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Laura Garcia, Universidad Politécnica de Cartagena, Spain

SOCIETY TRENDS 2023

Forward

The International Conference on Technical Advances and Human Consequences (SOCIETY TRENDS 2023) inaugural series is a dedicated series of annual events to focus on the society existential technical paradigm: “Where are We Going?”. The conference was held in Valencia, Spain, November 13 - 17, 2023.

Technical and handily solutions brought tremendous opportunities for humans. The pace the society hastily created calls for preparedness and continuous adaptation for avoiding adverse effects.

Awareness, informal denials, and weak counteractions are becoming useless at the status of the pace of innovative tendency, considering the technology complexity and weak humankind capabilities for adapting to new services/technologies.

Apart useless intended features and unintended bugs, on purpose intruders (bugs, virus, worms, etc.) are freely running on hardware & software. Unintended or ill-intended back doors are common features of all systems and applications, putting cyber-security, critical services, and ultimately all citizens at risk.

Apart security breaches and privacy invasion, addiction via the metaverse applications / environments are the main new unknown in terms of consequences.

In the recent decades, society detrimentally sacrificed the safety privacy driven control, as well as emotional and physical capacities in favor of prompt action and untested decisions, not necessarily the best. Therefore, a careful education and awareness are suitable.

We take this opportunity to thank all the members of the SOCIETY TRENDS 2023 Technical Program Committee as well as the numerous reviewers. The creation of such a broad and high-quality conference program would not have been possible without their involvement. We also kindly thank all the authors who dedicated much of their time and efforts to contribute to the SOCIETY TRENDS 2023. We truly believe that, thanks to all these efforts, the final conference program consists of top quality contributions.

This event could also not have been a reality without the support of many individuals, organizations, and sponsors. We are grateful to the members of the SOCIETY TRENDS 2023 organizing committee for their help in handling the logistics and for their work to make this professional meeting a success.

We hope the SOCIETY TRENDS 2023 was a successful international forum for the exchange of ideas and results between academia and industry and to promote further progress with respect to technical trends in society. We also hope that Valencia provided a pleasant environment during the conference and everyone saved some time for exploring this beautiful city.

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Chord Extraction Method in Development of a Score Click Playback System

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***Abstract*—The purpose of this study is to recognize the locations of the chords from sound data of recorded piano performances. Previous methods have been unable to recognize all the musical scales contained within a chord and to identify the location of the chord. To identify the chord points, we adopted two ideas. The first idea is that, in instances where multiple notes of the same musical scale are present, if even one note reaches the predetermined threshold, it is considered as representing the respective scale. The second idea involves moderating the determination of whether the threshold has been exceeded. To validate the efficacy of the proposed method, piano performances of scores containing chords were recorded, and the method's ability to identify chord locations from the recorded data was assessed. The results demonstrated a notable improvement in identifying chord points with the proposed method, achieving an approximately 88% identification rate of musical notes, which is significantly superior to the approximately 14% achieved by the preceding method.**

Keywords—Chord, Score Analysis, Video Analysis, Piano Lesson.

I. Introduction

Piano practice is crucially centered around repetitive practice. Students, for instance, record their performances and, through subsequent review, identify areas needing improvement. They then engage in continual practice, making necessary corrections based on these identified areas. Previous studies have proposed various methods to support piano lessons [1]–[8].

In this study, we have been developing a system that enables users to view a recorded piano performance from a specified bar by selecting a bar within a piano score displayed on-screen.

In the system we are developing, it is necessary to synchronize the visual onset of notes in the score with those in the performance video. To synchronize the visual onset, identification of the correspondence between notes in the score and the auditory output in the recorded performance is required. Wakiyama et al. have proposed a method for identifying which measure in a musical score corresponds to a played piano sound [9]. Piano performances encompass a variety of techniques, including chords, which involve striking two or more notes simultaneously using not only the fingers but also the pedals. This method is capable of identifying the musical scale of a note when only a single note is sounded momentarily. However, it was unable to identify the musical scale for sounds produced by striking two or more notes simultaneously, such as chords. The objective of this study is to recognize the scales of chords from recorded piano sounds.

In this paper, section II describes the previous method and its associated challenges. The proposed method will be explained in section III, and the validation of its efficacy and its consideration will be described in section IV. Finally, section V gives a summary of this study.

II. Previous Method

In this section, the preceding method for identifying musical scales is introduced, and the reasons for its inability to recognize chords are elucidated.

A. The Previous Method for Identifying Musical Scales of Piano Performances

The procedure utilized by the previous method to determine which notes in the musical score correspond to the sounds of the piano in the recorded performance is introduced herein. This method consists of five steps.

1) Recognize musical notes from images of the scores using OpenCV [10].
2) Retain the recognized notes as sequence data in chronological order.
3) Time-frequency analysis using Constant-Q Transform (CQT) [11] for sound data of recorded piano performance.
4) Extract notes one by one from the sequence data in step 2, and use the frequency corresponding to the musical scale as a search key to search the results of step 3 in chronological order.

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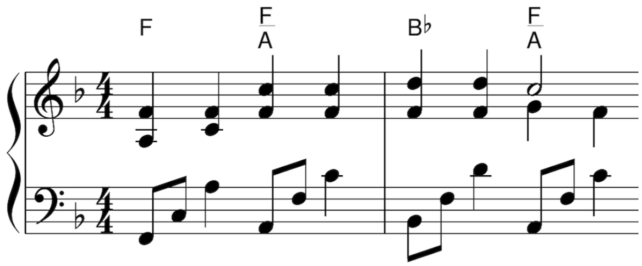
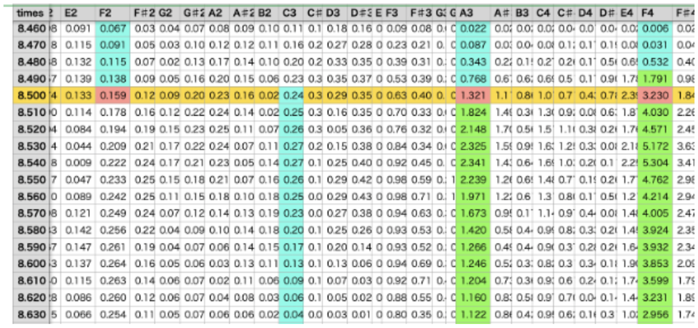


Figure 1. A score sample.

TABLE I
THE ORDER DATA CONVERTED.

No.	Musical scale		
1	F4	A3	F2
2		C3	
3	F4	C4	A3
4	F4	A2	C5
5		F3	
6	F4	C4	C5
⋮		⋮	



times	2	E2	F2	F#2	G2	G#2	A2	A#2	B2	C3	C#	D3	D#3	E	F3	F#3	G3	G	A3	A#	B3	C4	C#	D4	D#	E4	F4	F#4
8.460	8	0.091	0.067	0.03	0.04	0.07	0.08	0.09	0.10	0.11	0.1	0.18	0.16	0	0.09	0.08	0.	0	0.022	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.006	0.0
8.470	8	0.115	0.091	0.05	0.03	0.10	0.12	0.12	0.11	0.16	0.2	0.27	0.28	0	0.23	0.21	0.	0	0.087	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.031	0.0
8.480	8	0.132	0.115	0.07	0.02	0.13	0.17	0.14	0.10	0.20	0.2	0.33	0.35	0	0.39	0.31	0.	0	0.343	0.2	0.1	0.2	0.2	0.1	0.5	0.6	0.532	0.4
8.490	7	0.139	0.138	0.09	0.05	0.16	0.20	0.15	0.06	0.23	0.3	0.35	0.37	0	0.53	0.39	0.	0	0.768	0.6	0.6	0.6	0.5	0.1	0.9	1.7	1.791	0.9
8.500	4	0.133	0.159	0.12	0.09	0.20	0.23	0.16	0.02	0.24	0.3	0.29	0.35	0	0.63	0.40	0.	0	1.321	1.1	0.8	1.0	0.7	0.4	0.7	2.3	3.230	1.8
8.510	0	0.114	0.178	0.16	0.12	0.22	0.24	0.14	0.02	0.25	0.3	0.16	0.35	0	0.70	0.33	0.	0	1.824	1.4	0.3	1.3	0.9	0.0	0.6	1.8	4.030	2.2
8.520	4	0.084	0.194	0.19	0.15	0.23	0.25	0.11	0.07	0.26	0.3	0.05	0.36	0	0.76	0.32	0.	0	2.148	1.7	0.5	1.5	1.1	0.3	0.2	1.7	4.571	2.4
8.530	4	0.044	0.209	0.21	0.17	0.22	0.24	0.07	0.11	0.27	0.2	0.15	0.38	0	0.84	0.34	0.	0	2.325	1.5	0.9	1.6	1.2	0.3	0.0	2.1	5.172	3.6
8.540	8	0.009	0.222	0.24	0.17	0.21	0.23	0.05	0.14	0.27	0.1	0.25	0.40	0	0.92	0.45	0.	0	2.341	1.4	0.6	1.6	1.0	0.2	0.1	2.2	5.304	3.41
8.550	7	0.047	0.233	0.25	0.15	0.18	0.21	0.07	0.16	0.26	0.1	0.29	0.42	0	0.98	0.59	0.	1	2.239	1.2	0.6	1.4	0.7	0.1	0.2	1.7	4.762	2.9
8.560	0	0.089	0.242	0.25	0.11	0.15	0.18	0.10	0.18	0.25	0.0	0.29	0.43	0	0.98	0.71	0.	1	1.971	1.2	0.6	1.3	0.8	0.1	0.5	1.2	4.214	2.9
8.570	8	0.121	0.249	0.24	0.07	0.12	0.14	0.13	0.19	0.23	0.0	0.27	0.38	0	0.94	0.63	0.	0	1.673	0.9	0.1	1.1	0.9	0.4	0.0	1.4	4.005	2.4
8.580	3	0.142	0.256	0.22	0.04	0.09	0.10	0.14	0.18	0.20	0.1	0.25	0.26	0	0.93	0.53	0.	0	1.420	0.5	0.4	0.9	0.8	0.3	0.2	1.4	3.924	2.3
8.590	7	0.147	0.261	0.19	0.04	0.07	0.06	0.14	0.15	0.17	0.1	0.20	0.14	0	0.93	0.52	0.	0	1.266	0.4	0.4	0.9	0.3	0.2	0.2	1.6	3.932	2.3
8.600	3	0.137	0.264	0.16	0.05	0.06	0.03	0.13	0.11	0.13	0.1	0.13	0.06	0	0.94	0.69	0.	0	1.246	0.5	0.3	0.8	0.3	0.3	0.1	1.9	3.853	2.0
8.610	0	0.115	0.263	0.14	0.06	0.07	0.02	0.11	0.06	0.09	0.1	0.07	0.03	0	0.92	0.71	0.	0	1.204	0.7	0.3	0.9	0.6	0.2	0.1	1.7	3.599	1.7
8.620	8	0.086	0.260	0.12	0.06	0.07	0.04	0.08	0.03	0.06	0.1	0.05	0.02	0	0.88	0.55	0.	0	1.160	0.8	0.5	0.9	0.7	0.0	0.1	1.4	3.231	1.8
8.630	5	0.066	0.254	0.11	0.05	0.07	0.06	0.06	0.02	0.04	0.0	0.03	0.01	0	0.80	0.35	0.	0	1.122	0.8	0.4	0.9	0.6	0.1	0.3	1.0	2.956	1.7

Figure 2. An example of CQT result.

TABLE II
A EXAMPLE TIMESTAMP LIST.

No.	Musical scale			Time
1-1	F4	A3	F2	8.500
1-2		C3		8.830
1-3	F4	C4	A3	9.200
1-4	F4	A2	C5	9.960
1-5		F3		10.310
1-6	F4	C4	C5	10.690
2-1	A#2	D5	F4	11.490
⋮		⋮		⋮

5) If the value is searched in chronological order and exceeds the threshold value, it is assumed that the searched note is found, and the appearance timing of the note in the performance data is recorded in a timestamp list. Steps 4 and 5 are repeated until the last note in the score is reached.

In step 1, the PDF or scanned music score is converted to image data, and the notes and lines of the score are recognized using recognition technology, specifically through template matching. The musical scale of the recognized note is identified by the position of the lines and the notes.

In step 2, the recognized musical scales are converted into sequence data in order from the left. Figure 1 presents a piano score sample, while Table I shows the sequence data converted by recognizing the musical scale from the score in Figure 1.

In step 3, a CQT is performed on the sound of the recorded piano performance. CQT is frequently utilized in the analysis of musical signals. By using CQT, the strength of frequency at each point of sound data can be obtained as a value. Figure 2 illustrates the result of applying the CQT of the music data of a certain performance.

Each musical scale is determined by frequency, and the horizontal axis of this table represents the music scale. The vertical axis indicates time and progresses downward.

In step 4, based on the converted ordinal data, each item is extracted in order and used as a search key. In the case of the table in Table I, the search is performed in order starting with No. 1. When No. 1 is selected, three scales, F4, A3, and F2, are subjected to the search. The search examines the frequency portion corresponding to the musical scale in chronological order for the values of the angular frequency band obtained by CQT.

In step 5, if the search identifies a point that exceeds the set threshold, it is assumed that that musical scale was sounded at that time. Then, the appearance timing of the note is recorded in a timestamp list. Table II is an example of a timestamp list. The number to the left of the No. is the bar number in the musical score, and the number to the right indicates the sequence in which the notes appear within that bar. The times in the table represent the times when it is assumed that the musical scale was pressed because the threshold was exceeded.

If the search process does not find the point that exceeds the set threshold within a certain amount of time, the musical scale of the next item is searched.

B. Some Problems of The Previous Method

Previous methods were unable to discern the timing of lower octave key presses when scales of identical types were played simultaneously. A chord is the sounding of multiple scales by striking two or more notes. In Figure 1, the initial note comprises three distinct notes: F4, A3, and F2. In this case, the key press timing for F2 could not be ascertained using the previous methods.

III. PROPOSED METHOD

In order to detect chords from the sound of recorded piano performance, two ideas are introduced.

The first idea is that if multiple notes within a chord share the same musical scale, and at least one of them surpasses a predefined threshold, all notes of that particular musical scale are deemed to have been pressed. For example, consider a scenario where F4 and F3, which share the same musical scale,

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TABLE III
RECOGNITION RATE OF THE PROPOSED METHOD AND PREVIOUS METHODS.

	Proposed method				Previous method
Threshold	1.0	1.5	2.0	2.5	1.0
Chord only	29.55	63.64	88.64	0.00	11.36
ALL note	27.94	60.29	88.24	0.00	14.71

occur simultaneously in a score. If F4 exceeds the threshold, F3 is also considered to have been pressed, regardless of its actual value.

A second idea is to relax the determination of the threshold. Initially, a search is conducted for three scales. If this search is unfruitful, the number of scales is reduced to two, and subsequently to one if the search still yields no results. If the scale is not found in this way, the quantity of musical scales subjected to the search is reduced by one by one.

IV. Confirmation Of Extraction

In this section, the efficacy of the proposed method is substantiated through a structured experimental approach, aimed at ascertaining the capability of detecting chord points within the musical data of chord scores played on the piano.

A. Experimental Setup

To validate the efficacy, a comparative analysis between the note identification rates of the proposed method and the preceding method is conducted. The musical score used in this experiment contains not only singular notes but also chords [12], with performers utilizing pedals to actuate the keys during play The recognition of a note is determined by comparing the manually pre-verified start time of each measure with the adjudication time of each measure, as recognized by the system Both the proposed method and the previous method require a threshold setting as a parameter. The threshold of the previous method is designated at 1.0, whereas the proposed method is subjected to four threshold patterns: 1.0, 1.5, 2.0, and 2.5. The search timeout time was set to 2.6, correlating to the time span of one bar from the song.

B. Result

Table III shows the results of recognition rates for piano performances of musical scores containing chords. The proposed method achieved the highest note recognition rate at a threshold of 2.0. In addition, the recognition rate of the previous method was lower than that of the proposed method even when utilizing the same threshold.

In piano performances that incorporate chords, it was determined to be effective to assume a chord is identified when one or more of the notes sought are found. It was also observed that contingent upon the threshold, the position of the musical note might not be accurately recognized.

V. Conclusion

This study aimed to recognize chord points from the sound data of recorded piano performances. Previous methods were unable to recognize all scales within a chord, nor could they identify the point of the chord. To identify the chord points, we adopted two ideas. The first idea is that, when multiple notes of the same musical scale are present, if at least one reaches the threshold, it is considered as the same note. The second idea involves moderating the determination of whether the threshold has been exceeded. To validate the effectiveness, a piano performance of a musical score containing chords was recorded, and it was confirmed whether the proposed method could identify chord locations from the recorded data. As a result, the proposed method was able to identify chord points more effectively than the previous method. Future work will involve experimenting with other songs.

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***Abstract*—Augmented Reality (AR), together with other technologies collectively referred to as eXtended Reality (XR), can offer opportunities in education for experiential learning and the visualization of abstract concepts. However, there is a lack of universal design and significant challenges for students with disabilities. This paper presents a case study of AR technology used in Norwegian schools to identify inhibitors and facilitators for the inclusive use of AR in education. We let students with and without visual and cognitive disabilities try out an AR app for books. The AR app would superimpose virtual 3D models and videos on the books similar to a pop-up book. Interviews with educators and a focus group session with developers identified opportunities, benefits, user expectations, best practices, challenges, common pitfalls, and recommendations and concrete measures to address said challenges and pitfalls. Our study emphasizes the lack of support for assistive technologies, the over-emphasis on visual stimuli that can be hindering for students with visual disabilities, the significant demand of AR on cognitive capabilities, which might be challenging for students with cognitive disabilities, and the lack of awareness of and access to guidelines and best practices among developers. We suggest enabling compatibility with assistive technologies, increased multi-modality that engages hearing and touch, and increased usage of visual explanations and elements like symbols and icons. In addition, we suggest collecting, organizing, and promoting existing and new guidelines for the universal design of both XR and AR. We argue that many of our findings for AR are relevant to other technologies gathered under the umbrella of XR, including Mixed Reality (MR) and Virtual Reality (VR).**

Keywords - Universal design; accessibility; usability; inclusion; eXtended Reality; Augmented Reality; Virtual Reality; Mixed Reality; XR; AR; MR; VR; education; learning; disability; barriers; solutions.

I. Introduction

eXtended Reality (XR) is an umbrella term to describe Virtual Reality (VR), Mixed Reality (MR), and Augmented Reality (AR) [1]. XR has been used in entertainment [2], industry [3], and education [4][5]. XR has benefits for education including new interaction methods, a high degree of sensory immersion, and high information density [4]. We previously examined the state of universal design of XR usage in Norwegian primary schools [5][6][7][8].

We conducted a literature review about the different uses of XR, their opportunities and challenges, and we identified solutions to overcome these challenges and enhance the integration of XR in primary education [5][6]. This review shows that there are systemic and technical challenges that require improved pedagogical research and integration, skill-set and acceptance improvement among educators and decision-makers, infrastructure development for XR in schools, and development of funding and procurement schemes for the technology [8]. Further, there is a need for increased co-creation of XR technology, the identification of barriers for students with disabilities, the development of solutions for said barriers, the advancement of standardization of guidelines and best practices, and the development of methods to assess the degree of accessibility and usability of an XR device or application [7].

Moreover, we recruited informants among educators, decision-makers, representatives from civil society organizations, and developers of XR technology [7][8]. The participants emphasized the benefit of XR as an experience-based technology that can facilitate the visualization of abstract concepts in an engaging and motivating way [7]. The informants also highlighted the need for making pedagogical benefits and limitations of XR better visible, including advice on utilizing opportunities XR technology offers, while mitigating challenges [8]. Especially the need for case study research and applicable solutions in schools has been emphasized. Likewise, there is a significant lack of research focusing on users and students with disabilities [7][9][10]. Last but not least, existing guidelines and best practices for digital user interfaces in general [11][12][13], and XR in particular [14][15][16][17], lack general recognition, acceptance, and compliance among developers [7]. The Web Content Accessibility Guidelines (WCAG) for accessibility and usability of digital interfaces, for instance, serve as standards in many national and international ICT regulations [11][12][13][18][19][20] but lack an adequate translation for XR technology.

In this work, we attempt to decrease the knowledge gap by presenting results from a case study that investigates the accessibility and usability of a concrete AR application used in Norwegian primary schools. We conducted user testing, interviews, and a focus group to identify AR application opportunities and barriers and solutions to these barriers. The research involved students with and without disabilities, their educators, and AR developers.

In this paper, we first present the protocol for user testing and interviews, and its implementation in Section II. Then, we present the results of the user evaluations and interviews conducted in the fall of 2022 in Section III and discuss our observations in Section IV. Finally, we conclude with suggestions for future research and improvements to the universal design of XR technology in Section V.

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II. Methodology & implementation

Our accessibility and usability assessment was inspired by inclusive-design approaches and strategies for the evaluation of design artifacts by focusing on user-centered evaluation, iterative processes, addressing the whole user experience, the integration of multidisciplinary skills and perspectives, and an iterative technical and formative evaluation [21][22]. We used user evaluations by students based on a thinking-aloud approach as a primary research method. Here, we identified the key features of the AR application and specified tasks that participants were asked to complete. A secondary method was focus group and semi-structured interviews engaging educators and developers [23][24]. The protocols for the interviews consisted of guiding questions and conversation starters focusing on accessibility, usability, and universal design of AR in education.

In the current study, we evaluated an AR application for mobile devices called Ludenso Explore, developed by Ludenso AS (cf. Figure 1). The app is an extension to the science book Solaris 9 used in Norwegian primary schools [25]. Ludenso Explore is similar to a traditional pop-up book in that students, after downloading the app, can gain access to several types of interactive content by scanning the pages of their book. Depending on the content, the app then shows a virtual interactive 3D model, a video that is superimposed on the paper page, or links to external digital learning resources on the publisher's web pages (cf. Figure 1).

The user evaluations involved four primary schools in Norway during the fall/winter of 2022: Jordal ungdomsskole, Midtstuen ungdomsskole, Holmen barneskole, and Greåker videregående skole. These schools represented a diverse range of students with and without disabilities. In this study, we focused specifically on cognitive and visual impairments. A total of 34 students between 9 and 16 years of both genders participated. 15 children had cognitive impairments. The cognitive impairments can be categorized as ASD and developmental disabilities. Several of the students had personal assistants and teachers who also were interviewed. Three students had visual impairments. One student had a significant amount of remaining vision, another had limited remaining vision, and one student was completely blind. We also interviewed a teacher with severe visual impairment. During the user evaluations, the students completed the tasks defined in the protocol, using the AR app on their phones or on the devices we provided. We asked them to comment aloud what they were doing and thinking as they completed the tasks, at the same time as we encouraged conversation with follow-up questions. The observations from these user evaluations were supplemented by conversations with 11 educators and three AR developers, which were conducted during one-on-one interviews and focus groups.

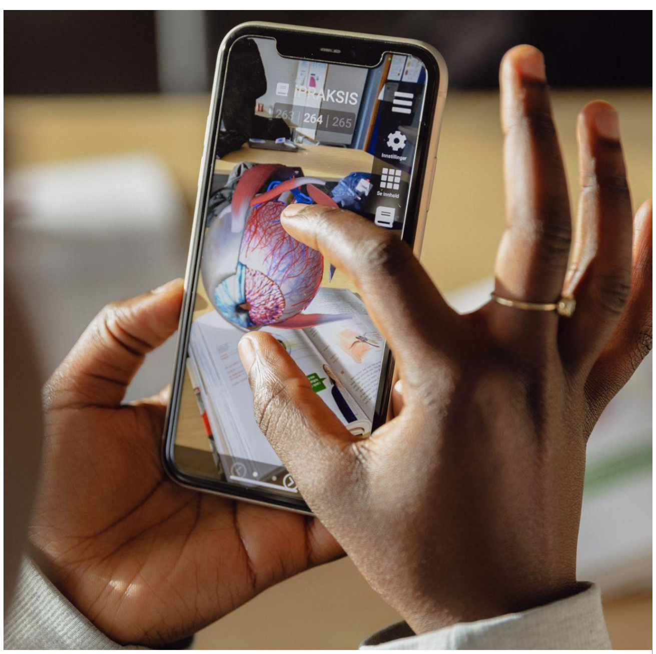

Figure 1. A student interacts with a virtual 3D model in the Ludenso Explore app on a smartphone. © Johanne Nyborg

At least two researchers were present for each user evaluation. One researcher led the evaluation by presenting tasks, supporting students, and asking questions. The other researcher focused on observation and notetaking. We did not take any recordings during the evaluations to preserve the students' privacy. After the evaluations, each researcher transcribed observations from the experiments conducted a thematic analysis of their notes, and summarized identifying themes to extract the most relevant and important points. Both researchers discussed their respective data sets. Finally, they summarized and compacted the findings across all evaluations combined.

III. Results

Here, we present benefits and pedagogical opportunities, user expectations and best practices, systemic and practical challenges, and common technical and functional pitfalls. Further, we provide organizational recommendations and concrete measures to improve universal design of AR. We grouped observations into sections. Each category is summarized in bold font, followed by detailed explanations and examples.

A. Pedagogical Opportunities and General Benefits

AR can engage students with the curriculum in novel and more practical ways. AR can effectively illustrate abstract ideas and "obscured" objects, like atoms or planets, replacing the need for physical models. AR can enhance practical knowledge compared to text or 2D sketches.

AR typically captures students' interest and attention better than traditional learning materials, leading to increased interest, motivation, and engagement. This increased engagement and motivation might be related to the use of innovative technology and the fact that many students are highly responsive and significantly drawn to tablets and mobile apps. Likewise, AR can provide various gamification elements that stimulate engagement. At the same time, research questions the long-term effect of XR technology in light of the so-called novelty effect [4][10].

Consequently, AR might add variation to the learning process that can lead to positive learning effects, such as enhancing cognitive skills like comprehension and cooperation. For instance, AR allows for interactive exploration, enabling students to move around and zoom in on models, which can result in a better learning experience and increased understanding. AR may invite students to cooperate around the virtual content and to learn from each other when navigating the app.

AR, on par with other digital learning aids, can provide benefits for the organization and distribution of curriculum materials. Organizing the curriculum digitally has the advantage of consolidating various resources in one easily accessible place for all students. Educators can more flexibly choose and use learning resources in the classroom.

AR has the potential to increase inclusion if the accessibility of AR technology is properly addressed. Compared to the challenges of adapting analog learning aids in the past, AR can offer more flexible and easier adoption, as long as universal design is addressed from early in the design and development process. In general, digital learning aids including AR could more easily be adapted for screen readers than traditional paper books. Likewise, AR could provide interfaces for assistive technology like hearing aids and alternative input/output devices. However, this requires developers to be aware of users with disabilities and address their needs satisfactorily.

AR serves as a suitable learning alternative for those who prefer visual and less text-based approaches, such as students with dyslexia, ADHD, or learning difficulties.

B. User Expectations and Best Practices

Users anticipate seamless and efficient user experience while utilizing an app, including installation, general usage, and scanning and tracking of virtual content. The students in the study appreciated the simple and convenient installation process of an AR app that can be downloaded from app stores like Apple's App Store or Google Play. They also appreciated robust and reliable tracking of AR content, particularly 3D models.

Users respond positively to user-friendly interfaces with intuitive and familiar functions and elements. The students appreciated quick and easy access to digital content, such as videos and 3D models. The students appreciated an interface that is easy to understand and intuitive, with comprehensive buttons and tabs. Choosing the right default is also essential. Many students, for instance, preferred watching videos in full screen. Likewise, they appreciated features like auto-play combined with the initial muting of the video.

An intuitive navigation within the AR app was positively received. This includes navigation of AR content based on functionality known from other apps like zooming in and out using pinch gestures, along with familiar icons for full screen, muting, and other functional elements.

Users prefer a variety of interactivity options with virtual content. Many students preferred the option to access and freely interact with virtual content like 3D models by choosing it from a digital library instead of using image recognition or AR markers that restrict them to the literal confines of the paper book. Also, many students preferred using the standalone function for 3D models, i.e., the possibility to place 3D models in the physical room without connection to the physical paper book.

C. Systemic and Practical Challenges

AR might encounter technical and practical challenges in schools. There might be limited access to necessary hardware and reliable online access with sufficient capacity in schools. Also, limited physical environments can hinder AR use in practice, like overcrowded classrooms with restricting space to move around in.

Lack of digital skills and experience with AR among educators and students might be a challenge. AR requires technical skills, posing a potentially steep learning curve for users, particularly older teachers who may struggle or are reluctant to adapt. Students with disabilities might lack the necessary skills to use AR devices.

Insufficient universal design of digital learning tools, including AR, is likely to negatively impact accessibility for students with disabilities.

There is a lack of awareness of and expertise in universal design of AR among developers and decision-makers in schools and authorities. The awareness and knowledge about accessibility and usability among developers can be improved. The participating developers were partially familiar with general programming guidelines for accessibility and usability [26] [27] [28]. Even though national and international legal requirements exist [18][19][20][29], these are not widely known to developers.

Some developers were aware of WCAG [11] [12] [13] but reported that their knowledge about them was very superficial and not embedded in any organizational or structural routines. When presented with surveys of barriers [9][15] and accessibility guidelines for gaming and XR [9][14][15][16][17], the participants were not aware of them.

Universal design is by some considered costly and conflicting with aesthetics. The developers were concerned that limited resources and restrictive development budgets in AR companies may lead to situations where universal design is neglected. The developers in the study also reported a lack of demand for universal design of AR applications by decision-makers in schools, education boards, and authorities.

Focus on visual presentation of the virtual content can be a challenge for some students. AR predominantly embraces visual aspects, limiting its suitability for individuals with visual impairments or cognitive challenges. It is our impression that sensory and auditory elements, such as sound effects and tactile feedback, are not adequately addressed in today's digital learning tools, including AR.

AR and other digital learning tools may distract students. Students may be distracted by other apps. Potential noise issues can occur when multiple students use the digital learning tools simultaneously, for instance by playing video simultaneously.

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D. Common Technical and Functional Pitfalls

Some apps may have technical challenges related to their stability, performance, unexpected behavior, or erroneous tracking of virtual content that can disrupt the user experience, together with unreliable devices and the lack of cross-platform compatibility. An AR app might freeze and exhibit unexpected behavior, requiring restarts. Some students reported that their devices went into sleep mode while watching videos. Other students reported that some AR apps might be incompatible with newer versions of iOS or Android, limiting their usability.

Many students reported that they experienced unreliable tracking behavior in many AR apps. Some students struggled to choose the best camera position and angle for proper scanning of the AR markers. Other students experienced challenges due to heterogeneous illumination conditions or physical distortions of the AR markers.

Some apps lack tutorials, explanations for specific features and functions, intuitive presentation of functions, and sufficient feedback functionality. An AR app might lack suitable guides or tutorials, especially for users new to AR. The students in the study inquired about explanations of AR and its possibilities in general, and how to navigate an app's features in specific.

Navigating the interface of an AR app and understanding its elements and functions might prove challenging for some users. Some functions might not be explained sufficiently. Some students might not understand features like muting, and full-screen mode when indicated by icons only. Features like choosing 3D models from a library instead of scanning might be particularly difficult for and feel non-intuitive to students with cognitive impairments.

Apps might lack feedback after functions have been completed, either successfully or failed. An AR app might not provide proper feedback on functionality, like downloading content, leaving users uncertain about successful or failed downloads.

Some apps lack localization for the country in which the app is deployed. An AR app targeted at Norwegian schools that is only available in English can pose difficulties for younger users or users with cognitive disabilities who may not fully understand the language.

AR apps might not conform to universal design requirements and common accessibility guidelines. An AR app might not adhere to commonly used accessibility guidelines [13][16]. The most common missing measures include alternative ALT text for images, support for screen readers, proper semantic markup, adjustable text sizes, audio descriptions for videos, and keyboard navigation.

The content of an AR app might be unsuitable for students with cognitive impairments. Videos may be too complex or delivered at a fast pace, posing difficulties for reading and comprehension.

Motion-based navigation of 3D content can be challenging for students with and without disabilities. Visually impaired students might encounter challenges, as well as any students in small classrooms. Physical devices, such as tablets, may be challenging for young or physically impaired users due to their weight.

E. Organizational Recommendations

There should be an effort to increase awareness of and expertise in universal design of AR among developers, educators, and decision-makers. Educators and decision-makers in municipalities need increased expertise in and awareness of accessibility, usability, and universal design of AR at all levels including development, testing, and procurement. Awareness can be raised by revisiting literature about barriers to XR technology and their solutions [5][8][9][15][16]. Likewise, training for developers and decision-makers should focus on universal design of ICT and digital inclusion in general, considering how universal design requirements can be integrated with modern and effective development and production.

Schools should consciously demand universal design of digital learning materials and content, including AR, as a mandatory requirement by referencing existing legislation and living it in practice, too.

Research on the cost-benefit of universal design in AR should be conducted and shared with stakeholders. Especially, the hypothesis that universally designed AR is more beneficial and cost-efficient than AR without UD should be investigated.

Priority should be given to the development, organization, and distribution of guidelines, best practices, evaluation methods, and action plans. All digital learning materials and content should comply with national and international legal requirements and standards for universal design of ICT [18][19][20][29]. Existing guidelines for universally designed programming, XR, games, and user interfaces should be distributed and promoted among developers [12][13][14][16][17][26][27][28]. Relevant guidelines and best practices for AR and XR should be organized and highlighted for the production of XR applications (cf. Section III.F).

More research on the needs of and challenges for XR users with disabilities and the solutions to said challenges is needed. More resources and literature targeting the universal design of XR in general and AR specifically should be developed for vendors of XR technology and content.

Companies should create and implement concrete plans on how universal design is integrated into their development and production of products and services. Automated accessibility and usability tests, e.g., contrast checks, should be available for developers. Checklists, recommendations, and best practices tailored to XR and AR should be created.

Development should include user testing throughout the entire planning, implementation, and testing stages of the production process, making the app as flexible, robust, and glitch-free as possible. Developers should deploy an agile development process with multiple iterations of planning, execution, review, and retrospective [30]. In this process, bugs and performance issues can be uncovered and then fixed. From the planning stage to pre-release, the app should be assessed by actual students with and without disabilities.

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F. *Technical and Practical Measures to Increase Universal Design of AR*

Robust and stable scanning of the markers or image recognition should be a priority, as well as stable and robust tracking. This includes accommodating various exterior conditions related to lighting, surface texture, and structure, as well as a variety of possible user interactions. The AR app should be compatible with the latest versions of operating systems like iOS and Android.

Efforts should be made to enhance the usability and user experience of an app by facilitating access to documentation and tutorials, including a feedback mechanism, and highlighting essential functions. Comprehensive installation instructions and documentation should be available to users. Tutorials and explanatory texts/illustrations for AR in general and specific app features should be provided. Instructions and information about pedagogical possibilities and the functionality of AR in education should be provided to teachers and decision-makers. A feedback mechanism should be provided throughout the installation process and app usage that allows users to report bugs or send in suggestions.

The most common functions should be easily understandable. Existing features like unmuting videos or standalone 3D models should be highlighted and provided with clear explanations.

Internationalization and localization in the primary country language should be made available. The language used in texts should be kept as simple as possible for better comprehensiveness.

AR content should be available in offline mode, including 3D models, video snippets, and audio files.

Developers should revisit the presentation of text, speech, and non-textual elements by offering textual and non-textual alternatives to support students with visual and cognitive impairments. An AR app should incorporate both text and visual representation for its AR content, elements, and functions including explanatory descriptions and illustrations [15]. On the one hand, AR apps should increase the use of non-textual elements like symbols, icons, images, graphic elements, and images of 3D models to support students with cognitive impairments. On the other hand, all functional visual elements should have explanatory and descriptive text alternatives. If support for screen readers is yet unavailable, a text-to-speech feature can be considered.

Efforts should be made to conform with existing standards, guidelines, and best practices. An AR app should be designed according to the latest WCAG [12][13], in particular the following success criteria :

- Support for keyboard navigation and screen readers (cf. Guidelines 2.1 and 4.1).
- Captions and audio description, or a text alternative for all videos (cf. 1.2.2 and 1.2.3).
- Text alternatives for all visual elements (cf. 1.1).
- Recommendations for distinguishable elements including the use of color, contrast, text size, dynamic adaptation, and text spacing (cf. 1.4).

An AR app should be designed according to W3C's XR user requirements [16], including the following guidelines:

- Adaptation to various assistive aids and output devices (cf. 4.1, 4.8, 4.13, and 4.14).
- Alternative navigation options include using voice commands and providing alternatives to motion controls (cf. 4.2, 4.5, and 4.9).
- The option to personalize content for students with cognitive challenges (cf. 4.3).
- Establishing safe spaces and time limits to prevent overwhelm and exhaustion (cf. 4.11 and 4.12).
- Allowing interaction speeds for, among others, text, video, and audio (cf. 4.15).
- Captions for audio-visual media (cf. 4.19).

Developers should follow best practices aiming at programming in general [26][27][28], and XR technology and games in specific [14][17].

AR and XR equipment and apps should accommodate special needs, both physically and programmatically. Support for assistive technology and alternative input and output devices should be implemented. AR and XR equipment should be lightweight and work on a variety of screens and devices [15]. Compatibility with common assistive technology should be enabled, including screen readers or text-to-speech tools for users with low vision, hearing aids for those with a hearing impairment, voice or gaze command, and wheelchairs with motor or mobility impairments [9][15]. Note that the most common aids are regular glasses that should be compatible with all AR and XR devices [31]. Alternative input devices are keyboards, computer mice, customized controllers, or buttons, whereas alternative output devices include additional external screens, customized headphones, or refreshable braille displays [9][15].

Compatibility with these aids should work both programmatically and physically. Programmatically, by providing an interface or API for these technologies, e.g., screen readers, input or output devices. Physically, by not interfering with or hindering the usage of assistive technology, e.g., hearing aids, wheelchairs, or glasses. Moreover, all digital information needs to be available and accessible with and without assistive technology, e.g., through text alternatives for screen readers.

Compatibility with screen readers like VoiceOver / TalkBack for students with visual impairments should be prioritized. Likewise, navigation within the interface and the virtual world through alternative input devices should also be prioritized.

Developers should enhance the multi-modality of the virtual content. AR content should be presented through various modalities, i.e., engage multiple senses simultaneously, such as hearing and touch [15]. AR content should be expanded through modalities, such as sound, vibration, 3D-printed artifacts, and tactile display units. Different modalities should also be considered for user interaction, including auditory elements like sound effects, vibrations, and tactile feedback. We advise employing user preferences for modalities, combined with profiles for personalized experiences.

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Presentation of the virtual content without tracking should be available. There should be the possibility for a purely virtual representation of 3D models within the app through a so-called "stand-alone" mode. This would allow exploration without scanning book pages, tracking markers, or placing models in the classroom.

Navigation within the virtual content should be possible without motion control through on-screen buttons. Navigation through various control methods, such as buttons, keyboard, motion control, gestures, and voice commands should be available. Navigation without motion control should be available through plus and minus buttons for zooming, buttons to rotate 3D models, or buttons to view the inside of models by zooming inside. Rotation should be possible along all axes, i.e., the x-, y-, and z-axes.

The AR app should have a certain level of tolerance for input errors when it comes to navigating the 3D models. There should be designated areas on the screen where fingers and palms can be placed without triggering unintended gestures.

AR apps should consider including more interactive features and educational content that is available both online and offline. AR apps should incorporate more interactive elements, such as opening/closing parts of models and displaying dynamic processes or animations. Gamification elements, such as progress indicators, levels, challenges, rewards, and competitions could be included. A collection of educational tasks that can be used outside the curriculum and without internet access could be provided.

Measures to address distractions should be implemented. AR and digital learning materials should limit potential digital distractions. Features like locking the app or disabling the exit button for students can be considered. Notifications from other apps, particularly social media, should be disabled during app usage.

Age and skill set, e.g., reading and abstract thinking, recommendations for using the learning tool should be provided in the description of an app and its content.

IV. DISCUSSION

The current study validates previous observations and introduces new findings regarding AR and other XR technologies in education. Although we have focused on AR, many of the findings can be applied to Mixed Reality (MR), Virtual Reality (VR), and other digital learning aids as well. AR shares many similarities with other digital learning aids that rely on tablets or mobile phones, as they utilize the same underlying technology. Thus, many of our findings are relevant to other tablet, mobile, or computer apps as well. Moreover, the differences between AR, MR, and VR technologies are blurred. For these technologies are often placed inside a "virtuality continuum", also referred to as eXtended Reality, with a completely real environment on one end and a completely virtual environment at the other end [1][32]. Thus, most findings for AR are transferable to other XR technologies. The barriers associated with the necessary hardware, for instance, become more apparent in VR and MR than in AR, as both VR and MR require more extensive and immersive equipment. Thus, barriers related to virtual worlds and the demands placed on the user's abstraction and spatial sense become more apparent, as the level of immersion increases for MR and VR compared to AR. Likewise, the dominating focus on visual aspects is relevant for all XR technologies. In future research, we recommend investigating multiple types of XR technologies, while indicating which findings are most or least relevant to each respective type.

Positive outcomes mentioned in the literature could be confirmed, such as increased motivation, collaboration, interest, and experiential learning [5][8]. Further, our study confirms practical challenges mentioned in the literature related to space and illumination limitations of the physical environments, availability of XR devices, and Internet availability in schools, along with the need for improved digital and XR skills among teachers, decision-makers and students [5][8]. In previous research, educators reported the lack of educational AR content suitable to national curriculums and daily routines in schools [5][8]. We addressed this challenge in the current study by evaluating an AR solution tailored to the Norwegian science curriculum. Nevertheless, participants in this study pointed out that there is still a need for more content in other subjects.

The insufficient representation of students with disabilities during the development and testing of XR technology [5] is addressed in this study by including students with disabilities. Generally, this inclusion might lead to improved user experience for all students: Simplifying the user interface, integrating icons and graphical elements, and adding sound and vibration effects might benefit students with and without disabilities alike. This synergy is commonly referred to as the "curb-cut" effect [33][34]. Thus, future research could investigate how integrating students with disabilities in evaluations including other minority groups, such as those with hearing, motor, and mobility disabilities, as well as people with chronic conditions, could provide numerous benefits.

The study further confirms the lack of accessibility and usability of current XR technology [5][7]. Barriers include the absence of support for assistive technology like screen readers, alternative input/output devices, glasses, hearing aids, or wheelchairs, and the complexity of virtual content for users with cognitive disabilities [5][7][9]. Without adjustments, AR and XR are little suited for people with cognitive disabilities and largely unusable for students with visual disabilities. We particularly suggest making sure that the app is compatible with and does not hinder the use of assistive technologies. Furthermore, we suggest exploring alternative modalities, such as sound effects, vibrations, (physical) 3D-printed artifacts, and tactile displays to enhance accessibility. Examples of such solutions are a white cane with auditory and tactile feedback in VR [35], or a toolbox with improvements for users with low vision [36]. Additionally, incorporating icons, images, and graphical elements may be helpful for students with cognitive challenges who lack linguistic capabilities and the ability to process abstraction. An example of this is using pictograms and icons for users with cognitive disabilities [37].

Our findings from the interviews with developers of XR technology echo previous findings [5]. Companies are often

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aware of universal design to some extent but lack the necessary resources and tools to enhance the accessibility and usability of their technology. Developers may also not be aware of barriers faced by users with disabilities or lack the expertise to adequately address these barriers. Existing guidelines and frameworks from other ICT areas [11][12][13][14][17], are often not adequately communicated. Additionally, developers express the need for easily accessible and usable best practices. The participating developers noted that many customers do not prioritize increased universal design, which may lead to a lack of emphasis on universal design at the management level. Developers of systems should be made aware that several directives and legal regulations already exist that require the universal design of digital learning aids [18][19][20][29].

Therefore, we suggest increasing the awareness of and expertise in universal design among developers, designers, and decision-makers responsible for procuring digital learning resources in both the private and public sectors. This can be achieved by promoting existing guidelines, visualizing concrete barriers, providing specific solutions to these barriers, and offering practical best practices. Additionally, guidelines from other areas like programming or video games [11][12][13][14][26][27][28] should be reviewed for their relevance to XR technology. Likewise, we argue that WCAG, originally developed for websites, is also relevant for XR through the integration of WCAG 2.0 and 2.1 in national and international legislations for ICT in general and digital learning aids in specific [12][13][20].

At the same time, AR companies should incorporate dedicated procedures for universal design in their development and evaluation processes. This may include automated or manual checks for accessible and user-friendly user interfaces, testing for compatibility with ATs, and regular user trials involving students with and without disabilities. Similarly, decision-makers, educators, and buyers of digital learning solutions should demand and test for compliance with universal design requirements. The referenced guidelines and standards for user interfaces, video games, programming, and XR applications in this paper, provide some examples of what XR developers can use during the development process, and to which decision-makers can refer for requirement specifications.

Finally, our findings demonstrate the consequences of inaccessible learning resources used in schools, as well as the potential for improved integration if universal design is adequately addressed. Inaccessible digital learning resources can easily result in knowledge gaps, with students who lack essential knowledge struggling to keep up when more advanced topics are introduced. Students with disabilities, particularly those with visual impairments and cognitive challenges, are especially vulnerable to these difficulties. However, AR can serve as a suitable alternative for learners who rely less on text-based approaches, such as students with dyslexia, ADHD, and other learning disabilities. These findings align with findings from previous research we conducted [5].

V. CONCLUSION

In this article, we presented a case study that explores the universal design of Augmented Reality (AR) technology in educational settings. We believe that the findings will also be relevant to other technologies under the umbrella of eXtended Reality (XR), such as Mixed Reality (MR) and Virtual Reality (VR). Central to the assessment is the evaluation of an AR-based pop-up-like book designed for primary schools in Norway. User evaluations and interviews were conducted with students, including those with disabilities, educators, and developers to assess the opportunities and benefits, user expectations and best practices, challenges, and common pitfalls of using AR in educational materials. The study especially identified barriers faced by students with visual and cognitive disabilities. Furthermore, we provided recommendations and concrete measures to improve the integration of AR into the primary school curriculum and enhance its accessibility and usability for students with and without disabilities.

One significant challenge highlighted is the heavy reliance on visual stimuli in AR, which may pose difficulties for students with visual disabilities. Another challenge is the complexity and virtuality of AR putting a significant demand on the cognitive capabilities of the students, including spatial visualization ability and the concept of virtuality. This makes AR challenging for students with cognitive disabilities, especially in cases where the app lacks both visual and textual explanations. These challenges should be addressed by employing different approaches, such as incorporating alternative modalities like sound and tactile feedback, utilizing visual explanations, enhancing engaging symbols and icons to captivate students' interest, and offering textual descriptions as alternatives for visual content. Consequently, these improvements could enhance the accessibility and usability of AR technology for students with and without disabilities alike.

Moreover, many students with disabilities rely on assistive technology, like screen readers, hearing aids, glasses, or wheelchairs. Developers need to ensure that the AR application, including its operation, is compatible with these technologies, both physically and programmatically.

Finally, we recommend raising awareness of and expertise in universal design among developers and decision-makers in private companies and public institutions. This can be achieved by gathering best practices, consolidating existing guidelines for AR and XR technology, adapting relevant guidelines from other ICT areas, and making these guidelines easily accessible and widely distributed to developers and designers.

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Synchronized Recording System Using Multiple Smartphones

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***Abstract*—The author aims to pass down the tradition of classical music to the next generation by significantly reforming and evolving traditional piano teaching methods. Most of the studies on piano lessons aim to teach beginners how to accurately read scores and play the keys with accurate rhythms and without mistakes. This study aims to enable intermediate students to master musical expression. A system was developed to retrospectively analyze the movements of the upper body, hands, and feet from various angles using synchronized recording with multiple smartphones or tablets. This allows for multi-angle viewing without the need for complex wiring or data transfer from USB cameras or video cameras. By objectively evaluating actual performances, it is anticipated that disparities between the ideal and reality will be identified, and new challenges will be discovered.**

Keywords- Piano Lesson; support; Recording system; visualization.

I. INTRODUCTION

This paper is part of research conducted at Japanese music universities to pass down the tradition of classical piano to the next generation. Most of the previous studies on piano lessons [1] - [15] have been aimed at helping beginners learn how to read scores accurately and play keys with accurate rhythms and without mistakes. The Idea, Connection, and Extension (ICE) model [16] is a framework describing phases of learning. In the piano ICE model, these preceding studies were in the Idea stage.

This study focuses on the Connection stage in which musical expression is acquired. In order to acquire musical expression, it is necessary to understand the overall picture of the song and play it using the whole body, not just the fingertips Recording one's own play-through on video and reviewing it is important. However, traditional video playback platforms did not allow for quickly cueing up specific phrases or scenes.

This study aims to develop a "Piano Lesson Total Visualization System" that allows the user to instantly check the movements of the performer's body (upper body, hands, feet) in conjunction with the score [17] - [19]. In this study, we report on the development of a system that can utilize smartphones and tablet devices to record performances from multiple angles and allow playback from annotated points through cueing up.

The remainder of this paper is organized as follows. In Section II, this paper discusses the results of a survey on reviewing piano lesson videos, and Session III explains the concept of the proposed system that visualizes the entire piano lesson. Section IV discusses the multi-angle recording system developed in this study, and Section V provides conclusions and discusses future work.

II. QUESTIONNAIRE SURVEY RESULT

We conducted a survey regarding reviewing piano lesson videos [17]. The following responses were obtained:

(1) Most of the students record their piano lessons. However, almost none of them reviewed all previously recorded lesson videos due to a lack of time and motivation to watch the videos from the beginning until the end.

(2) Students feel dissatisfied when watching the videos, e.g., "I can't see how I touch the keyboard," "I can't see my own face or hear my tone."

(3) Students were dissatisfied with video viewing, e.g., "It takes too much time to find my desired video from the video archive," "It is difficult to pinpoint the part that I am interested in," "It is difficult to go back in time to watch."

(4) Students and instructors have complaints about the device itself and application when handling the device, e.g., "Connecting is difficult," "I don't know how to use the app."

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III. The System Concept

We have the following concepts for the visualization system of piano lessons:

(1) A system that can synchronize recording using multiple smartphones or tablets. This function will be discussed in Section IV.

(2) The system can instantly play a specific part of the video, playing the video from the measure clicked by the user. The association between the score and the video is made by comparing the scale recognized from the score and the pitch recognized from the video. These functions are currently successful with some melody scores and arpeggio staves [19].

(3) Videos recorded in the system are added to the calendar index by score name and recording time. Past and current performances can be instantly searched.

IV. The Developed System

The developed system realizes multi-angle recording and linkage of recorded performance videos and calendars.

A. System Architecture

This developed system consists of a server and a client. The server side is implemented using the Laravel framework, and the client side is implemented using Vue.js. The server coordinates with database and file management, as well as previously developed [19] score analysis and video analysis modules. The client provides a calendar, score upload, video recording, and video viewing to the user.

B. Recording

This section explains multi-angle recording using an example of three angles: the upper body, hands, and feet. Four smartphones are used. One is used as the controller machine for starting/stopping and for recording with the microphone. The remaining three smartphones are used as video cameras.

After logging in on the controller smartphone, the system displays a QR code when selecting the score that the user uploaded in advance. The QR code contains the URL of the recording web address and user authentication information. When the user scans the QR code with another smartphone and clicks to allow camera access, the camera activates and will be in the recording standby state. Figure 1 shows the placement during the recording of a performance and each camera angle.

Recording is synchronized with the start/stop signal from the controller device, and automatically uploaded to the server upon completion. This allows for multi-angle recording without the cumbersome wiring of USB cameras or data transfer from video cameras. This system has been tested for operation using Chrome browsers on PCs, iOS, and Android. The audio is saved in mp3 format on iOS, recording is possible in mp4 format for up to approximately 12 minutes (110MB), and on Android, in WebM format for up to approximately 27 minutes (45MB).

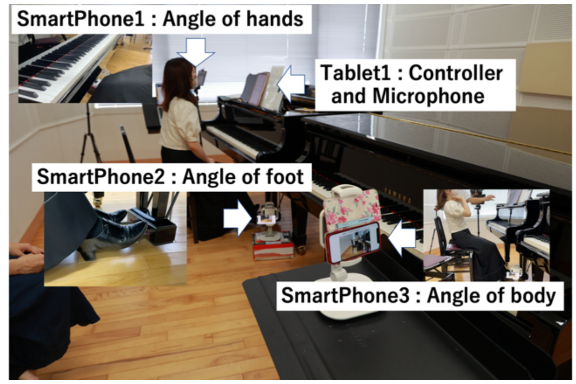

Figure 1. Example of camera angle.

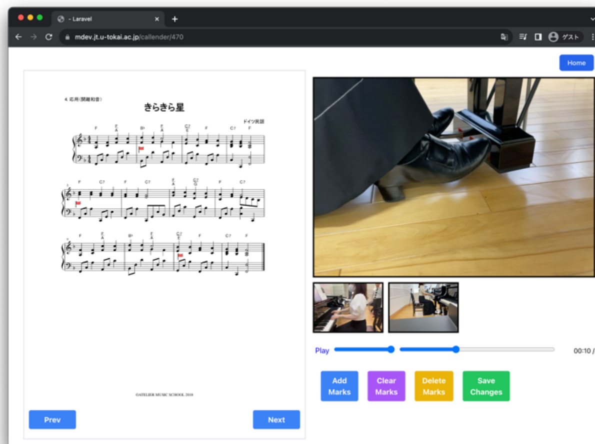

Figure 2. Example of score and video viewing page.

C. Review

When the user clicks on an index (score name and practice time) on the calendar, the score and the video are displayed. Figure 2 is the viewing page. One angle of the video is displayed prominently, while the remaining angles are displayed as thumbnails. Selecting a thumbnail switches between the enlarged display and thumbnail display. If the previously developed Score Analysis Module [19] and Video Analysis Module [19] allow the linkage of scores and videos, playback can be started from the corresponding scene by clicking on a measure in the score. If a module cannot be parsed correctly, the user can watch the video once and add an annotation to the timestamp they want to review, making it easier to review from the second time onwards. In the example in Figure 2, annotations are added at the 2nd, 5th, and 11th measures during the initial listening session.

D. Trial

Before using this system in an actual class, we conducted a demonstration and interviewed an instructor.

- USB cameras are difficult to set angles because the screen is not visible. On the other hand, smartphone cameras are easy.

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- It is convenient because no data transfer is required.
- The sound quality is not very good.

E. Discussion

The purpose of this research is to develop a user interface that enables recording and playback from multiple angles using readily available PCs and smartphones, simplifying the review process through annotation functionality, all without the need for special equipment for the “Score Click Playback System.” The current system can only record up to 12 minutes, so it cannot record an entire 60 minutes lecture. However, it is possible to record a single performance. In addition, being able to review immediately without data transfer is considered useful for reviewing performances External microphone support may be needed to improve sound quality issues.

V. Conclusion

This study aimed to record performances from multiple angles so that performers themselves can check how they use their bodies. Traditional single-camera shooting had problems, such as difficulty checking the use of hands and feet when shooting the whole. In this study, a multi-angle recording system was built that can shoot in cooperation with multiple smartphones. Future work will be to make the sound quality clearer. And then, examine the effectiveness of the system in actual lessons.

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Measuring AI Education Performance with Flipped Learning Based on Bloom's Taxonomy Objectives

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***Abstract*— As the importance of Artificial Intelligence (AI) capabilities increases across industries, the demand for AI education for young job seekers is also increasing. However, non-majors in related fields face difficulties in learning due to the lack of specialized learning content and prior learning opportunities. This study aimed to implement an AI education program through flipped learning for young job seekers and evaluate its effectiveness. The study included 80 students from a South Korean university AI training program, randomly assigned into control and experimental groups with 40 majors and 40 non-majors in each. In the end, the experimental group achieved higher academic results than the control group, particularly on higher-level items.**

Keywords- Artificial intelligence; Education; Flipped learning; Young job seekers.

I. INTRODUCTION

Currently, the demand for artificial intelligence manpower is exploding in various fields, but it is challenging to supply manpower through formal education within a short time. Although artificial intelligence can be classified as a computer science discipline, it has a wide range of fields and applications, so it is not just for science and engineering majors. Still, it is considered an essential literacy for modern people in the era of the Fourth Industrial Revolution. However, in order to learn AI, primary computer languages, basic mathematics, computer algorithms, and other essential learning contents are required in common.

In the non-degree AI training program for young job seekers, a large number of trainees receive intensive training for a limited period of time. In addition, it is challenging to provide individual scaffolding for learners with varying levels of prior knowledge in the classroom, as AI education is conducted using the Project-Based Learning (PBL) method that combines theory and practice. In order to increase learner motivation and promote achievement, learner-centered education is necessary for individual learners in all majors [1]. Non-majors can repeatedly learn online video materials using the flipped learning method as scaffolding outside the classroom, based on individual capabilities and progress. It is possible to implement out-of-classroom classes in which memory and understanding in Bloom's hierarchy of educational objectives [2] are learner-driven. As a result, it is expected that efficient and effective learner-centered AI classes will be possible, as it will be possible to secure class time for complete learning and higher-level classes such as practical exercises and projects through summarizing and answering questions about core contents in the actual classroom.

This study aimed to effectively implement AI education for both non-CS (Computer Science) majors and those who struggle to learn AI. To achieve this, an experimental study was conducted using a learner-centered approach by adopting the flipped learning method. The study measured academic achievement and the effectiveness of achieving learning goals in the higher dimensions of Bloom's Taxonomy.

The remainder of this paper is organized as follows. The related works of flipped learning and Bloom's Taxonomy are presented in Section 2. The methodology of this study is explained in Section 3. Section 4 showcases the study's results. Finally, the paper concludes with Section 5.

II. RELATED WORK

In this section, we describe Flipped Learning and Bloom’s Taxonomy that are closely related to the topic of this paper.

A. *Flipped Learning*

Flipped learning is a learner-centered teaching method that allows instructors to utilize classroom time efficiently and effectively [3]. Baker used the term "The classroom flipped" [4], and Bergmann and Sams, teachers in Colorado, USA, created and provided online class videos for students who could not attend class and defined it as flipped learning [5]. Prior to that, there was a teaching method of learning the material in advance out of class and doing learner-centered activities in class. Still, with the development of technology and the advent of the information age, the role of the instructor has shifted from being a source of information to helping students learn how to handle information [6]. This phenomenon is expected to intensify with the rise of artificial intelligence and big data during the Fourth Industrial Revolution. As a result, the flipped learning teaching method is predicted to expand and advance.

B. *Bloom’s Taxonomy*

Bloom categorized the hierarchy of educational objectives as remembering, understanding, applying,

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analyzing, evaluating, and creating [2]. Bergmann and Sams reversed Bloom's hierarchy of objectives for flipped learning, suggesting that memory and comprehension occur outside the classroom, while higher-order thinking of application, analysis, evaluation, and creation are promoted in the classroom [5].

In Figure 1, Bloom's inverted pyramid [7] shows the application of Bloom's Taxonomy to the flipped learning model.

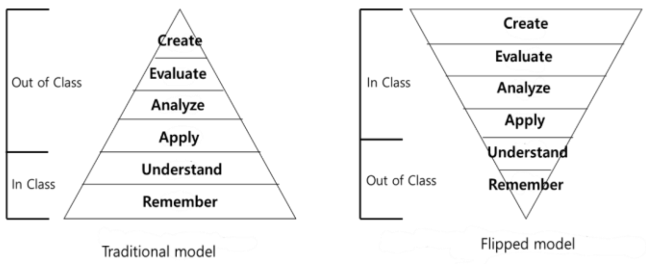

Figure 1. Bloom's reversed taxonomy [7]

Pre-learning lecture videos provided out of class are a good content delivery tool to achieve the lower levels of Bloom's taxonomy, namely remembering and understanding and in-class learning can be valuable to foster higher-level learning, namely applying, analyzing, evaluating, and creating.

III. METHODOLOGY

This study was conducted on 40 control and 40 experimental group students enrolled in the artificial intelligence education program at a university in South Korea. Adopting a quasi-experimental research method with a non-identical control group before-and-after comparison, the control group received a traditional curriculum with only classroom lessons and no flipped learning. In contrast, the experimental group received flipped learning lessons using pre-learning video content created by the instructor and uploaded to the LMS (Learning Management System) as TABLE 1.

TABLE I. FLIPPED LEARNING PLAN BASED ON BLOOM'S TAXONOMY

Area	Traditional Class (Control group)	Flipped Class (Experimental group)
Remember	Face-to-face lecture	Pre-learning lecture video (about 30 min.) Face-to-face lecture
Understand	Face-to-face lecture	LMS, Padlet Face-to-face lecture
Apply	Hands-on programming training	Hands-on programming training
Analyze, Evaluate, Create	Project work	Project work

For the experimental study, the control and experimental groups were given the same study time, content, test difficulty, assignment content, and number of assignments.

IV. RESULT

The academic achievement results of the lower and higher-level items of the test of the control group and the experimental group showed a statistical difference as indicated in TABLE 2.

TABLE II. COMPARISON OF ACADEMIC ACHIEVEMENT

Learning level	Group	*N*	Mean	SD	*t*	*p*
Lower-level	Control	40	27.00	13.39	2.108*	.038
	Experimental	40	32.27	8.44		
Higher-level	Control	40	16.20	11.66	2.648*	.010
	Experimental	40	22.08	7.81		
Total	Control	40	43.20	23.57	2.581*	.012
	Experimental	40	54.35	13.82		

* $p<.05$

In particular, the scores of the experimental group were significantly higher in the higher-level items compared to the lower-level items, aligning with the goal of flipped learning, which is the achievement of higher-level learning objectives. As academic achievement significantly improved in the entire test and in all lower and higher-order items, it can be concluded that flipped learning-based AI education has a positive impact on enhancing academic achievement.

V. DISCUSSION AND CONCLUSION

This experimental study showed that the application of the flipped learning method in AI education for young job seekers improved academic achievement in both lower and higher-level items measured by the test. In a traditional classroom, lower-level learning, which corresponds to memory and comprehension in Bloom's Taxonomy, takes place face-to-face between the instructor and the learner, so the instructor can immediately identify the learner's level of understanding and adjust the difficulty and pace of the lecture to the learner. On the other hand, the memory and comprehension learning that occurs in flipped learning is replaced by pre-made videos, which makes it difficult for instructors to identify learners' needs in real time. Despite these disadvantages, flipped learning is a self-paced learning method that allows young adult learners with diverse backgrounds and prior knowledge to learn the basics of retention and comprehension at their own pace outside of the classroom. In addition, learners can engage in meta-learning, where they can learn at a higher level through online collaboration tools outside the classroom, group activities in the classroom, and questions and answers with the instructor, which is a strength of flipped learning that is difficult to achieve in traditional classrooms with limited class time.

Since this study was conducted with a relatively small sample size, consisting of 40 individuals in each group (control and experimental) for both majors and non-majors, totaling 80 participants, it is essential to conduct multiple iterations of experimental research in the future. This will allow for the analysis of effectiveness based on results from a larger and more diverse population.

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