Introducing IoT and Wearable Technologies into Task-Based Language Learning for Young Children

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Abstract—In the last few years, in an attempt to further motivate students to learn a foreign language, there has been an increasing interest in task-based teaching techniques, which emphasize communication and the practical use of language, thus moving away from the repetitive grammar-translation methods. Within this approach, the significance of situating foreign language learners in scenarios where they can meaningfully learn has become a major priority for many educators. This approach is particularly relevant in the context of teaching foreign languages to young children, who need to be introduced to a new language by means of very concrete vocabulary, which is facilitated by the use of objects that they can handle and see. In this study, we investigate the benefits of using wearable and Internet-of-Things (IoT) technologies in streamlining the creation of such realistic task-based language learning scenarios. We show that the use of these technologies will prove beneficial by freeing the instructors of having to keep records of the tasks performed by each student during the class session. Instead, instructors can focus their efforts on creating a friendly environment and encouraging students to participate. Our study sets up a basis for showing the great benefits of using wearable and IoT technologies in streamlining 1) the creation of realistic scenarios in which young foreign language learners can feel comfortable engaging in chat and becoming better prepared for social interaction in a foreign language, and 2) the acquisition and processing of performance metrics.

Index Terms—Human-computer interaction, internet-of-things, language learning, sensor data, wearable devices

1 Introduction

In the last few years, in an attempt to further motivate students to learn a foreign language, there has been an increasing interest in task-based teaching techniques, which emphasize communication and the practical use of language, thus moving away from the repetitive grammar-translation methods [1]. Within this approach, the significance of situating foreign language learners in scenarios where they can meaningfully learn has become a major priority for many educators. This approach is particularly relevant in the context of teaching foreign languages to young children, who need to be introduced to a new language by means of very concrete vocabulary, which is facilitated by the use of objects that they can handle and see [2]. Towards this end, the interaction through sensor-enabled objects and wearable devices has a great potential to support learning due to hands-on engagement, enabling the collaboration and role to be played by each student. Furthermore, the use of these technologies can minimize the cognitive load in learning, by enhancing the learning and collaboration of children through everyday physical objects, wearable technologies and real-world scenarios. Compared to other techniques, task-based language learning with tangible user interfaces has the potential of enhancing the educational experience and creative problem solving activities bringing students to the next level of learning [2].

In a recent study aiming to get an overall picture of the educational affordances of wearable technologies, Bower and Sturman [3] have reported on the conclusions derived from a survey counting with the participation of more than 300 educators. Their study also comprised a brief review of the latest efforts on the use of wearable technologies in education. All empirical studies cited in [3] were targeted to adults making use of head-mounted displays or Google Glass.

The study highlighted one of the main challenges preventing the widespread use of these technologies in the classroom: a large percentage of educators are neither familiar with these new technologies, nor convinced of the benefits of introducing them into the classroom. Issues such as cost, cognitive overload, privacy, and those of an ethical and social nature were among the main concerns raised by the survey respondents.

Antle and Wise [2] have pointed out that educators should play a major role in guiding the development of hands-on activities that meet the curricula objectives. In turn, developers should be responsible for putting together the elements that make up systems capable of seamlessly integrating the data captured by the wearable and ambient sensors into a valuable source of information for students and educators.

Gilman et al. [4] have analyzed the tools provided by current ubiquitous learning systems for the four main different user roles, namely students, teachers, developers and researchers. Their analysis revealed that current systems mainly satisfy the needs of students, but most current

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systems do not provide teachers with on-line monitoring or analysis tools for student performance. They identified an opportunity for developers and researchers to explore and implement systems based on the real use of devices.

In a recent study [5], Munoz Cristobal et al. introduced a system aimed at helping teachers in the coordination of teaching activities taking place in and outside the classroom. Following the principle that students learn better when they are immersed in real scenarios, the authors developed a system to help the teacher in the multiple aspects of implementing and running educational activities in various educational scenarios. The authors realized that teacher awareness during the outdoor activities is a major issue; this is particularly relevant when working with young children. The use of mobile devices allowed the teachers to be aware of the students' actions during and after the activities.

Tan and So [6] investigated the relationship between activity design and discourse on mobile learning-assisted field trips. Their main findings showed that students' interaction with the physical setting has a profound impact on the way they interpret an activity and their engagement with the activity. They argued that technological tools play a mediating and supporting role in framing mobile learning solutions.

Closely related to the work herein, Hooper et al. reported an IoT-instrumented kitchen for English speakers interested in learning French [7]. The system implemented an augmented kitchen by inserting digital sensors into all the kitchenware and ingredients. In this way, the system is able to detect users' activities and provide timely feedback or more details about a certain cooking action. Users are also able to communicate with the system by using an interactive screen. Each task was designed to teach specific vocabulary and grammar structures. Unlike our proposal, theirs was exclusively centered on a kitchen scenario and for an adult audience interested in culinary activities.

Muller et al. [8] introduced an approach based on wearable and IoT technologies to record context from the workplace and to visualize the data as content for reflective learning. They developed and tested a system prototype for the process of training caregivers and rescuers. Due to the nature of their activity, the correct action at a given point in time can only result from their previous experience. The use of wearable and IoT technology enabled the recording of their behavior while performing their work as well as the acquisition of an overall picture of the general organizational issues. The authors acknowledge the benefits that IoT and wearable technologies may bring by enabling the recording and review of data as reflective contents. However, they recognize that a reflection session has to be carefully planned in order to get the most from the data captured by the technology. Such studies encouraged us to develop IoT and wearable technologies for teaching environments.

The main objective of the work herein is to show that the use of wearable and IoT technologies can greatly contribute to the needs of task-based language learning for young children. As pointed out by recent studies, IoT/wearable teaching tools should not only enable the creation of friendly and engaging task-based learning environments, but they should also provide teachers with on-line monitoring and student evaluation tools. To guide our work, we therefore focus on the following four main research questions:

RQ1. Can students' engagement be generated and maintained through the use of IoT/wearable assisted task-based environments?

RQ2. Do IoT/wearable-enabled learning scenarios enhance collaboration and communication among students?

RQ3. Do IoT and wearable technologies successfully guide the students through the tasks?

RQ4. Do IoT/wearable technologies improve the quality of learning?

We start by designing and setting-up a platform capable of transforming the classroom into a space where young children are given the opportunity to sort out words involving concrete objects and to interact while performing a task leading to a common goal. This addresses one of the main educational requirements in the field of foreign language learning for young children, or in Coffman's own words [9]: "When introduced into the foreign language classroom, young children need very concrete vocabulary that connects with objects they can handle or see". That is to say, in order to avoid dealing with abstract ideas, Cameron [1] recommends dealing with topics that children find familiar, such as family and friends or school life. Since they have a clear mental image of these objects or activities, it is easier for them to process the information in the foreign language.

We also report our findings on the real and tangible benefits for the instructors that are provided by the use of wearable and IoT technologies. In fact, similar to the work in [9], our results show that wearable and IoT technologies may play an invaluable role in recording the context from the classroom. Instructors may then analyze the data as content for reflective learning. That is to say, instructors may change or modify the teaching activities based on their past experience.

2 The Task-Based Learning Classroom

This section briefly describes the organization and management of a classroom, as well as the introduction of wearables and IoT technologies into the classroom.

2.1 Classroom Management and Organization

It is well known that the classroom environment is influenced by the guidelines established for its operation, its users, and physical elements [10]. In the particular case of task-based language learning involving young children, the organization of the classroom involves the arrangement of tables, chairs and, more importantly, the organization of special designated areas. Since students will be doing different things in the classroom, it is important to designate specific areas in order to optimize learning and reduce distractions. Furthermore, the organization of the classroom has to be carried out by taking into account the type of interactions between the students. Activities may be performed individually, in pairs or in groups. In this way, children learn to associate scenarios with words, objects, and more importantly through interactions with their peers under the supervision of the instructor. In a given scenario, an object may be associated with a real-world environment that allows the children to perform the tasks related to it. For instance, a group of students will share the responsibility for finding the various ingredients required to proceed with the task of preparing dinner. While some children will have to go shopping, following the instructions provided via remotely activated signals, others will be in charge of finding the appliances and kitchenware to lay the table. In this case, the teacher will have to designate two sectors: one sector will be designated as the market, while the second sector should represent the cupboard. A third sector should be identified as the kitchen, where all the students will meet in order to prepare the recipe. From the above, it is clear that the classroom should be divided into sectors and provisioned with the required resources to foster the types of interactions that may occur between participants, including individual, pair and group work. From now on, we will refer to those sectors where interactions occur individually or in pairs as context sectors, and group sectors will be the term used to refer to those sectors where the interactions involve the whole group.

The planning of a task-based lesson such as the one described above does not only require the preparation of material and organization of the classroom, but also the setting of reasonable expectations for students' behavior. Monitoring the class and adjusting lessons accordingly are two important elements in the successful implementation of a task-based learning approach [1]. Providing timely feedback on the goals will help to meet the teaching goals. The students can see that while they are still not able to complete some classroom tasks with the same ease as other students, progress is still being made.

Teachers should be able to monitor these goals and adjust lessons to make sure that all of the students are progressing adequately. In order to be able to make an accurate evaluation of the adequacy of the task as well as the level of participation of each student, the teacher has to keep a record of the key performance parameters of the task session. In fact, record keeping is seen as an area where the use of IoT and wearable technologies should prove invaluable.

2.2 Introducing IoT/Wearables into the Classroom

One of the main objectives of our study is to show that the use of sensor-based objects and wearable devices enabling the creation of realistic scenarios should prove invaluable in classroom task processes. As pointed out in [11], nowadays a large number of language teachers express great interest in task-based language teaching, but they do not know where to start. The use of sensor-activated objects and wearable devices should provide them with the tools to create and manage task-based scenarios including everyday objects and friendly interfaces. Via a simple interface, instructors should be able to set up a scenario including sensor-based objects and wearable devices. The former should address one of the main challenges of teaching a foreign language effectively to young children: the need to be introduced to a foreign language using a very concrete vocabulary that connects with objects they can handle or see [1].

As for the use of wearable devices, they provide instructors with the means to follow up on the interactions being performed by each and every student during the task. Data associated to statistics, such as the number of interactions having been performed correctly at a first attempt, the number of attempts required to complete an interaction, the time required to complete a given interaction, and the number of times a student has required further assistance from the instructor, can easily be collected,

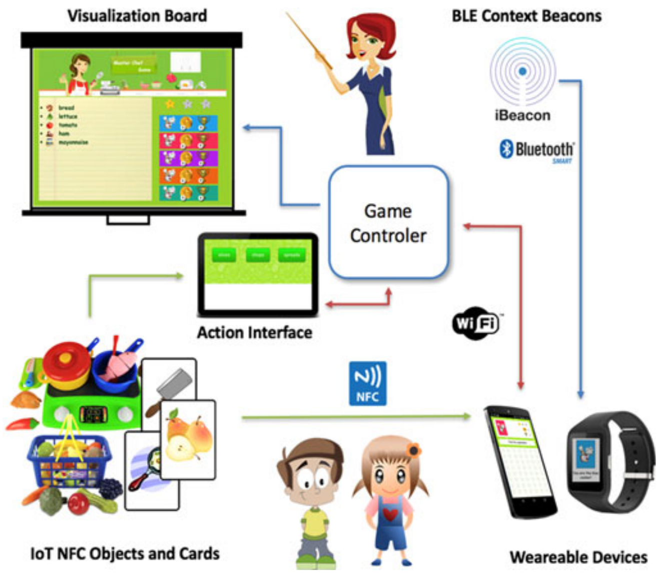

Fig. 1. System components.

processed and visualized. The post-processing of the data captured during a given task can provide the instructor with relevant information on the progress of each and every student. Such information is highly relevant to the day-to-day follow-up and final evaluation [8].

The use of IoT/wearable technologies should also prove of great help in preventing a child from being left behind or from dominating in a given task. It is therefore necessary for each child to be provided with a wearable device that uniquely identifies its owner. However, the choice of the wearable devices to be used requires a clear understanding of the actions composing the task as well as the learning goals. Wearable and IoT devices should be seen as the building blocks of novel intuitive interaction technologies. Furthermore, the execution of each action should be followed by the proper feedback message. This will encourage the student to proceed till the successful completion of the task.

3 System Architecture and Implementation

This section describes how we deploy the different objects within the scenario, then we give a simple example of a common task that is frequently performed, and lastly the scenario itself is described.

3.1 IoT and Wearable Technologies

Figs. 1 and 2 depict the main elements of the proposed solution and the organization of the classroom into sectors, respectively. The organization of the classroom into sectors is based on: 1) context sectors, where the students have to identify the objects from a list; and 2) a group sector, where the teacher will be coordinating the activities involving all the students using the items collected in the context sectors. The characteristics and operations of the main system elements depicted in Fig. 1 are:

The *Game Controller* is the core of the system. It is composed of a server whose main function is to coordinate the execution of the task, which it does by exchanging data and control messages with wearables using the WiFi network. It

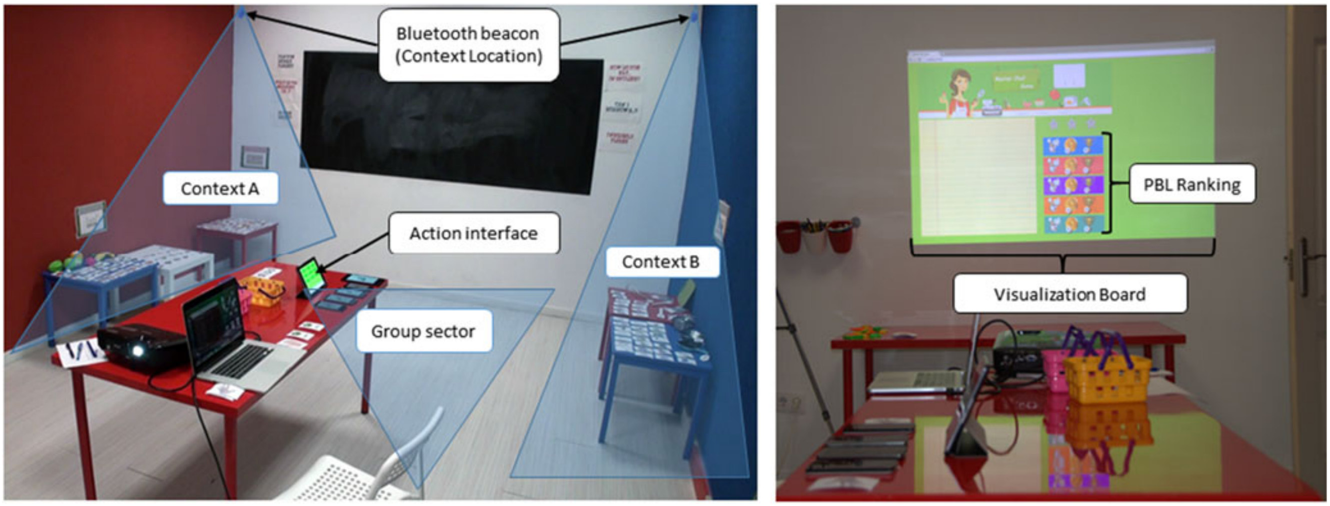

Fig. 2. Organization of the classroom.

is also in charge of displaying information regarding the progress of the task on the Visualization Board and of keeping track of the location of the wearables using the data reported by the Bluetooth nodes (iBeacons).

WiFi and Bluetooth Communications. The WiFi connection conveys the outcome of the action being performed to the central game controller. The Bluetooth interface provides the means of identifying, via the wearable device, the location of each wearable (child) within the classroom.

Bluetooth beacons are used to estimate the location of the students. Depending on the student's location, the information provided by the beacon is used to guide the students around the classroom. For instance, if a student currently located in Context A is asked for an item found in Context B, the system lets them know that they have to proceed to the appropriate sector.

Visualization Board. This is used to display and play the outcome in response to the interactions being performed by the students during the session. The screen is also used to display information regarding the status of the task, such as the objectives achieved and the points awarded to each student.

IoT objects and cards. The children have at their disposal a collection of IoT objects. Each object should have been previously marked using an NFC tag. Furthermore, each child should be provided with an NFC-activated id card. The number and types of objects used in a given class session should be determined on the basis of the scenario, the level of complexity of the task to be carried out and the main learning goals. For instance, if the subject matter is preparing a recipe, the IoT objects may consist of food products and kitchenware items. However, the teacher may choose to use a larger number of items than the ones required to prepare a given recipe with the main purpose of challenging the students to identify a given item from among a large number of objects. Depending on the resources available and the scenario, the types of objects used may range from real items to picture cards.

Action Interface. This system element consists of a tablet whose operation is supervised by the teacher. It is used in those activities involving the participation of the whole group.

Wearable devices. When deciding on the type and features of the wearable devices to be used in the classroom, the designers have to have a clear understanding of the learning methodologies employed by the teachers. In the case of a task-based language learning approach for young kids, students are asked to identify concrete objects by their names and to interact with other students and the teacher by sharing or conducting a task involving objects. As already pointed out, the use of wearable devices should help to focus on the interactions to be performed and to keep track of the interactions performed. For the purpose of our study, the use of a wearable device, such as a smart watch or a smart phone equipped with an NFC reader, and Wi-Fi and Bluetooth interfaces should meet the requirements of a task-based language learning setup for young children. Our design choice can be justified by taking a closer look at a typical task-based language class session. We start by distinguishing between two major interaction modes: one in which a given student will be required to identify an object in reply to a request; and a second mode under which the students will be asked to participate in an activity involving other members of the group. A task-based class session can therefore be thought of as taking place in two major modes. The first one comprises those activities performed in a Context Sector, where students will be mainly asked to find one or more objects. The second one defines the activities performed in the Group Sector, whose main goal is to promote interaction among the students. It is worth mentioning that during a given class session, it is possible that only one or both operation modes take place.

The above organization sets the basis for defining the features and utilization of the wearable devices. It also allows us to specify the interface between the students and the system. When working in a context sector, students will be asked to find one or more objects. When an object is found, the student uses his/her wearable device to scan the IoT object via the embedded NFC reader. For instance, if the student is asked to look for a banana, he/she should simply find the object and scan it. In response to the student's

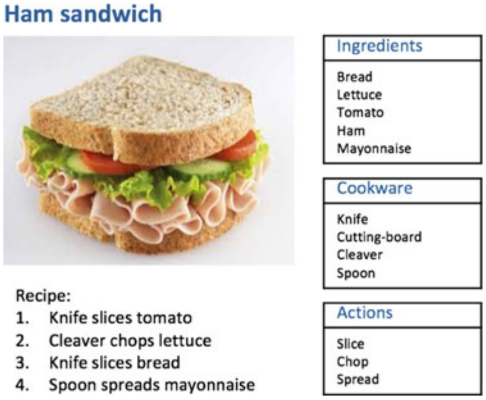

Fig. 3. Description of a sample scenario.

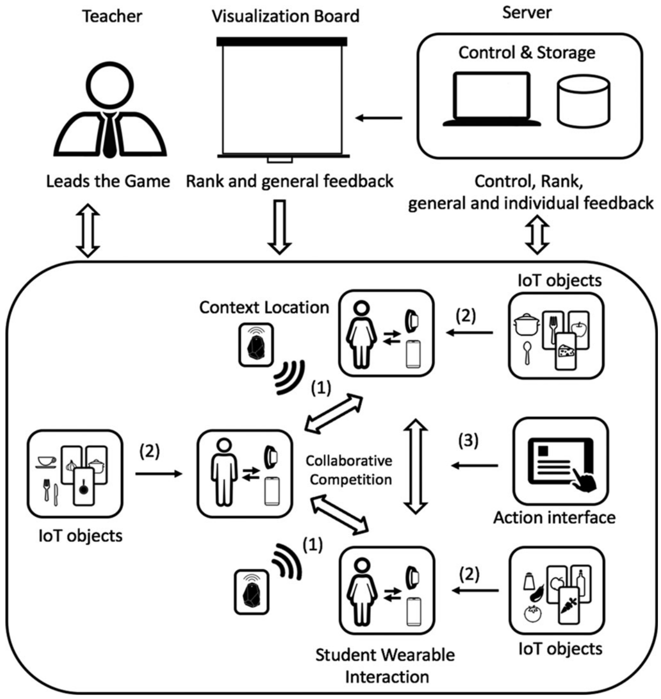

Fig. 4. System operation.

action, a message will be displayed and played on the Visualization Board. In the case of the object not corresponding to the one being asked for, the student will be asked to try again. On the contrary, if the student has picked the right object, a cheering message will be issued. All feedback messages provided to the student will be delivered through the Visualization Board and speakers.

When the students gather together with the teacher in the Group Sector, the teacher will be in charge of coordinating the actions to be performed in order to complete the task. The teacher will assign turns to the students and encourage collaboration among them. In this sector, the students will have to interact with the system via the group action interface and the Visualization Board. In other words, the kids will have to pay attention to the teacher's instructions, and then they will have to interact with the system via the interaction interface. This arrangement offers three major advantages over traditional task-based learning activities: 1) the IoT and wearable devices help to keep track of the steps that have been successfully completed; 2) teachers are relieved of the task of manually keeping a record of the level of participation of each kid; and 3) kids are more likely to follow the instructions provided by the instructor and the system. In other words, teachers should be able to focus more on guiding and encouraging the students rather than having to worry about keeping records and constantly tell them off.

3.2 A Sample IoT/Wearable Assisted Task

Before proceeding to describe the system design and implementation, in this section we first describe a typical task-based language-learning scenario. We point out, where necessary, how the IoT and wearable technologies may help to improve classroom activities.

Let us assume that the teacher has defined a task whose ultimate goal is to prepare a recipe. The recipe consists of a list of ingredients and cookware utensils, as well as a procedure, and a list of interactions to be performed (see Fig. 3). The task has been organized into two main parts: one to be carried out in the context sectors and the other one in the group sector.

Before the start of the class, the teacher organizes the classroom into one or more context sectors and one group sector. The number and nature of the context sectors will depend on the task. The IoT objects belonging to a given context will be placed within the same sector (see Fig. 4). Each sector is identified by an iBeacon, whose main function is to determine the location of the wearables. In this way, the system is able to keep track of, and guide, the students around the different context sectors.

During the first part of the session, the students will have to look for the ingredients and the kitchen utensils. In this scenario, they will have to go to the sector representing *The Market* to look for each recipe ingredient and to *The Cupboard*, to look for the kitchen utensils. For each item in the list, they will have to look for, pick up and scan it using the NFC interface of the wearable devices. As already mentioned, students receive immediate feedback after each interaction. A cheering message is displayed and played for every right answer. In the case of the object not corresponding to the one in the list, or if it has already been found, a feedback message encouraging the student to try again or letting them know that the interaction has already been performed is issued. All the kids can follow the status of the task as it proceeds by consulting the Visualization Board. Once again, a student is allowed to carry out a given interaction only if they are in the right context sector. For instance, if a student has been sent to look for an ingredient, they will be directed to the sector where the ingredients can be found. If they enter another sector, a warning message is sent to them indicating that they should go to the corresponding sector.

For instance, in order to slice the tomato, which is Step 1 of the recipe (see Fig. 3), the student simply has to scan both objects and then point to the corresponding verb, 'slice' in this case, on the screen of the action interface. In order to encourage social interaction and the participation of all students, the teacher will indicate who will be in charge of performing the actions. Furthermore, the instructor may also invite other students to become involved by asking them, for instance, to pass the target object to the child in charge of performing the action. Each student actively involved in the current step will also have to reply. The kid will have to ask for it and both the lender and the borrower will have to scan the object using their wearables and point to the verb on the screen of the action interface. All interactions are logged by the system, including the teacher's request. Finally, the student in charge of slicing the tomato will scan the two objects using the group interface. Then the child will have to point to the verb displayed on the tablet's screen and state that he/she has sliced the tomato: "I sliced the tomato with the knife".

The corresponding feedback is then displayed and played, via the Visualization Board. All the oral exchanges during this activity will be recorded by the system using the wearable devices. The interactions may have to be repeated in the case of the object manipulated not corresponding to the one being asked for, or if the child has been unable to choose the right verb or if the instructor is not satisfied with the students' performance. Furthermore, all the interaction outcomes, whether wrong or right, are automatically logged by the system. The teacher may then review them after the class.

3.3 System Operation and Implementation

Bearing in mind that the main objective of our study is to design and evaluate the benefits of using IoT/Wearables in the deployment of a language learning system, we should focus here on the design decisions concerning the interfaces and feedback provided to the students. One of the major design challenges is to design natural and non-invasive interfaces. This is particularly important when developing a system to be used by a group of young kids. It is also important to provide adequate feedback to the kids in order to keep their attention and engagement till the completion of the tasks. To this end, the system implements a Points, Badges, and Leaderboards (PBL) score scheme. Students are awarded points for each interaction that is correctly performed.

Fig. 4 depicts the system operation. As shown in the figure, the teacher leads the task. The server controls the execution of the task by collecting and processing all the data collected during the class session, following the script prepared by the teacher. The Bluetooth beacons, named Context Location (1) in the figure, determine the position of the students. When they are in a context sector, the students use their wearable devices to interact with the IoT objects (2), and when in the group sector, they use both the wearable devices and the action interface (3).

Following the description of a typical task-based class such as the one described above, we can identify the following user/system interactions:

- Student-Wearable: visual and oral via the screen, the microphone and the speaker. The feedback messages are generated by the server in response to an interaction, for instance, the scanning of an object.
- Student-Wearable-IoT objects: students scan the objects via the NFC reader embedded in the wearable. The wearable object sends information to the server.
- Visualization Board: visual and oral, addressed to the group. The display shows the PBL score, object lists and the steps required to complete a collaborative task. It also shows messages which are usually accompanied by positive feedback sounds.
- Bluetooth: interaction between the Bluetooth beacons and the wearable devices to guide the students around the classroom. The beacons periodically broadcast guiding messages within the range of a context sector.
- Action interface: This interface is used during the activities performed in the group sector. The students, under the guidance of the teacher, are asked to collaborate through the manipulation of the IoT objects.

The system generates two types of feedback messages:

- General feedback: addressed to all students. They consist of both visual and audio cheering or try-again messages. They are conveyed via the Visualization Board and the wearable of the student having performed the interaction.
- Individual feedback: sent only to the student via the wearable device. They are generated whenever the system detects that a student is not in the right sector.

Fig. 5(a) and (b) depict the flowcharts of the interactions that take place in the context sector and the group sector, respectively. In both cases, the students have to scan the objects in order to accomplish the tasks. They receive positive or negative feedback depending on whether they have, or have not, picked the right object, respectively. The system also updates the Visualization Board, showing the points awarded to the student.

Regarding the implementation details, the system has been configured as a client/server. We have developed the system running on the server and the wearable devices using HTML5, Javascript, Web sockets, and Node.js. Taking into account that our solution should accommodate a wide spectrum of wearable devices, we decided to make use of

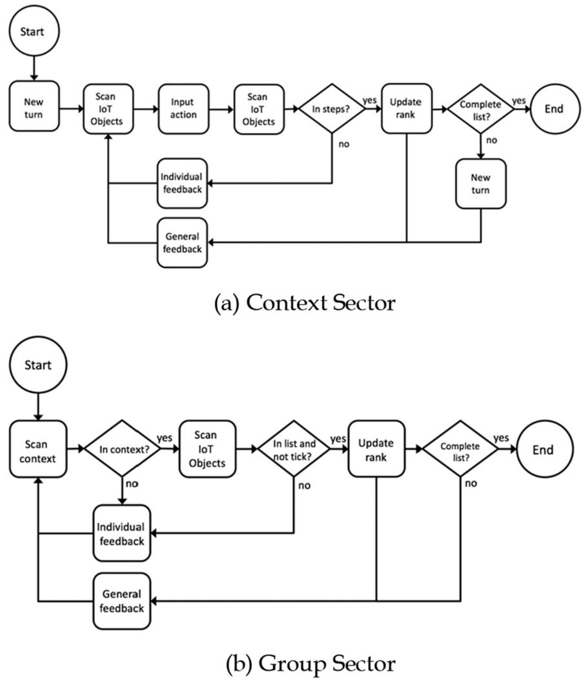

Fig. 5. Interaction process for (a) Context sector and (b) Group sector.

Fig. 6. Students looking for the recipe ingredients.

HTML5. Being a standard, HTML5 guarantees the portability of the application to practically all types of wearable devices on the market. As for the interconnection technology, we decided to use Websockets. This technology implements a full-duplex communication channel per client via a TCP socket. These features guarantee the reliability and time requirements of the application. Students should receive proper feedback as soon as they scan an object.

4 Evaluation

In this section, we present the results obtained during a set of trials conducted in a real language academy in the city of Albacete, Spain. The main objective of the evaluation is twofold: 1) to show that the use of IoT and wearable technologies provides the means to automatically capture relevant information on the progress of a class session, and 2) to evaluate the impact of these technologies on the learning process.

The first goal will help to identify metrics such as the number of times a student attempts to perform a task, the number of right and wrong answers, and periods of high/low participation per student. All these metrics provide useful information on the execution of the class session. Based on their analysis, the teachers can identify the strengths and weaknesses of a given task and/or identify those students requiring further assistance. However, these metrics do not provide us with much information on the impact of these technologies on the learning process. Issues, such as whether the use of wearable technologies could distract students, and the impact on the quality of learning, cannot be completely captured by these metrics. In order to address the second objective, we decided to film the class sessions using a fixed camera and a mobile camera. We have limited our analysis to the four major research questions (RQ) posed in the introduction section.

4.1 Experimental Setup and Methodology

Fifteen young children participated in our trials. They were all able to follow simple instructions and to participate in a simple conversation in English. In order to evaluate the impact and benefits of using IoT/wearable technologies in the teaching process, we conducted the same activity using flashcards (paper-based task). Accordingly, we organized the children into three groups. Two groups, namely Groups A and B, participated in the IoT/wearable task-based class activities, while Group C carried out the same activities using the flashcards. We fixed the number of participants involved in our trials following the recommendations in [12], [13], which state that more than 90 percent of usability and user experience issues can be detected with five participants. Their ages range from five to ten years, with a mean of 7.33 and standard deviation of 1.885. They did not have previous experience of using the system, but they all often play games using mobile devices and computers: 43 percent of them play regularly and 57 percent play occasionally. As for Group C, they have some previous experience of using flashcards, but not in the context of an English class activity.

The tasks in our trials consisted in preparing various recipes. Similarly to the recipe explained above, each recipe in our trials consisted of two parts. As shown in Fig. 2, prior to the beginning of the class, the classroom was organized into two context sectors (the Market and the Cupboard) and a group sector. During the first part, the students had to look for the items required to prepare the recipe. They first had to look for the ingredients and then for the kitchen utensils (see Fig. 6). During the first phase, the students were free to proceed, i.e., they were not assigned turns. They just had to collaborate and organize themselves to find all the items required to prepare the recipe. During the second phase of the task, the students had to collaborate, in the group sector, and prepare the recipe under the teacher's supervision. In this case, the teacher assigned turns to the students.

Fig. 2 shows the organization of the classroom. The market place consisted of 85 items: 75 picture cards and 10 objects. The cupboard consisted of forty IoT items: 30 cards and 10 objects. All the items carried an NFC tag. In the group sector, the students had to complete a total of 15 steps involving the use of two objects and an action (verb). Table 1 shows the list of recipes used in the experiment.

During our trails, the students used five smartphones equipped with NFC, Wi-Fi and Bluetooth interfaces. The action interface was implemented on a tablet. All the mobile devices ran under Android. Each IoT object was identified using a 13.56 MHz NTAG 213 and a memory capacity of 144 Bytes. The Visualization Board was implemented using a projector. The server was implemented on a laptop equipped with speakers (see Fig. 2).

Table 1
Session Recipes

Recipe	Task	Ingredients	Cookware	Actions	Steps
Ham sandwich	0	5	4	3	4
Fruit and pasta salad	1	11	6	9	7
Vegetables cake	2	11	6	10	10

Our original plans were to provide each kid with a smartwatch. However, at the time of initiating the project, we were unable to obtain a fully operational application on a smartwatch. For this reason, we decided to use smartphones instead. We believe that our findings should not deviate from those expected when using smart-watches. In fact, one of our main goals was to design a set of simple interactions in order to reduce the negative impact due to distractions. Furthermore, our system has been designed by taking into account that teachers need to know what the students are actually doing [9].

At the beginning of the class, the teacher explained to the kids the principles of operation of the system and the details of the activities. During the first part of the task, the teacher only assisted the students while they were looking for the required items. During the second part of the task, namely preparation of the recipe, the teacher assigned turns to the students. As for Group C, the kids made use of flashcards. In this case, the teacher had to lead all the actions, check that all the actions had been completed, keep a record of the performance of each student and provide proper feedback.

In order to obtain data on engagement, motivation, verbal sentences, and emotions while performing the tasks, two video cameras were used during the sessions. The purpose of this direct observation method, widely used by the Human Computer Interaction community, is to collect information allowing the evaluator to assess the subjects without altering their environment [14].

At the end of the sessions with groups A and B, the students filled in a survey based on the Smileyometer scale [15]. Based on their experience, they had to choose one of the five pictorial representations, ranging from awful to brilliant, to express their opinion on the activity. They were also given a simplified version for children of the IMI survey consisting of two questions: (1) have you enjoyed playing?; and (2) would you play again? [16]. Two members of our research team analyzed the videos taken during the class sessions in order to evaluate the intrinsic motivation, extrinsic motivation, attention focused on the concepts or on the devices and level of collaboration, verbal interaction and communication among the children.

4.2 Results

In this section, we first review the main benefits in terms of the information that can be obtained from the data captured using the wearables and IoT devices. Metrics such as the number of right vs. wrong answers, and the level of participation of each student can be obtained from the data captured though the wearables and IoT objects. This invaluable source of information can be used to review the adequacy of the tasks on the basis of the performance of each student or the group as a whole.

Figs. 7 and 8 show the statistics for each student and both groups, A and B, during the class sessions, respectively. The class session with group A consisted of two tasks, Task 1 and Task 2, while group B completed three

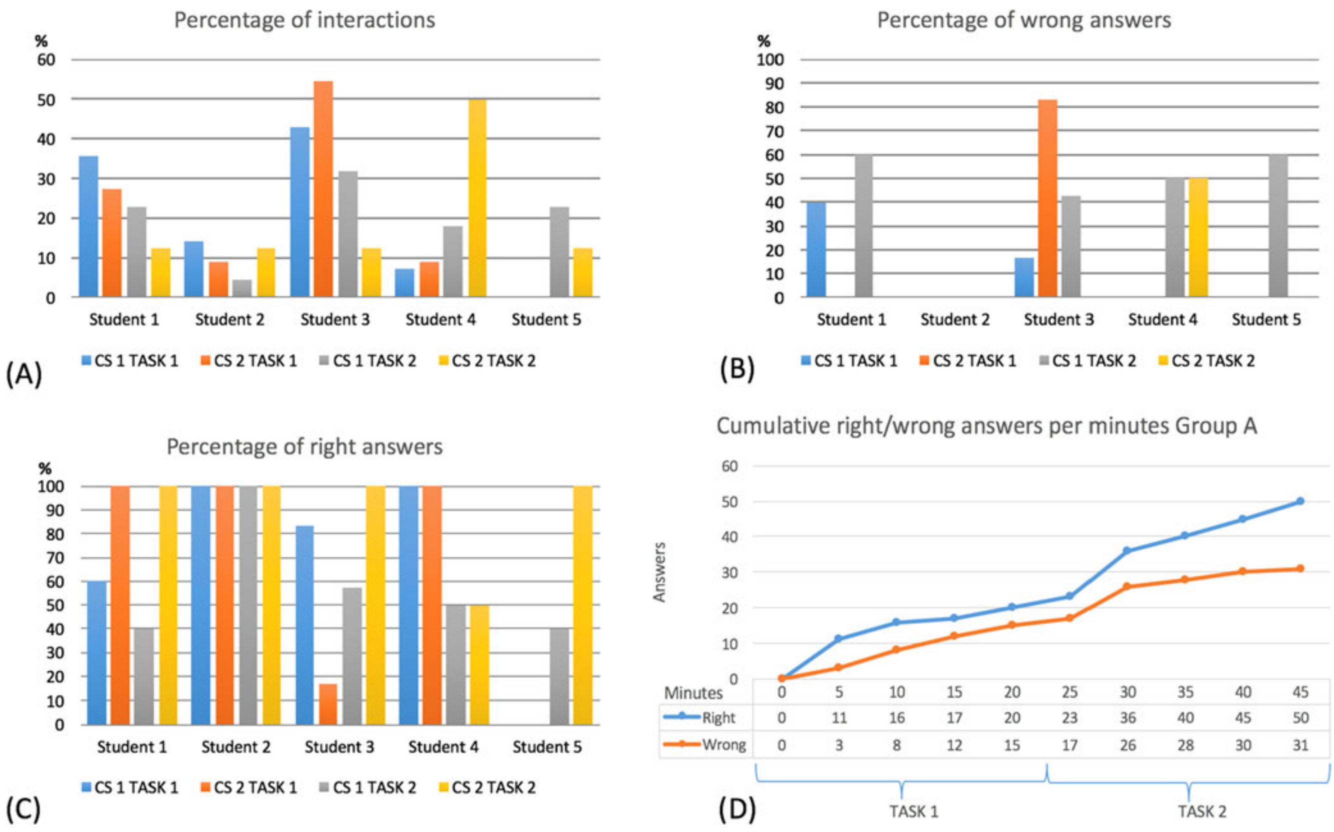

Fig. 7. Task statistics.

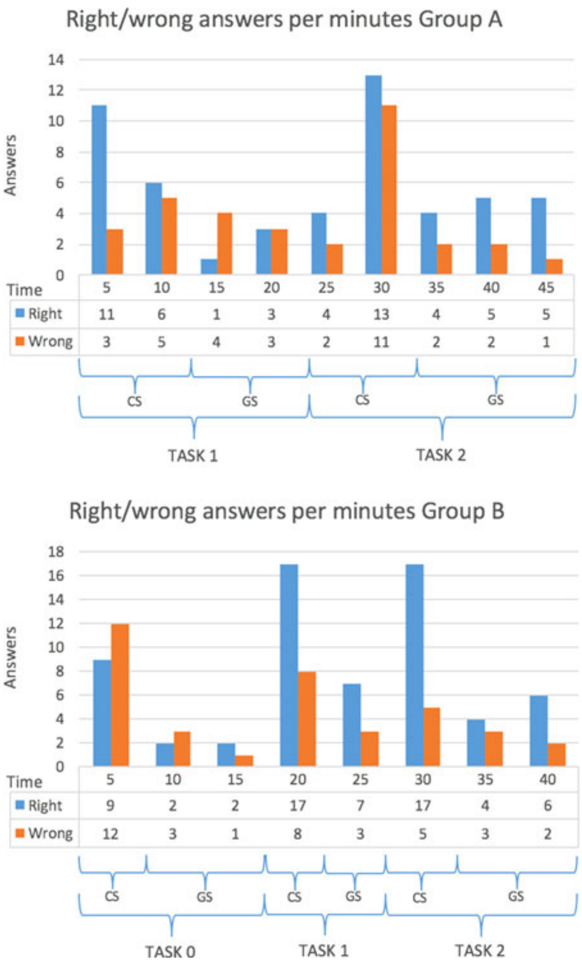

Fig. 8. Right/wrong answers.

tasks. All these tasks consisted in the preparation of a recipe. For the sake of clarity, in the figures we denote by CS the activities performed in the context sector, in which the students had the freedom to look for the recipe ingredients individually, i.e., they were not forced to collaborate. In turn, GS refers to the activities performed in the group sector, where the teacher asks the students to collaborate in the recipe preparation. In order to obtain a better insight into the kind of information a teacher may derive from the data collected by the interactions between the IoT and wearable devices, we report the statistics in periods of approximately five minutes.

In the case of group A, the results show that during the first five minutes of task 1 (recipe 1), the number of right answers was very high, i.e., students made very few mistakes. During the following five minutes, the number of right answers was slightly higher than that of wrong answers. If we take a closer look at the results for task 2, the number of wrong answers experienced a big increase while the number of right answers remained practically unchanged. This unexpected result can be explained by taking a closer look at the level of participation of each kid in the group. Fig. 7(a), (b) and (c) show the percentage of interactions, and right and wrong answers per student during the CS phase for each of the tasks (recipes). Fig. 7(a) shows that during the first five minutes of task 1, two students, namely students 1 and 3, performed most of the interactions. It also shows that student 5 did not participate at all. However, during the second task, student 5 obtained excellent results while the level of participation of students 1 and 3 dropped significantly. In fact, this information was confirmed by analysis of the video taken during the class session. The video revealed that during the first task, students 4 and 5 had problems integrating into the group, while during the second task students 1 and 3 assisted them. This clearly shows that the use of wearables and IoT objects sets the basis for the development of an invaluable monitoring tool. Based on the data captured during the class session, the instructor may change the scheduling of the activities on the fly, or he may plan them differently by following the input from the data provided by the wireless devices. In fact, Muller et al. have recently pointed out the benefits of using the data recorded by the IoT and wearable technologies as reflective contents [8]. Our results confirm the great potential of IoT/wearable assisted task-based teaching tools.

Fig. 8 shows the results for group B. By comparing the results obtained for both groups, the results show that group B had more difficulties during the first five minutes of task 0, while both groups obtained similar results during the GS phases of all tasks. This can be explained by the fact that the complexity of this phase is a little higher. The students first had to pick two items, scan them using the tablet, and then choose the verb by pointing on the screen of the tablet. Based on the information obtained from the data captured by the system, the teacher can reorganize the class. For instance, he may decide to change the rules of the task with the aim of improving collaboration among the students, or decide to place students exhibiting better language skills into another class.

In order to further assess the benefits of the system for the learning process, we now proceed to review the results obtained from the analysis of the surveys conducted after the sessions, and the analysis of the videos recorded during the class sessions.

The videos are an important source of information that allows us to assess the benefits of using IoT and wearable technologies. We focus our attention on obtaining answers to the four aforementioned research questions. In the following, we present the methodology and results obtained for each of the four key questions.

RQ1. Can students' engagement be generated and maintained through the use of IoT/wearable assisted task-based environments?

With regard to the children's motivation, two sources of information were considered: the results from the survey and those from classroom observations.

Recent field experiments have shown that intrinsic motivation produces deeper engagement in learning activities, better conceptual learning, and higher persistence at learning activities [17]. Taking into account the benefits that have intrinsic motivation in learning, we analyzed both the intrinsic and extrinsic motivation to determine the children's engagement while performing the learning tasks in IoT environments using wearables and IoT technologies.

Intrinsic motivation is based on enjoyment or interest. In this case, and in accordance with [18], we chose the following factors/indicators: curiosity (CU), explorer (E), collaboration (CL), challenge, and control (CN). Extrinsic motivation is based on external rewards or avoiding

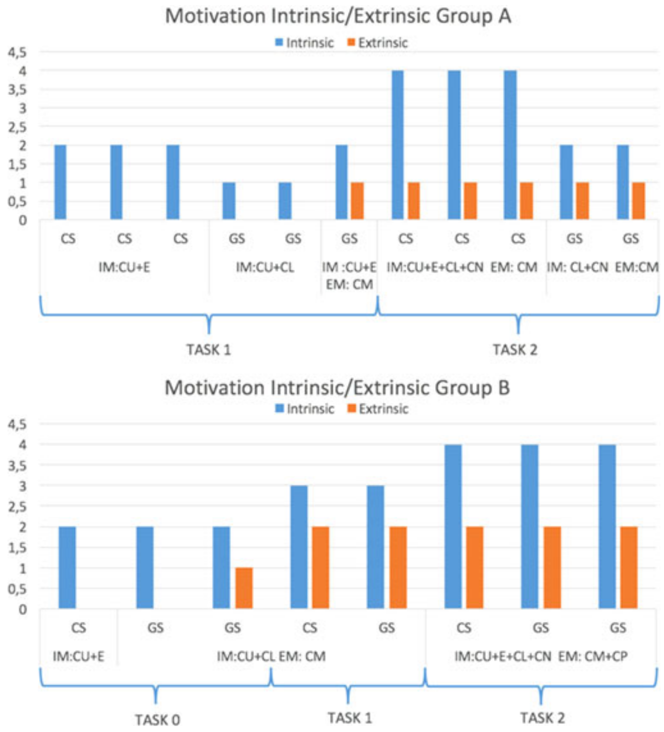

Fig. 9. Intrinsic/extrinsic motivation.

negative consequences. The factors for measuring the extrinsic motivation are points (P), rewards (R), competitiveness (CP), and the comments from the teacher and classmates (CM). Each factor adds a point, which indicates the number of factors (both intrinsic and extrinsic motivation) observed while performing the tasks.

After analyzing the video, we witnessed that in the first class sessions for both groups, when conducting actions in the context sectors, factors for intrinsic motivation such as curiosity and exploration (CU + E) were triggered. In the following sessions, children took control of some of the activities. In fact, they felt more confident in engaging in a simple conversation while picking up the objects at the *Market* or the *Cupboard*. During the group activity, the kids followed the instructions provided by the system by waiting for their turn. This facilitated the task of the teacher, who was able to follow the level of participation of each child, while the system enabled the automatic recording of each action performed by the kids. However, there is room for improving the design of this activity. In particular, the inclusion of actions involving more than one student could help with improving the social interaction among the participants while reducing the waiting time for their turns.

The results showed that the intrinsic motivation prevails above the extrinsic motivation. They find exploring a real environment more attractive and interesting, and it allows them to collaborate and improve the verbal communication with their classmates. However, while working with the tablet in the group sector (GS), some children became distracted while waiting for their turn. Furthermore, the limited size of the tablet screen offered reduced visibility for some children.

The enjoyment (Smileyometer) test results were as follows: 100 percent of the children thought that the games were "brilliant". None of them thought that the games were awful, really good or not very good. Our results suggest that the children were highly motivated to play IoT learning games, even at the end of the classroom session (see Fig. 9). After analyzing the results, we notice that the system increases the engagement of children because intrinsic motivation dominates over extrinsic motivation. Regarding the technological tools, the children are more easily motivated in IoT environments and with wearables than playing around a tablet.

As for Group C, the results show that the extrinsic motivation prevails. At the beginning of the session, they paid attention to the instructions provided by the teacher. However, the kids quickly started to compete for the objects and the attention of the teacher. Some kids even leaned over the table edge in an attempt to get a card. In turn, the teacher had a hard time keeping a record of the actions being performed and providing accurate feedback on an individual basis. In fact, some kids misinterpreted the feedback provided by the instructor or felt that they were not given the right credit for a given action. When asked to fill in the Smileyometer, two of the kids expressed that they did not like the activity at all.

RQ2. Do IoT/wearable-enabled learning scenarios enhance collaboration and communication among students?

Collaborative learning is an important team process, playing a major role in language learning. The classroom is an excellent place to develop social and communication skills, and to improve decision-making, engagement and knowledge acquisition.

In order to evaluate the level of collaboration among the students, besides the information provided by the data captured through the IoT and wearable devices, we analyzed the video material. We count the number of interactions with the system and their peers. The results show that at the beginning of the session, the children displayed little interaction (see Fig. 10). As they became more confident with the technology and the content of the task, they started to collaborate and help their peers. We noticed a significant difference between the two groups. During the process of getting the objects, Group B was less likely than Group A to engage in a collaboration. As for the second phase, when the students had to prepare the recipe, they helped each other to find the objects, but they were less cooperative when it came to interacting with the tablet. The teacher had to assign turns in order to accommodate everyone.

In the case of Group C, the kids showed little interest in collaborating. They had a hard time keeping focused on the task while waiting for their turn, and some of them even walked away from the table. At times, the teacher had to tell some kids off, making it impossible for her to keep a record of the progress made by the students.

RQ3. Do wearable and IoT technologies successfully guide the students through the tasks?

From our analysis of the video material, we notice that during the first part of the first task, namely the CS phase, the children paid more attention to the wearables (see Fig. 11). This can be explained by the fact that they needed to become familiar with the system interface. However, as they became acquainted with the system, they focused their attention on the objects (content to be learned), the recipe (Visualization Board) and started helping their peers.

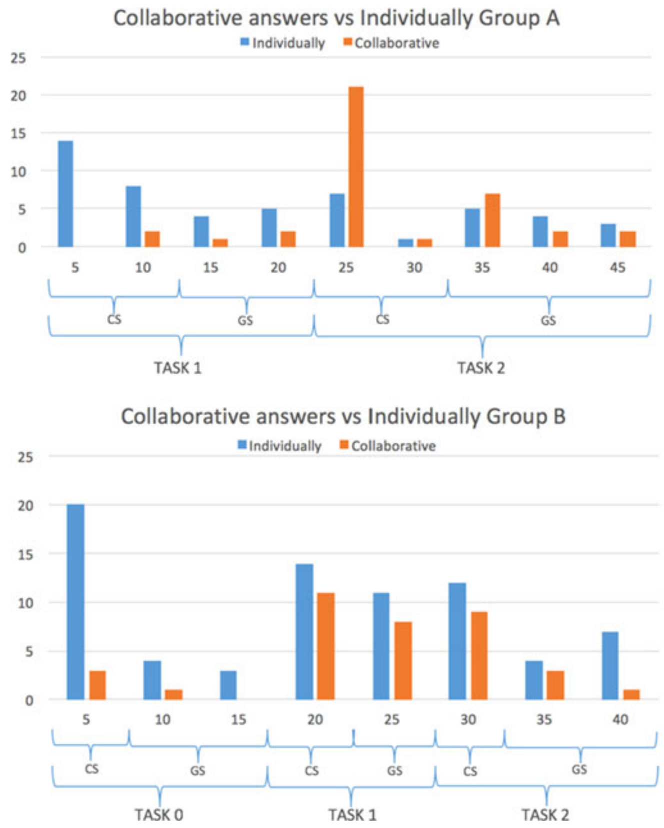

Fig. 10. Collaboration.

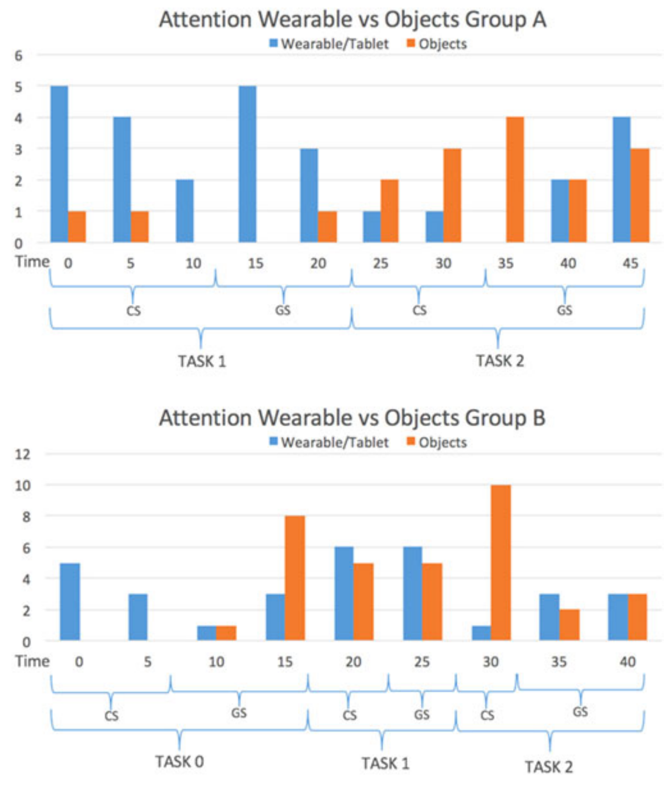

Fig. 11. Attention.

As for the results for the GS phase of the tasks, we notice that the students collaborate while looking for the items, focusing mainly on the objects. Since they had to interact with the tablet in order to point to the verb connecting the two objects, our results show that the students pay equal attention to the objects and to the tablet. However, looking back at the results shown in Fig. 7, we notice that the students have made proper use of the tablet by reducing the number of mistakes made during the GS phase of task 2.

In the case of Group C, the kids focused mainly on the objects. After a while, they showed little interest in collaborating, interacting with their classmates or following the teacher's instructions. In turn, the teacher had a hard time to keep the attention of some of the students while recording the actions being performed.

RQ4. Do IoT/wearable technologies improve the quality of learning?

In order to obtain an insight into the impact of the use of the technologies on the learning process, we should look at the progress made by the students throughout the classroom sessions. Fig. 8 shows that by the end of the session, which was task 2 for group A and task 3 for group B, the students obtained better results: the number of wrong answers significantly decreased by the end of the sessions for both groups. This is an excellent result taking into account that the class session lasted almost an hour. From a pedagogical point-of-view, the results show the effectiveness of interleaving periods of group work with fun (play) activities. Through the use of IoT and wearable technologies, we have been able to get the most out of the fun period. While looking for the items, the students learn new vocabulary. Each interaction during this period is recorded, thus making it possible to keep track of the level of participation of each kid. In an attempt to assess the effectiveness of the learning process, two weeks later the kids were asked to take a test. The results showed that the students in group A and B remembered 85 percent of the more unfamiliar words and more than half of the verbs; while the results for Group C revealed that some students had a very hard time remembering more than half of the more familiar nouns, and almost none of the verbs.

From the post-test phase (simplified IMI survey), the following results were obtained. In response to the questions, 100 percent of the children perceived the game as innovative and exciting. 100 percent would like to play it again. 60 percent of them enjoyed using the physical objects and wearable devices, because they felt curiosity and interest in the activities. 20 percent expressed more interest in the objects than the wearables, while the remaining 20 percent enjoyed using the wearables. In the case of Group C, only three of the five kids expressed interest in participating again.

We obtained the following results from non-verbal messages [19]. The first reaction of the children when using the system for the first time was as follows: 40 percent of the children felt afraid, 40 percent were nervous and 20 percent were happy. After having used the system, our results showed that all the kids were positively surprised by the activities.

5 Discussion and Future Work

In this study, we have started by analyzing the potential benefits of using IoT and wearable technologies in the area of task-based language learning for young children. Once having analyzed the main motivation for this teaching methodology and the difficulties in introducing it into the school, we have identified the areas where the use of IoT and wearable technologies may have an impact. We then developed and evaluated a system prototype. Based on the feedback obtained from the children and teachers, and the data collected during the trials comprising a comparative analysis with traditional task-based activities, we have identified the following major areas that can benefit from the use of IoT and wearable technologies:

Classroom management and organization. The act of clearly identifying each sector and defining the tasks to be performed therein clearly contributes to the successful execution of the class sessions. Students feel comfortable moving around the classroom while carrying out the task. The use of the wearable and IoT devices proved to be an attractive way of interacting with the system from any location within the classroom [1]. The Visualization Board also proved to be an excellent vehicle for keeping all the kids informed of the tasks being performed. They kept consulting the outcome of their actions by referring to it. As expected, tangible objects were always preferred over the tagged flashcards, confirming that kids prefer to work with real objects [9].

Learning experience. The system has proved to be very useful in coordinating the steps to follow and establishing a familiar scenario, such as the one reported in [7]. The teacher is then able to focus on stimulating them to participate. Students receive continuous and immediate feedback from the system and the teacher. The wide adoption of this technology in the education sector will very much depend on the ability of designing a friendly editing tool capable of meeting teacher expectations. The successful adoption of IoT and wearable devices in task-based language learning for young children will clearly require the collaboration of teachers and system designers.

Evaluating the effectiveness of the learning-teaching process. The analysis of the data captured through the wearable and IoT represents an invaluable source of information. Based on the information obtained, the teaching staff can evaluate the level of engagement and progress of each student, as well as the effectiveness of the teaching approach. Similar to the findings reported in [8], we have found that the data captured by the wearable and IoT devices become an invaluable source of information to the instructors. Based on the analysis of the data captured, the instructors may plan other activities to address special needs, such as reinforcing the participation of some of the class members, or reviewing specific vocabulary or grammar principles.

System usability evaluation. At the end the sessions of groups A and B, the teachers filled a System Usability Scale (SUS) questionnaire [20]. The SUS questionnaire consists of a simple ten - item scale subjective usability assessment. The scale yields a single composite number representing a measure of the usability of the system. Our proposal scored 81.25 (out of 100), i.e., the teachers had a very positive view of the system.

Class size. Large class sizes have been one of the major issues preventing the wide implementation of task-based learning. From our trials and based on the feedback from the participating instructors, we have found that the use of IoT/wearable technologies frees the instructor from the burden of recording, and to a certain extent, from having to coordinate every move. This can be seen as a major benefit from the point of view of class session logistics by allowing the instructor to focus on students' performance. Studies have shown that young children level smaller classes led to students receiving more individual attention from teachers, and having more active interactions with them [21]. However, the recommended class size will very much depend on the actual scenario and activities to be performed.

From the evaluation of our system prototype, we have gained an insight into end-user expectations. One of the main issues to be addressed relates to the interactions that take place in a task-based learning session, and therefore the type of features required of the wearables and IoT devices. Some of the immediate issues requiring study are:

Wearable features. Since one of the main goals is to promote the use of the foreign language, it is clear from the analysis of the video material that the proposed solution will greatly benefit from the integration of microphones. As for the use of more sophisticated interfaces, such as Google Glass, such devices when used in the classroom could distract students, which is a particularly relevant issue when dealing with young children.

System features. Our trials have shown that record keeping is an area where the use of IoT/wearables will have a major impact [8]. However, the system should incorporate, among others, friendly access interfaces to the data obtained through the interaction between the IoT and wearable devices, and report preparation.

Task preparation and costs. The development of friendly interfaces and tools facilitating the preparation of task-based class sessions would contribute to the widespread adoption of a task-based language learning approach among the teaching community. The possibility of deploying a wide spectrum of scenarios would prove invaluable to the learning experience, including outdoor activities, as in [5]. Based on our experience on setting our system protoype, we can anticipate that once having defined the task, the teaching staff should be able to set the IoT and wearable devices within minutes. As for the cost of the proposed solution, the proposed solution can be developed taking into account that students may bring their own devices: a trend that it is gaining popularity due to the widespread use of mobile devices [22]. Such solution will further enable the integration of a wide spectrum of wearable devices.

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