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The effects of augmented reality on students' academic achievement and motivation in a biology course[1]

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Abstract

This study aimed to investigate the effects of augmented reality (AR) activities on students' academic achievement and motivation in a biology course. For this purpose, a mixed study was conducted, and a pre- and post-test control group model was used. In addition, the opinions of the experimental group students and the teacher about the augmented reality activities were taken, and classroom observations were made during the study. The study group consisted of 40 (22 female, 18 male) ninth-grade biology course students. While the control group followed the biology course program, the experimental group students conducted AR activities in addition to the course program using tablets. Consequently, it was found that the motivation of the students in the experimental group increased more than that of the students in the control group. However, no significant difference was found between the academic achievement scores of the groups. The teacher and the students stated that augmented reality activities might be effective in increasing course success and motivation.

Keywords: Augmented reality, biology course, academic achievement, motivation

[1] This study is based on the first author's master's thesis and it was conducted under the project number 4244-YL1-15 at the Scientific Research Projects Coordination Unit, Süleyman Demirel University in Turkey.
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Introduction

Biology course content may be found abstract and complex by students (Gilbert, 2004). Also, teachers try to explain those subjects in narrative methods (Vanderlelie, 2013). Besides abstract and complex information, cell biology covers many things that are too small to see with the human eye, such as, protists and cells, requiring special high-tech microscopes that are not affordable for schools (Huk, 2006; Jenkinson, 2018). This abstract and invisible subject matter can cause difficulty learning or low achievement in courses (Chiu, DeJaegher, & Chao, 2015; Friedler & Tamir 1990; Lock, 1997). In particular, false examples and overgeneralisation cause misunderstandings in biology courses (Saidin, Halim, & Yahaya, 2015). For these reasons, visualisation and visualisation technologies have become important for biology courses. Visual illustrations not only improve students' activity and motivation but also open a way to learn besides from text-based knowledge (Chiu et al., 2015; Cook, 2006; Jagerskog, 2015; Wu, Lin, & Hsu, 2013).

Today, augmented reality (AR) is one of the newest visualisation technologies in educational environments. AR has been used in many fields for its visualisation features in embodying and demonstrating abstract or invisible content (Hung, Chen, & Huang, 2017). One of the most commonly used definitions for AR has been that of Milgram and Kishino (1994), using the reality-virtuality (RV) continuum (Figure 1), which has been accepted as a part of mixed reality. According to the RV continuum, environments are defined depending on their location within the mixed reality area.

[Insert Figure 1 about here]

Another common definition has been given by Azuma (1997). According to his definition, AR is a technology that allows users to see a combination of the real world and virtual objects, able to change their view but not affect the original reality. According to Azuma, AR has essential requirements. Firstly, it must incorporate a combination of real and virtual environments. Secondly, it must provide real-time interaction. Thirdly, it should include 3D materials. Azuma changed the main approach of AR with this new definition, so that it became more flexible and device-friendly without head-mounted displays.

Although AR is not a new technology for many fields, it is a new and usable technology in education. AR studies in education began in 2003 (Bacca, Baldiris, Fabregat, Graf, & Kinshuk, 2014). Literature review studies show that researchers have been investigating the effect of AR in education for almost two decades in different fields with different variables (Akcayir & Akcayir, 2017; Bacca et al., 2014; Bower, Howe, McCredie, Robinson, & Grover, 2014; Ozdemir, 2017). In general, AR supports student self-learning while providing a more pleasant educational environment where real materials are supported by virtual ones (Chen, 2006) and where both types of material facilitate effective learning (Liarokapis et al., 2004; Liarokapis & Anderson, 2010). Some studies show that AR can affect academic achievement positively in some content areas such as, Biology (Jamali, 2017), Physics (Abdusselam, 2014; Lin, Duh, Li, Wang, & Tsai, 2013), Architecture (Fonseca, Marti, Redondo, Navarro, & Sanchez, 2014), Geometry (Ibili, 2013) and so on. In contrast, some studies show that AR does not affect academic achievement in Biology (Chang, Chung, & Huang, 2016; Chiu et al., 2015) and Physics (Abdusselam & Karal, 2012; Enyedy, Danish, Delacruz, & Kumar, 2012). Some studies also show that AR positively affects motivation in different student groups and lessons for example Biology (Chien, Su, Wu, & Huang, 2017; Safadel & White, 2018), Chemistry

(Dunleavy, Dede, & Mitchell, 2009; Wojciechowsk & Cellary, 2013), Architecture (Fonseca et al., 2014), Physics (Ibanez, Di Serio, Villaran, & Kloos, 2014), Visual arts (Di Serio, Ibanez, & Kloos, 2013).

As can be seen above, there are only five studies on AR usage in biology education come across during the literature review. One of these have used AR for teaching molecular biology to university students (Safadel & White, 2018) while the other remainings have used AR for teaching bacterias (Hung et al., 2017), plant planting (Chang et al., 2016) and teaching plants by their leaves (Chien et al., 2017) for elementary school students. Therefore, existing studies are very limited in number, focus on specific biology content and employ only a few populations. This study will make original contributions by focusing on different biology content (e.g., Protistas, Colonies, Mushrooms, Plants, and Animals) and using uninvestigated population (e.g., high school students). Moreover, prior studies call for experimental studies to show the impact of using AR in educational environments (Bower et al., 2014; Santos et al., 2014; Satpute, Pingale, & Chavan, 2015; Uluyol & Eryılmaz, 2014). This is another rationale or gap for why the present study was designed as an experiment. Furthermore, it has been suggested that motivation should be studied in AR research in educational context (Albrecht, Folta-Schoofs, Behrends, & Von Jan, 2013; Cheng & Tsai, 2013). Only three of the existing studies explored the role of AR in student motivation in biology education. However, their results were not consistent because two of them showed the positive effect of AR (Chien et al., 2017; Safadel & White, 2018) whereas the other did not find any effect on motivation (Hung et al., 2017). The present study has some potential to shed more light on this inconsistency through contributing diverse evidence in terms of biology content and student level to the very limited research on motivation and AR in biology education. Finally, AR is useful for making invisible contents visible and giving concrete examples for abstract contents in biology education. AR also provides more accurate illustrations of too small or big subjects and too fast or long processes (Cook, 2006; Hung et al., 2017). Therefore, the effects of AR activities on students' academic achievement and motivation in biology course were investigated in this study.

Method

Research design

In this study, the effects of AR activities on students' academic achievement and motivation were investigated in a ninth-grade biology course. For this purpose, a mixed study was conducted, with a pre- and post-test control group model employed. Although individuals were not assigned randomly to the groups in the study, the experimental and control groups were chosen at random, which means that the study has a quasi-experimental design. Before the experiment was carried out, pre-tests were done on both the control and experimental group. Along with the content of the ninth-grade biology course curriculum, AR activities with tablets were carried out with the experimental group students. Meanwhile, the control group students followed the standard, curriculum-based instruction program. After the experiment was over post-tests were done on both the experimental and control groups. An important strategy used to strengthen research design and ensure validity and reliability in research is the triangulation of data collection methods (Patton, 1990). To this end, the opinions of the experimental group students and the teacher about the AR activities were collected and classroom observations were made during the study.

Study group

The study group consisted of 40 (22 female, 18 male) ninth-grade high school students in Turkey. The classrooms were arranged by the school administration accounting for the academic achievement levels of the students and classified as A, B, and C, so that each classroom had students with high, medium and low levels of achievement. The school administration told us which classrooms had the same achievement levels. The experimental and control groups were chosen for random selection: the control group came from class B students while the experimental group came from class C students. Each group contained 20 students.

The pre-test results were compared to check for group equivalence before the empirical process began. No significant differences were found between the experimental and control groups' academic achievement in the pre-test results ($t = -0.53$, $p > 0.05$). Similarly, no significant differences were seen in the means for their motivation towards the course (Wilks' $\Lambda = 0.86$, $F_{(6-33)} = 0.93$, $p > 0.05$). Information about student gender, levels of tablet use, levels of internet use and internet access are shown in Table 1. It can be said that the study groups possessed similar characteristics and were equal before the study's implementation.

[Insert Table 1 about here]

Data collection instruments

Achievement test (pre-test, post-test)

An achievement test was developed by the researchers to determine the effect of AR activities on the students' academic achievement. The achievement test was developed in two stages. In the first stage, a question pool was created by the researchers and biology course teacher. The question pool included 36 questions from the ninth-grade biology curriculum subject "Protists, Colonies, Mushrooms, Plants, and Animals". This question pool was reviewed by a measurement and evaluation expert and two field experts. Based on the feedback from experts, some questions were removed, and some of them were edited considering the validity of the content. In the second stage, a pilot test (29 items) was done on 129 10th-grade students who had previously taken the biology course. After item analysis, 18 items with item difficulty index (Pj) values between 0.20-0.80 and item discrimination index (rjx) values over 0.30 were directly included in the test. In addition, two items with item discrimination index values between 0.20 and 0.30 were edited and included in the test on expert opinion to ensure the content's validity. The KR-20 reliability coefficient of the 20-item achievement test was found to be 0.76. Test scores were based on the number of correct answers ranging from the lowest score of "0" to the highest score of "20".

Motivated Strategies for Learning Questionnaire - MSLQ

The Motivated Strategies for Learning Questionnaire (MSLQ) was developed by Pintrich, Smith, Garcia, and McKeachie (1993) to determine students' motivation toward a course. Karadeniz and her colleagues (2008) adapted this questionnaire into the Turkish language. The original MSLQ has two subscales: motivation (31 items) and learning strategies (50 items). During adaptation, analyses were done on 762 participants for the motivation component and on 1100 participants for the learning strategies component. Results of factor analyses show that the motivation subscale has six factors and the learning strategies subscale nine factors, according to the original scale's factor structures. After a confirmatory factor analysis, six items from the motivation subscale and five from the learning strategies subscale were removed due to their low factor loadings (Karadeniz et al., 2008).

In this study, only the MSLQ motivation questionnaire was used. It consists of 25 items rated on a seven-point Likert-type scale with a score range of 25 to 175. A high score indicates a high level of motivation for the course. It includes six subscales: Intrinsic Goal Orientation (IGO – 4 items), Extrinsic Goal Orientation (EGO – 3 items), Task Value (TV– 5 items), Control of Learning Beliefs (CLB – 3 items), Self-efficacy for Learning and Performance (SLP – 5 items), and Test Anxiety (TA – 5 items). In the present study, the internal reliability score of the overall scale was 0.83, and the internal reliability scores for the subscales ranged from 0.68 to 0.78.

Semi-structured interview and observation forms

At the end of the study, semi-structured interviews were held with the teacher and students to learn their views on AR activities. For this purpose, a semi-structured interview form was developed by the researchers. Also, observations were made in the classroom environment during the study to examine the AR activities performed by the experimental group students. An observation form was developed by the researchers to follow the classroom situation during implementation. These forms were sent for review to a measurement and evaluation expert and two field experts. They were revised taking into account the experts' feedback. The data obtained from the interviews and observations was analysed descriptively, and is given briefly to support the quantitative results and the discussion below.

Experimental process

Before the experimental procedure, the study school was selected, the necessary and ethical permissions were received, and preparations were made in cooperation with the course teacher. Firstly, the activities and characteristics of the materials that can be presented with AR were determined. As the first stage of preparation, the materials and activities have been decided synchronically with course teacher. Secondly, activity sheets, to be used in the experimental procedure, were planned as printed material. They contain brief knowledge about the course and target images for AR apps, using the weekly course plan. Next, the determined three-dimensional materials were modelled using Sketchup and Autodesk 3D's MAX software to create three-dimensional materials for visualisation (Figure 2). When these preparations were complete, all the materials were checked by the teacher and two field experts. Based on their feedback, necessary adjustments were made. Lastly, in a pilot study, the materials were tested via the tablets by a small group of students and the final arrangements were made.

With the preparation stage complete, the experimental phase was begun by carrying out the pre-test. Students answered the pre-test under their teacher's guidance in their classrooms. Once the study groups were identified, the experimental group was told about the experiments. Information on the scope of the study, the students' responsibilities, the technology and the apps' working system was provided.

[Insert Figure 2 about here]

The experimental process of the study is shown in Figure 3.

[Insert Figure 3 about here]

The study began on the same day of the weekly lesson schedule for the experimental and control groups. The experimental group students performed 15 AR activities, which were supplied through activity sheets, under the supervision of the course teacher over five weeks.

These activities aimed to help visualise the abstract concepts of the course, which the students understood poorly, using AR apps. In this way, the teacher's verbal expressions were enhanced with AR, which takes the role of demonstrator, so that abstract content becomes easier to learn. The activity sheets, which were used by the students together with AR apps on a tablet during the study, were appropriately distributed during the weekly schedule.

The biology lesson teacher taught the subject matter to both the experimental and control group every week according to the course schedule. When it was time to study the subject samples, the experimental group students studied three-dimensional content and videos on tablets using AR apps in the classroom environment. The control group students studied the pictures and samples in the textbooks provided by the school as part of the curriculum. Also, it was observed that the experimental group students carried out the AR activities allocated as homework on the activity sheets outside of class. Throughout the study, the researcher observed the students' behaviour in class using a semi-structured observation form.

At the end of the study, the academic achievement test and motivation questionnaire were completed by the experimental and control group students to show the impact of the experiment. After the post-test was completed, the researcher held a semi-structured interview with the teacher and the experimental group students.

Data analysis

At the end of the study, the data were examined using SPSS 21 software. A descriptive analysis was made, and the results were used to outline the data and to check the necessary assumptions before analysis. Regarding normality assumptions, the scores of the groups were examined by histogram and box plot graph. In addition, the skewness and kurtosis coefficients of variables were observed to be between ±1. In this respect, it was concluded that each variable is normally distributed, and hence the normal distribution assumption was met (George & Mallery, 2003). To identify the multivariate normality, Mahalanobis distance values were controlled, and it was found that the multivariate normal distribution assumption was ensured. Therefore, parametric tests were applied.

A t-test was performed on the data obtained from the pre-test academic achievement scores of the experimental and the control groups, finding that there was no statistically significant difference between the groups. Further, covariance analysis (ANCOVA) was used to compare post-test achievement scores. Whether or not there was a statistically significant difference between the pre-test scores for the experimental and control groups' motivation subscales (IGO, EGO, TV, CLB SLP, and TA) was determined by multivariate variance analysis (MANOVA). Although there was no significant difference between the groups regarding motivation according to the pre-test scores, a multivariate covariance analysis (MANCOVA) was performed on the post-tests to decrease the error interval and to increase the statistical power of the analyses, and the pre-tests were used as covariates. All assumptions of ANCOVA and MANCOVA were checked and met before the analysis. The results are tested at the 0.05 significance level. Also, Bonferroni correction ($p < 0.05/6 = 0.0083$) was used so as not to make a Type I error for the MANCOVA results. Finally, a descriptive analysis was made of qualitative data from interviews with teachers and students and observations in class.

Results

ANCOVA analysis was performed to determine whether there was a significant difference between the academic achievement scores of the experimental and control groups. The results are given in Table 2.

[Insert Table 2 about here]

In Table 2, it is seen that there is no statistically significant difference between the mean scores of academic achievement of the experimental and control groups ($F_{(1-37)} = 0.90$, $p > 0.05$). This result shows that the academic achievement of students in the biology course did not change significantly depending on the instructional method.

Although students' academic achievements do not vary according to the instructional method, a MANCOVA analysis was conducted to determine the effect of the instructional method on their motivation. Descriptive statistics are given in Table 3.

[Insert Table 3 about here]

In Table 3, it is apparent that the scores of both groups were raised on all subscales. In general, the increase in the scores of the experimental group is higher than that of the control group. Similarly, when the adjusted mean scores are examined, those of the experimental group are higher than those of the control group for the variables other than test anxiety.

The results of the MANCOVA analysis are given in Table 4.

[Insert Table 4 about here]

Table 4 indicates a significant difference between the means for motivation in the experimental and control groups (Wilks' λ = 0.49, $F_{(6-27)} = 4.79$, $p < 0.01$, partial $\eta^2 = 0.52$). This result shows that the AR activities had a large effect on the students' motivation regarding the course.

Also, a univariate test (one-way ANCOVA) was performed to independently examine the effect of the instructional method on the subscales for motivation. The results are given in Table 5.

[Insert Table 5 about here]

In Table 5, it is seen that there is a statistically significant difference between the extrinsic goal orientation mean scores of the two groups in favour of the experimental group ($F_{(1.32)} = 14.78$, $p < 0.0083$, partial $\eta^2 = 0.32$). Similarly, there is a statistically significant difference between the mean scores for the self-efficacy of the two groups in favour of the experimental group ($F_{(1-32)} = 11.19$, $p < 0.0083$, partial $\eta^2 = 0.26$). In addition, the AR activities had a large effect on the extrinsic motivation and self-efficacy perceptions of the learners. However, there is no statistically significant difference between the mean scores for intrinsic goal orientation ($F_{(1-32)} = 3.00$, $p > 0.0083$), task value ($F_{(1-32)} = 2.09$, $p > 0.0083$) and control of learning beliefs ($F_{(1-32)} = 0.26$, $p > 0.0083$). Despite the fact that the experimental group showed an increase in the intrinsic goal orientation and task value scores, this result was not found to be statistically significant. Also, while test anxiety scores decreased further in the experimental group, there is no statistically significant difference between the mean scores ($F_{(1-32)} = 2.54$, $p > 0.0083$) of the groups.

Discussion

In this study, the aim was to visualise biology lessons' abstract and invisible subject matter, which students understand poorly, using two- and three-dimensional materials on tablets with AR apps. In this way, the teacher's verbal expressions were illustrated through the AR apps to provide a better learning opportunity for abstract and invisible content. Likewise, in related literature, AR activities have been used as learning activities, especially for visualisation and concretisation (Abdusselam & Karal, 2012; Chien et al., 2017; Fonseca et al., 2014; Ibanez, de Castro, & Kloos, 2017; Liarokapis et al., 2004; Liarokapis & Anderson, 2010).

However, the results of this study show that such activities, which focused only on demonstration of content, did not have much effect on the academic achievement of students. Some similar AR studies show that there is an increase in academic achievement (Lin et al., 2013), while others have not found any significant difference in academic achievement (Abdusselam & Karal, 2012; Enyedy et al., 2012; Ibanez et al., 2017). Moreover, Huk (2006) studied with 106 biology course students at the levels of college and high school, utilising desktop-based visualisation software. The results suggest that 3D visualisation of content does not affect students' academic achievement (Huk, 2006). Also, Berney and Betrancourt (2016) report that most studies that employ animations and graphs do not find a significant effect on learning gains.

There are many reasons why AR or other new technologies in the classroom may not have a significant impact on academic achievement. On the one hand, explanations of this situation might relate to the debate concerning the effects of media on learning, which in educational technology has continued for almost four decades (Becker, 2010). This debate was started by Clark in 1983 over whether media or method influences student success, and it is still in progress. After many years, Clark and Kozma's arguments met on instructional method needs (Becker, 2010; Yang, Wang, & Chiu, 2014). Therefore, this study may show that AR has a limited effect on academic achievement as a demonstration tool without a proper instructional method.

On the other hand, this situation might have been caused by focus on technology rather than content. Similarly, the course teacher emphasised that, while AR was useful in visualising and conceptualising the abstract concepts in the course, the learning activities should have been supported by more realistic visuals so that the students could interact with these. The teacher's opinion on this subject is as follows:

> It is difficult for students in the biology class to portray some living things or some events in their minds, which is why this is a good activity. However, it could be different; for example, we saw creatures, but students should have seen their respiration, not just the structures of cells or creatures. For example, we saw the euglenid, but besides this, I would like to see its respiration or movements using the whip. I think that when the other vital functions of the creatures are observable, it will be useful and more effective in learning environments.

When the interviews with the students are examined, it is understood that the study had a limited effect on them because it was carried out with limited subjects, duration, and activities. One student said: "*I had been progressing for three or four weeks when we started to use the app. It is interesting. It encourages us to participate in lessons*". This student declared that before the study students displayed less participation in lessons, and that participation had been raised during the study. Two students, who emphasised the limitations of the study, remarked as follows: “*The activities should be a little more appealing; the base must be reduced, not too complicated*”; “*I think it is good, but it can be improved a bit*”. Also, classroom observations showed that the individual studies of the students lead to them working in the schools because they are enrolled in the university entrance exam system at the same time.

This study also shows that motivation towards the course increased significantly even though there was no significant difference between the academic achievements of the students as a result of the AR activities. Similarly, previous literature shows that AR activities improve motivation for lessons (Di Serio et al., 2013; Ibanez et al., 2014; Wojciechowski & Cellary, 2013). Dunleavy and colleagues (2009) found that students who used AR were more motivated than students who used other technologies in their course. Additionally, Gooch (2014) emphasised that AR activities positively affect student ability, development of interaction and motivation in all age groups. It can be said that AR activities significantly influence students’ motivation and improve their motivational beliefs (Dunleavy & Dede, 2014).

Motivation can take its source from personal interest, desire and curiosity, as well as environmental factors and supportive elements (Ergun, 2009). In this context, it can be said that AR activities are an extrinsic motivation source for students. According to literature, in the course of AR activities, there is an increase in students’ interaction with the learning materials without any environmental limitations or dangers, and that this positively affects their extrinsic motivation (Thornton, 2014; Wojciechowski & Cellary, 2013). Similarly, in this study, the teacher, who noted that students loved the AR activities and showed increased interest, noted, “*Their interest in the lesson has been increased, you have seen it already, they are satisfied...*” Further, “*It is a good activity in that they can see what they do not know, and cannot see and reproduce in their minds...*” Students also made these remarks: “*Visuals help me understand, so* *it is good for me*“; “*We became more interested in the lesson because the subject became more fun...*”; “*This application is interesting, it allows us to better participate in lessons*”.

Moreover, observations made in the classroom by the researcher showed that student interest and attention increased over time as the course progressed. Students generally stated that thanks to the AR activities they had the opportunity to visually explore species they had not seen previously, species they did not know, and the structures of living things, so that the study increased their motivation in the lesson. Similarly, Di Serio and colleagues (2013) also pointed out that students are better motivated to interact with learning environments through AR activities.

Another finding of this study is that AR activities increased students’ self-efficacy for learning and performance in the course. They stated that they understood the lesson better and increased their belief in success. One student said, “*I’ve never learned biology before; now it’s more comfortable and easier to understand, I will get a higher grade on the exam than before*”, expressing a positive attitude towards passing the biology course. Similarly, Martin-Gutierrez et al. (2013), studying engineering students, and Ibanez et al. (2015), studying ninth-grade students, found that AR activities increased students’ self-efficacy. Overall, it is thought that students enjoyed an opportunity in the AR activities to see and examine organisms and their structures that they could not see and study under traditional school conditions.

This study uncovered no significant differences between the experimental and control groups regarding intrinsic goal orientation, task value, control of learning beliefs, and test anxiety. This may be due to the fact that students have the same intrinsic motivation and responsibility for the subjects of the biology course. Although the test anxiety level decreased in the experimental group, they still had anxiety about exams. While AR activities may have led to students becoming externally motivated and having increased perceived self-efficacy, because of the students focus on university entrance exam system at the same time, so students still experience test anxiety.

Conclusions

This study finds that AR activities do not make a significant difference in the academic achievement of students but positively affect their motivation for a course. It is understand that visualisation and concretisation of abstract concepts with AR increases students' interest and motivation towards the course. The results also indicate that achieving a better understanding of abstract concepts via AR activities helps students to develop their sense of self-efficacy. Furthermore, students enjoy the AR activities coupled with printed materials in the classroom environment. However, it appears that AR activities, mainly due to the burden of the exam-centred education system and the limitations of this experiment, may not be effective in creating meaningful differences in the academic achievement of students.

Limitations and implications

This study was carried out under the restrictions of permissions received from the school, with constraints on the research process and with the students having little time and availability due to exam periods. In this context, it is thought that, in a school with proper infrastructure, more long-term and interaction-based AR activities might influence students' academic achievement more positively. Furthermore, AR activities relevant to course content, along with the use of different methods in future studies, and active participation of students, will have a greater impact on learning outcomes. As can be understood from the views of the teacher and students, AR materials with better image quality, designs that are more interesting for students, and more interactivity will increase the effectiveness of instruction. Finally, when the related literature and the results of this study are taken into consideration, it could be beneficial to use more AR technology when preparing curricula and textbooks.

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Figure Captions

Figure 1. Reality-virtuality continuum (Milgram & Kishino, 1994)

Figure 2. Example of the 3D models (Euglena, paramecium, plant cell)

Figure 3. Experimental process