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Fostering Learning Motivation of Students with Reading and Spelling Difficulties by an AR-Enhanced Gamified Educational App for Literacy Learning

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***Abstract*—Students with special educational needs benefit from carefully designed learning approaches that consider both their individual learning requirements and the advances in teaching and learning methods and tools. This paper presents the initial exploratory results from a pilot study on the advancement of literacy skills through an innovative Augmented Reality (AR)-enhanced gamified educational app for students diagnosed with reading / spelling difficulties or dyslexia. A sample of 5 teachers and 23 students worked with the AR app for the duration of a school term and filled in standardized scales on student motivation upon completion of the pilot study. The analysis of the results indicates that both groups of teachers and students found the AR app motivating to a certain degree. However, there were challenges within the pilot implementation that impeded the successful app use and potentially delimited the perceived motivational effects. Conclusions and outlooks of research perspectives for further development highlight the necessity for further research in this important field.**

Keywords—Augmented Reality, Learning Motivation, Literacy Acquisition, Digital Game-Based Learning, Gamification, Dyslexia, Special Needs Educational Systems

I. Introduction: Study Context and Research Objective

Motivation is considered one of the key drivers for successful learning [1]. According to related research, AR has the potential to support student motivation and thus to facilitate learning processes when employed reasonably [2], [3]. The same has been confirmed for game-based learning and gamified learning scenarios [4], [5]. Yet, gamified AR-enhanced learning apps are an emerging field of academic interest and the state of research is still considered insufficient in many ways [6]–[8].

Whenever students with specific learning difficulties and requirements are involved, it is particularly important to carefully balance teaching and learning methods and existing technology in accordance with relevant research findings. However, there is limited research so far on the use of AR-enhanced applications in the context of literacy acquisition and even less evidence with regards to the target group of students diagnosed with reading / spelling difficulties or dyslexia even though estimations state that 25% to 32% of the general population underperform in reading and / or spelling tasks [9], [10].

This paper investigates the application of an AR-enhanced gamified educational app for literacy learning and introduces first exploratory results from an international and interdisciplinary study. The research question is: "Which effects does a gamified AR-enhanced learning app for literacy acquisition have on the motivation of students diagnosed with reading / spelling difficulties or dyslexia?"

The pilot study was conducted in the context of the European Horizon2020 project ARETE which aims to explore the effects of Augmented Reality on teaching and learning processes in Elementary schools across Europe. There are different pilot studies focussing on (1) literacy acquisition [11], (2) STEM learning [12], (3) positive behaviour [13], and (4) developing and testing an interactive toolkit for teachers to create own learning activities. The data introduced in this paper were collected in Pilot 1, where school classes used a gamified AR-enhanced learning app to facilitate literacy acquisition. The unique approach followed in the ARETE project supplements a comprehensive and carefully designed innovative AR-enhanced literacy learning app for students with reading and spelling difficulties with an international piloting strategy monitored by a comprehensive interdisciplinary research approach. The stakeholders involved are international and the interdisciplinary perspectives combine the app development with evaluations from the viewpoint of Human Computer Interaction-based research while at the same time including a field study in schools across Europe. The impact on students, teachers and teaching and learning processes is evaluated thoroughly from the educational perspective. This way, the project aims to bring forward relevant research from an educational field that currently has a number of research gaps, as the following literature review indicates.

II. Literature Review: Digital Game-Based Learning, Gamification, AR and Literacy Learning

Digital Game-Based Learning (DGBL) basically refers to learning through games on computers, mobile phones, tablets or any other digital devices. Prensky defines it as "any marriage of

educational content and computer games" [14, p. 145], although the growth of mobile technologies over the last 20 years requires an extension of this definition to include also mobile devices of all kinds. According to [14], DGBL feels like playing a "real" video game while content and context have been designed to facilitate a learning experience for a specific purpose. Various studies from diverse content areas have shown that DGBL approaches can enhance students' motivation to learn and also help increase learning outcomes if the conditions are suitable and supportive [15]–[18].

Gamification on the other hand does not mean playing a full game; instead, selected game mechanics such as, e.g., leadership boards, points, or avatars, are transferred to non-game learning contexts to stimulate learning [19]. While Prensky still depreciatingly describes that "'game-based principles' is the designer's way of saying 'I couldn't get them to let me use a game, but I snuck some ideas in anyway'," [14, p. 173], research has evolved over the last decades and shown that gamification can also support learning processes and be a valuable contribution to fostering learners' motivation [20]–[22].

With the development and growing commercial exploitation of AR over the last decades, teachers, educational researchers and app developers started to utilize the advantages of AR also in the contexts of education and gamified learning apps. A growing body of evidence suggests that this can be beneficial also for teaching and learning purposes; e.g., [6] proved that the learning motivation of undergraduate health science students was increased by using an AR mobile application. Similarly, [23] also concluded in the context of science teaching for elementary school students that AR can be a powerful motivator. [24] showed that AR and game approaches significantly promoted students' learning motivation with Taiwanese fourth graders in natural science courses. [8] conducted a systematic literature review of research, applications and empirical studies about Augmented Reality and Gamification in education. The authors summarized various benefits, including "positive behavioural, attitudinal, and psychological changes and increased engagement, motivation, active participation, knowledge acquisition, focus, curiosity, interest, enjoyment, academic performance, and learning outcomes" [8, p. 1] on the side of the students.

While the target groups of AR-enhanced DGBL activities are diverse, a considerable share of respective studies focus on learning in STEM contexts for students without special educational needs [25]. Fewer studies investigate if and how Augmented Reality and / or AR-enhanced learning apps with or without DGBL or gamification elements can lead to improved student motivation also for students with special educational needs. In this context, [26] argue that AR applications which support reading activities for students with ASD have a high potential of promoting student motivation. [27] did not find a significant difference between the learning results of children diagnosed with ADHD who worked with a literacy learning program that was enhanced by AR in one group and did not include AR in the other group. [28] analysed that reading scores of two children with ADHD and reading disabilities increased considerably during an AR-enhanced intervention. In a systematic literature review, [29] summarize that increased motivation and interaction are the most commonly mentioned advantages in studies on AR in educational inclusive contexts; however, they criticize methodological limitations in many studies, e.g., with regards to sample sizes.

As these examples and further sources demonstrate, evidence for the success and pedagogical effectiveness of AR-enhanced gamified literacy learning apps for students with special needs is still scarce and shows limited informative value and validity. Against this background, the research presented in this paper aims to address this research desideratum and to explore the motivational effects of an AR-enhanced gamified literacy learning app on students who are dyslexic or underperforming in standardized reading and spelling tests.

III. The AR-Enhanced Gamified App for Literacy Learning

A. App Objectives and Pedagogy

The "ARETE Read & Spell" app has been developed using the content from an existing evidence based literacy programme called WordsWorthLearning (WWL). While the literacy programme has successfully been used before, the AR-enhanced gamified app was applied for the first time in this study. The aim was to deliver innovative content using AR to enable the literacy learning process become more engaging and informative for students, by integrating computer generated animated AR-3D objects that are overlaid on top of the real world captured on their mobile device (tablet) camera. The target group are Primary School children (9–12 years of age) that have been identified with English language reading and spelling difficulties.

Effective learning in the school is dependent on the pedagogical approaches a school or teacher adopts in the classroom. The "ARETE Read & Spell" app is aligned with the 'Science of Reading Instruction' pedagogy, which focuses on the five pillars of early reading: phonemic awareness, phonics, comprehension, vocabulary and fluency [30]. The approach stresses the importance of explicit and systematic teaching of decoding and encoding, which has consistently given students a clear learning advantage [31]. It is now well accepted that effective, evidence based instruction emphasizing phonemic awareness and phonics as foundations for literacy development are essential. The aim of the "ARETE Read & Spell" app is to provide evidence based literacy instruction that considers individual students learning styles and the individual teaching competencies of the 'facilitator'. To reach this aim the app focuses on multisensory instruction (auditory, visual, orally tactile and cognitive/ linguistic props) that follow a clear hierarchical path. This reflects the normal stages of literacy development and incorporates detailed instruction for experienced / inexperienced 'facilitators' alike to follow and succeed in teaching their students. In addition to this, the "ARETE Read & Spell" app integrates AR features to help consolidate and generalise abstract literacy concepts being taught. It is designed to provide a 'scaffold' for the student, to facilitate collaborative learning and to enrich their learning experience, thus enabling them to meet their learning objectives.

B. Gamification and DGBL Elements

The "ARETE Read & Spell" App includes hands-on interaction with AR physical objects (e.g., protagonist, letters,

vowels, consonants, words, and flashcards) which are augmented through displaying digital contents on a screen. The app also provides a gamification activity that focuses on learning to read and spell.

The AR-enhanced DGBL approach and the paediatric voice recognition encourages students to engage with the educational content in a playful and positive way. The app provides a 'galactic' planetary route for learning, which encompasses repeated self-learning, interaction and feedback, to activate the students' interest and their motivation to learn.

The DGBL method uses a variety of integrated 'hands on' interactions with AR virtual objects. These serve as a scaffolding for learning to read and spell and include over 150 AR audio visual objects in the programme, with a function to either support a speech sound, explain a complex rule or as a prefix or suffix flashcard to explain their complexity and enhance memory through auditory, visual and linguistic means. The app gamification includes:

- Using Markerless AR to show a real environment on screen, to project 2D/3D Audio Visual virtual objects (e.g., in the classroom or at home),
- Quizzes that establish progress, with a guided option for revision and winning points towards prizes such as jig-saw building, planetary passport stamps and rockets,
- Tactile games with paediatric voice recognition software to teach the student to read speech sounds and words,
- Spelling games with abstract 2D/3D audio/visual language symbols and learning materials to present phonemes, words and sentences in an authentic teaching and learning environment,
- Flashcards with abstract 2D/3D Audio Visual AR objects for learning prefixes and complex suffixes,
- Teaching literacy unique rules using abstract AR objects to support effective early English language learning.

Fig. 1 summarizes the strategy behind the gamification elements in the "ARETE Read & Spell" app.

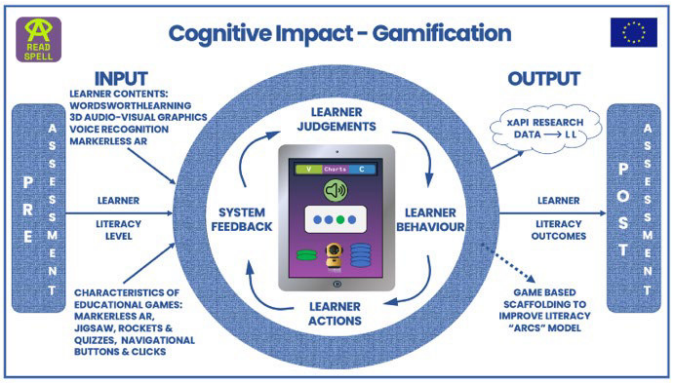

Fig. 1. Overview of App Gamification Strategy.

IV. Methodology & Sample

Pilot study 1 of the ARETE project is concerned with the literacy acquisition of students with reading and spelling difficulties. In an intervention from around October 2021 to June 2022, intervention group students worked with the interactive AR-enhanced app described above with the aim of fostering their literacy skills. The pilot study was closely monitored by a multifaceted and interdisciplinary evaluation approach focusing on the target groups of teachers, students and parents. The evaluation included an intervention and control group design with pre and post-tests [11]. The following metrics and sample descriptions introduce the data sources relevant for the focus on student motivation addressed by this paper.

A. Teachers

1) Metrics

The pre and post online surveys for self-assessment all teachers filled in addressed the following content areas: demographics and relevant previous experience; teacher attitudes and technology acceptance towards AR [32], [33]; teaching and learning processes during the intervention (post-test only); and an evaluation of the intervention or control group experience (post-test only). The scales for teacher attitudes and technology acceptance are introduced in detail in [34]. The questions on teaching and learning processes aimed to collect detailed information on the ways in which teachers realized the AR-enhanced intervention (intervention group) or their traditional literacy teaching (control group), e.g., with regards to the number of students involved, frequency and length of app use, methodology applied, social settings, cognitive processes addressed, and media used [11]. The items about the evaluation of the app or teaching experience required an overall rating, responses regarding enjoyment and satisfaction, problems and barriers, and the teacher's estimation on student motivation and classroom engagement.

The scale for the teachers' estimate of student motivation is based on Keller's established ARCS model [35] that conceptualizes motivation as an interplay of attention, relevance, confidence and satisfaction [36]. The scale used is a modified version of Huang *et al.*'s Instructional Material Motivational Survey (IMMS) [37] with an addition for Augmented Reality contexts as suggested by [38]. It includes 8 items (2 items per each of the 4 subscales of attention, relevance, confidence and satisfaction) and an additional summarizing item that inquires: "The intervention had a positive impact on my students' motivation".

2) Sample

The data included in this research are from a convenience sample of n=5 teachers (4 females, 1 male). 3 teachers are from Ireland and 2 teachers are from Italy. They are aged 48.4 on average (SD 8.6, range 37–58). One teacher has less than 5 years of teaching experience, one teacher has 5 to 10 years and the other three teachers have more than 10 years of teaching experience. When asked for their self-assessed expertise in using digital media for teaching and learning on a scale from 1 (very poor) to 5 (very good), two teachers gave a rating of 3 (acceptable), two teachers gave a rating of 4 (good), and one teacher rated his or her expertise as 5 (very good). In a sum score of previous AR experience ranging from 0 (zero experience) to

6 (maximum experience, also with AR for teaching and learning), the five teachers reached values between 0 and 3 (average: 1.6; SD: 1.1).

All in all, the sample of teachers is quite experienced in teaching and confident in teaching with digital media but has little experience with AR. As defined in the eligibility criteria for participation in the study, all teachers work in English as their primary teaching language and teach English to students from 4th to 6th grade who underperform in standardized reading and spelling tests.

B. Students

1) Metrics

Students who participated in the AR-based intervention completed an online survey on their motivation. The scale consists of 15 self-assessment items to be rated on a 7-point Likert scale ranging from 1 (not at all true) to 7 (very true). It is based on the Intrinsic Motivation Inventory (IMI) [39] which was used as a second well-established construct for measuring motivation in the ARETE project. The original IMI consists of 45 items from the following seven areas: interest/enjoyment, perceived competence, effort/importance, pressure/tension, perceived choice, value/usefulness, and relatedness. Factors and items may be selected depending on the respective research question. Hence, the following five subscales were defined as centrally relevant for the ARETE project context:

- Interest/Enjoyment;
- Perceived Competence;
- Effort/Importance;
- Pressure/Tension;
- Value/Usefulness.

3 items for each of these subscales were used in a version slightly adapted to the AR context.

2) Sample

The students were aged 9 to 12, in 4th to 6th grade, with English as their first language or main teaching language, having an average I.Q. and underperforming in standardized literacy tests. Significant hearing or visual impairments were exclusion criteria [11]. Participation in the online survey was voluntary. Yet, almost all students involved in the interventions filled in the scales. The convenience sample consists of n=23 students (13 female, 9 male, 1 unknown). 17 students are from Ireland and 6 students are from Italy.

V. Results

A. Teachers

Overall, teachers in the sample tended to confirm that the AR-based intervention had a positive impact on their students' motivation. In Fig. 2, the scores per motivational item are presented teacher-wise (T1-T5). Items marked with an (i) are inverted and were recoded in favor of a coherent presentation of data.

Notably, only one teacher gave a rating of 5 (strongly agree) to three items. Most teachers assessed most items between 3 and 4 which is also reflected in the mean scores for all items that range between 3 and 4. An exception to this outcome is the item

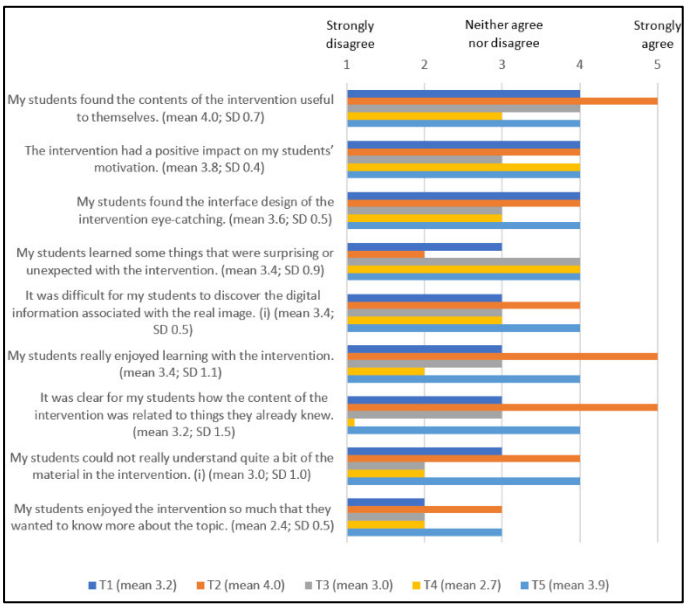

Fig. 2. Scores per motivational item (teacher survey).

"my students enjoyed the intervention so much that they wanted to know more about the topic". This item was rated with an average score of below 3; hence, teachers on average rather disagreed than agreed with the statement. Across all items, teachers had an average individual rating between 2.67 and 4.00 with 4 out of 5 teachers showing an average value of 3 or higher.

Asked for problems and drawbacks when working with the app in the online survey, teachers repeatedly mentioned technical issues with the app that impeded the progress: 5 out of 5 teachers ticked "technical issues with the app, not AR-related (e.g., long processing times, crashes)", 4 out of 5 teachers ticked "technical issues with the app, AR-related (e.g., poor marker detection)" and 4 out of 5 teachers ticked "I did not have enough time to work with the app properly".

B. Students

On the scale from 1 (not at all true) to 7 (very true), students rated all 15 items above the medium value of 4, thus showing overall agreement with all items. Within this range, table 1 presents the three items with the highest and the three items with the lowest agreement. Items marked with an (i) are inverted and were recoded in favor of a coherent presentation of data.

TABLE 1. AVERAGE SCORES OF SELECTED MOTIVATIONAL ITEMS (STUDENT SURVEY)

Item	Mean	SD
I put a lot of effort into these learning activities.	6.13	1.10
I didn't try very hard to do well at these learning activities. (i)	5.83	1.83
I am satisfied with my performance at these learning activities.	5.61	1.41
I felt very tense while doing these learning activities. (i)	4.61	2.25
These learning activities were activities that I couldn't do very well. (i)	4.61	1.70
I thought these learning activities were boring activities. (i)	4.30	1.72

On average, students indicated an average agreement of 5.18 (SD 0.87) with the statements on motivation. All students but one showed an average agreement above the medium value of 4. Thus, all students but one rather agreed with the motivational effects of the AR-enhanced intervention as defined by the motivational scale items.

VI. Discussion, Conclusion & Outlook

Within the research results described in this paper, almost all teachers and students confirm a certain motivational effect from the intervention of the AR app. These outcomes have to be contextualized in the light of certain limitations. Centrally, unforeseen challenges related to the global pandemic heavily impacted the pilot intervention phase. The number of teachers interested in participating in the innovative pilot study was lower than expected due to the teachers' high workload and extra commitment required to organize their teaching in pandemic times. Also, teachers who started the intervention were impeded by sick leaves and changing requirements for their lessons and were not able to complete the app and to work through the whole program as intended. These circumstances together with the comparably narrow and specialized target group of this pilot (only students with reading and spelling difficulties, only classes with English as the main language and with appropriate technological equipment) led to a small convenience sample. Hence, the results are not representative or transferable, but they still offer valuable insights on an individual level.

Another limitation relates to the nature of the scales used, which require self-assessments of teachers and students. A potential impact of subjective factors such as social desirability or different response types cannot be ruled out and further delimits the comparability of data.

Against this background, the teachers' results show a rather stable proximity to the medium value of 3 (neither agree nor disagree), and only one teacher fully agreed with certain statements on motivational effects. Moreover, no participant agreed with the statement "The students enjoyed the app so much that they wanted to know more about the topic". From these results, the conclusion can be drawn that a motivational effect was perceived but teachers apparently considered this effect as limited; the effect was rather not high enough to stimulate students' further interest in the topic beyond the obligatory work.

The challenges mentioned by the teachers in the survey and also the piloting circumstances suggest explanations for this outcome. First of all, certain functions and technological features of the app piloted did not work flawlessly on all devices used from the beginning and thus impeded a fluent app use. Bugs reported were addressed directly and several updates were provided in short timeframes. However, the feedback and communication structures in the project necessary to allow for an exchange between app developers and teachers while protecting participants' privacy and data at the same time resulted in delays. Moreover, according to the teachers' feedback the preparation and instruction of teachers was not fully successful in some cases, which also had an impact on the delivery of the intervention. In addition, some teachers noted they did not have enough time for the pilot, and no class finished the whole program as intended; this can be linked to the technical challenges mentioned and to the particularly challenging situation of the pandemic. Consequently, no student reached the final two levels of the app, where most of the innovative AR objects are integrated.

Still, in the student survey on motivation all items were rated with agreement and some items received quite high average values. It is noteworthy that three out of the four items with the highest rating belong to the subscale of effort/importance. This shows that the students attributed a high importance to learning with the app and consequently invested a lot of effort. On the other side of the scale, 3 out of the 5 items with the lowest rating belong to the subscale of interest/enjoyment, which suggests that the students felt a comparably limited enjoyment when working with the app. However, as even the items with the lowest agreement still show average values above 4, there is no area of motivation as defined by the IMI that has not been addressed according to the students.

Overall, the results suggest that even though there were technical as well as organizational challenges for the classes to take full benefit from the AR-enhanced app in their lessons, both teachers and students by the majority still perceived the apps to have a certain motivational effect. On these grounds, it will be worthwhile to further explore the potential AR-enhanced apps can have for literacy teaching and learning for students with reading and spelling difficulties and to replicate the study under optimized conditions and with a larger sample. As a secondary insight, it is worth investigating further on methods to enhance teachers' XR digital skills and media-related educational competencies. AR-enhanced gamified learning apps can have a motivating effect on student learning in the context researched in this project; however, it is necessary to ensure appropriate frame conditions ranging from the provision of suitable devices to a thorough training and support to ascertain that classes with various backgrounds and with heterogeneous students can fully benefit from the advantages and opportunities teaching and learning with AR can offer.

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