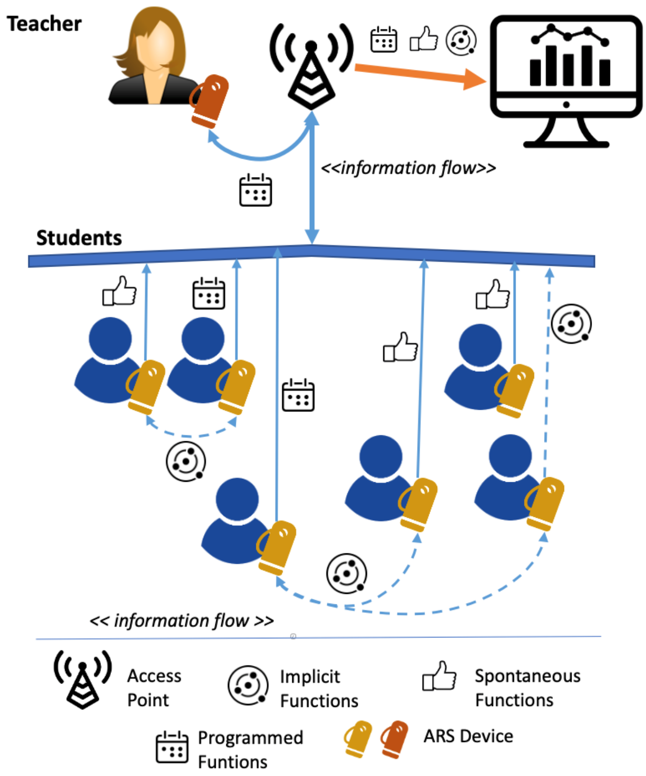

Fig. 1. Overview of the SmartFeedBack system based on ARS devices

C. Collected Data

The system is designed to support, in addition to the traditional participation functionalities (programmed activities), the rest of the activities previously exposed, related to the interactions in the classroom. These activities will be processed to provide, in the best way, the necessary information to the teacher. Therefore, there are three levels of information that the system must provide, each with data and visualization techniques specific to its purpose:

- *Instantaneous data:* This refers to the data that can be provided to the teacher during the development of the class. They should have a visual and simple format, typically by means of graphics, which do not require much effort or attention to understand them and make decisions. Examples may include concrete results of a scheduled activity (such as a survey) or *peaks* in positive student feedback.

- *Short-term data (daily):* This is the data that the teacher can analyze at the end of a class (or several of them) to evaluate what impact the different activities carried out have had, in order to plan the next sessions. Some of the data related to implicit functionality, such as automatic attendance control, are also included in this category.

- *Long-term data (historical).* These are the "raw" data, which will allow a deeper analysis and study the existence of a possible relationship with academic results. Included in this category are data on proximity between devices, which will also allow the analysis of individual and group behavior.

D. Implementation

This section briefly describes the hardware design of the device prototype, i.e., the arrangement of the electronic components on the printed circuit board, which is part of the augmented ARS. This design has been previously validated by functional tests on the protoboard. These tests have been used to check the compatibility of the various hardware components and their connection options. From this validated scheme, a highly replicable Printed Circuit Board (PCB) has been developed, using Electronic Design Automation (EDA) software. In Figure 2, the synthesized computer design of the first hardware prototype is shown (upper image) and the physical/real aspect of this prototype once it is assembled (lower image).

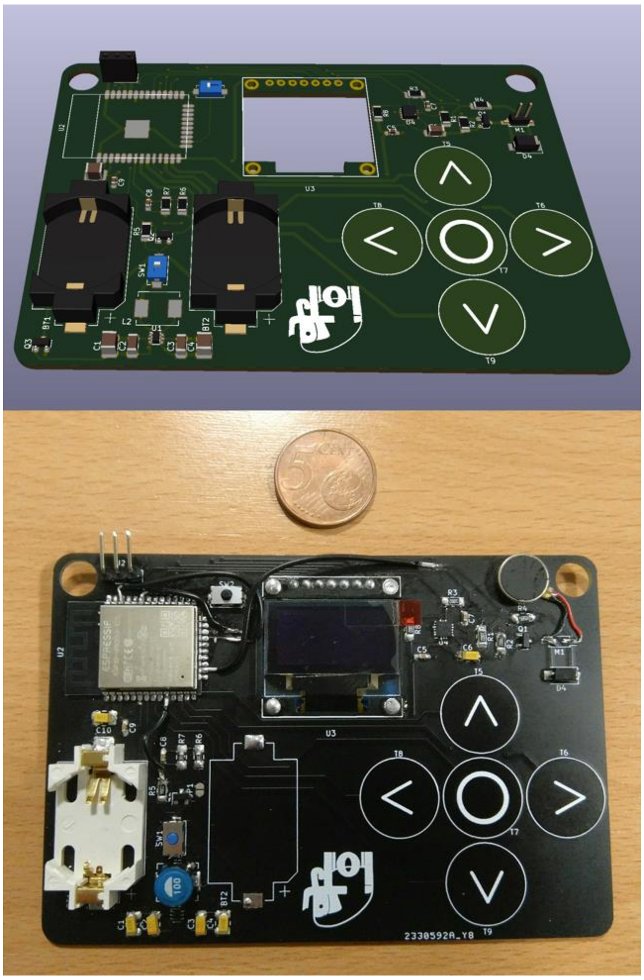

Fig. 2. Synthesized computer design of the prototype (top image) and first assembled functional prototype (bottom image) of the augmented ARS.

The device consists of a SoC (System on Chip) Espressif® ESP32-WROOM-32D (ESP32), which has an embedded microcontroller chip with a powerful 32-bit CPU and dual-core Xtensa® LX6. Each core can reach a maximum working frequency of 240MHz. Broadly speaking, the integrated one contains 448 KBytes of program memory (ROM), as well as 520 KBytes of physical memory for data and instructions; it also has integrated wireless transceivers for communication via Wi-Fi 802.11b/g/n + BLE 4.2 protocols. Another relevant feature of the ESP32 is its different power management modes, which allow to reduce the clicker consumption drastically, in those moments of time when there is no processing or communication activity.

In addition to the ESP32-WROOM-32D module, i.e. the communication and processing core of the augmented ARS device, the PCB incorporates a 3.3v DC voltage regulator, and two CR-2032 lithium battery sockets. As actuators, the hardware prototype incorporates i) a small Seeed Technology® 3VDC 316040001 DC vibration motor, to provide haptic feedback in specific circumstances; ii) a small 0.96 inch (128x64 pixels) monochrome OLED display to provide visual information to the user. Finally, as sensing components, the augmented ARS device is equipped with a triaxial accelerometer (STMicroelectronics® LIS3DH) and 5 capacitive touch buttons/pads, integrated in the PCB itself and connected to the ESP32 inputs that allow measuring capacitance variations in everything that conducts electrical charge (like human skin).

III. Trials

A trial has been carried out that serves as an initial evaluation of the design and functionalities of the *SmartFeedback* system, as well as to assess its usefulness in the teaching-learning process.

A. Material and Protocol

Although a first assembled prototype of the ARS physical device is available, a number of design and implementation decisions still need to be made before scaling up production. This is the main reason for the trial test described in this section. For this purpose, an initial software prototype has been developed that emulates the behavior of the ARS interaction device, through a web environment (Figure 3). The interactions that each student performs using his device are stored along with a time stamp. The emulated system includes programmed, spontaneous and implicit functionalities (in the latter case, only presence information is stored, but not raw data related to the proximity between devices). In this way, it is possible to obtain, from early stages, information that helps in the decision-making process in the final development of the system. A user-centered design is followed, making these participants from the beginning of *SmartFeedback* development.

Fig. 3. Augmented ARS web emulator for the realization of the trial proof of concept

The evaluation was carried out in the context of the subject "Teaching Innovation" in the specialty of Technology and Information Technology of the University Master's Degree in Secondary Education Teaching, due to the double profile (student and teacher in training) of the student population.

The participants were 19 students and the professor in charge of the subject. The evaluation was conducted during a two-hour class session, following the next protocol: (a) the professor explained to his students the basic concepts of the ARS devices and the functionalities of the *SmartFeedback* system; (b) he provided them with access to the web environment that emulates the ARS device and briefly explained its operation, encouraging them to use it during the class when they consider appropriate. To this end, the teacher developed the class normally, alternating teaching-learning methods during the session (inverted class, master class, collaborative learning, etc.). During the class, questionnaires and surveys (programmed activities) were integrated, which had to be answered through the ARS emulator. At all times, students were able to make spontaneous interactions of type "Like"; (c) at the end of the session, students were asked to fill out an opinion survey to find out their perception of the system and their possible real use in class. This survey was integrated into an online form system and was organized in three blocks of items, with a five-level Likert scale, from "(1) Strongly Disagree" to "(5) Strongly Agree". The first block of questions aimed to obtain general information about the validity and convenience of using dedicated/physical ARS devices in the classroom. The second block evaluated the perception of the functionalities and possible benefits of the ARS from the student's point of view. Regarding the third block, participants were asked to put themselves in the role of the teacher and evaluate various aspects of the system. Finally, an overall numerical evaluation of the system was requested, on a [1-5] scale.

B. Results

With regard to the overall rating of the system, an average of 4.12 out of 5 was obtained (σ=+/-0.6). Figure 4 shows the results obtained in the first block of items, about perception of participants about the physical device ARS. The aim was to obtain information related to the convenience of using a dedicated/physical device versus its digital equivalent, typically as an app on mobile devices.

Participants indicated that the physical device may favor greater and better use than equivalent versions in app version. In addition, the data show that the physical format may be less distracting to students, mainly because of the absence of notifications outside the teaching-learning process. Finally, there is a great acceptance of the concept of spontaneous interaction with the "Like" button.

Figure 5 shows the results obtained in the survey block regarding the use of *SmartFeedback* by students. From the answers given in this block, it can be deduced that most users believe that this system favors active participation in class. The rest of the questions try to obtain information about aspects related to the privacy of the interactions. There is quite a diversity of responses, but it can be inferred that the greatest concern about privacy is related to the public display of the "Like" interaction during class, and about the future correlation of the data with academic performance. On the other hand, most participants accept that the teacher has information about their interactions and that the system automatically saves their presence.

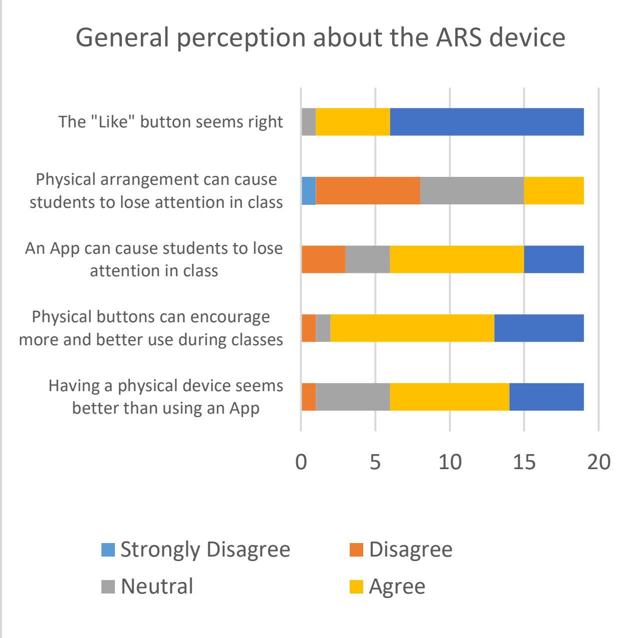

Fig. 4. First block of the survey on the suitability of the physical ARS device

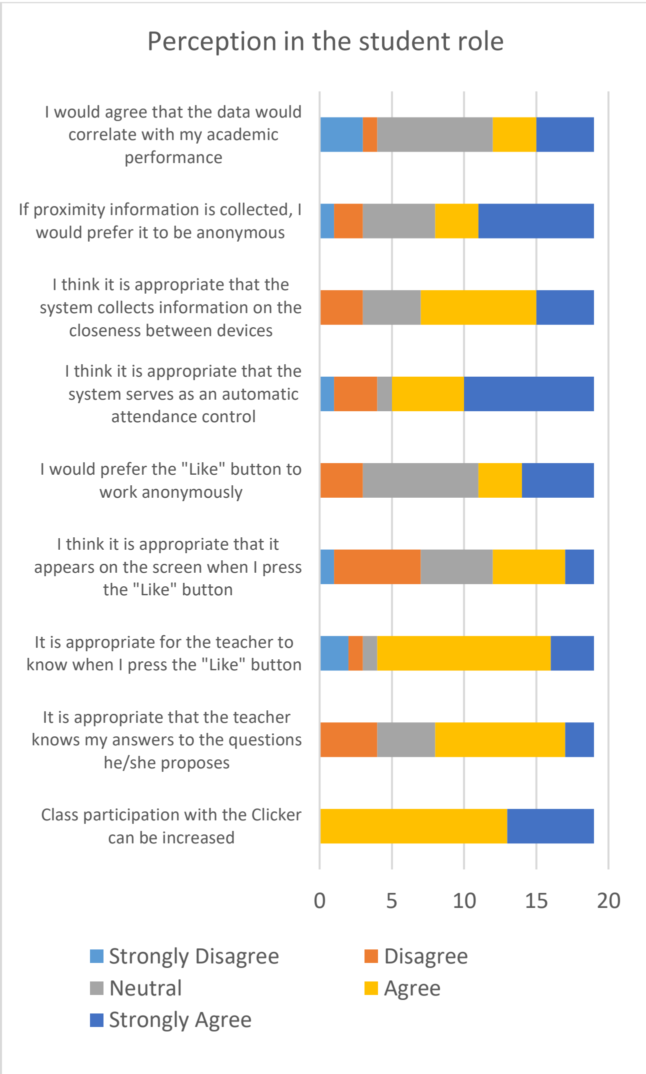

Fig. 5. Second block of the survey, on the perception of the system from the student's point of view

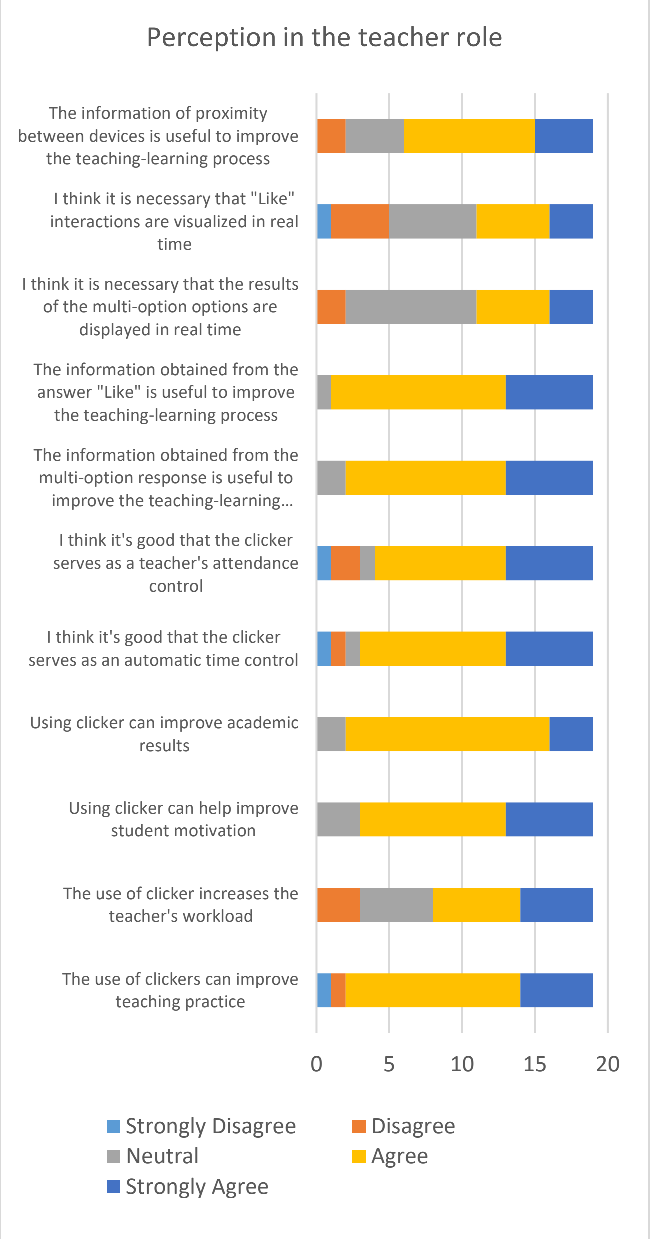

Fig. 6. Third block of the survey on the perception of the system, from the teacher's point of view

The results of the third block, about the perception of the system from the teacher's point of view, are shown graphically in Figure 6. It can be seen that they are very positive regarding the validity and convenience of the use of this system to improve the teaching-learning process. There is also considerable consensus on the validity of its use for presence control. There is a diversity of opinions on whether this solution can increase the teacher's workload and whether the results of both programmed and spontaneous interactions should be displayed in real time.

IV. Conclusions

The *SmartFeedback* system aims to make face-to-face academic activities more dynamic, promoting participation and meaningful learning strategies. In this sense, it not only supports activities based on questions and polls, but also allows and promotes students to provide spontaneous feedback on classroom activities, in a simple but effective way.

A preliminary evaluation has been made which will serve to carry out the complete development, both software and hardware, of the augmented ARS based on evidence. Specifically, the results of the proof of concept conducted support the proposed innovative feature set. For example, it is considered that spontaneous emotional interactions based on a "Like" button will make students more participatory, which should result in better concept acquisition and increased motivation. Likewise, while obtaining functional feedback from the system, the feasibility of including the device in the classroom as a teaching aid was confirmed.

In addition, participants highlighted concerns regarding the treatment and privacy of the data collected and displayed. In fact, there has been disagreement about it not being anonymous or being publicly displayed during the class. These comments should be taken into account for the future development of the system.

In any case, the preliminary evaluation shows that the proposed system is a valuable and new source of information for teachers, which will allow them to analyze the development of their classes and the impact of the activities on the students. This finding is considered essential for the development of future research based on the use of this system.

On the other hand, the results obtained from the trial facilitate decision making in the following stages of proposal development, reducing risks before scaling up the production of physical/dedicated ARS devices and the global implementation of *SmartFeedback*.

The contributions shown in this work represent the first phase of a larger project. The next step, once the augmented ARS device has been designed, prototyped and validated, is its production. The objective it to used it long periods in class and analyze in depth the pedagogical feasibility.

Acknowledgment

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