Augmented Reality and In-Person Piano Tuition:

Project Report

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1. Executive Summary

Introduction

The ‘Augmented Reality Piano’ research project that took place between July 2022 – July 2023. This report outlines the design and delivery of the project and describes and analyses its findings. It ends by offering recommendations for future use of augmented reality in instrumental teaching, and how hubs can effectively conduct future research in the adaptation of new technologies into instrument-teaching contexts.

The project is a collaboration between Wiltshire Music Connect, Leicestershire Music, Lincolnshire Music Hub, Norfolk Music Hub and the Royal College of Music.

The project was initiated in order to investigate the potential of augmented reality to increase pupil engagement and progress within one-to-one instrumental tuition. The research was carried out between April – July 2023 and worked with 6 experienced piano tutors and 32 beginner piano pupils aged 13-16 over a 10 lesson period. Half of the pupils had access to an AR headset both at home and in lessons. The remaining half undertook traditional lessons without access to AR. Data was gathered from piano tutors, pupils and parents using a mixture of questionnaires, interviews and lesson diaries.

Key findings

AR can enhance some areas of teaching and learning

The research show that, for some pupils, AR increases pupil **engagement**, supports more rapid **repertoire acquisition** and increases **pupil autonomy** both within lesson and at home.

AR can inhibit some areas of teaching and learning

It was common for tutors to report that the AR software led to incorrect **technique**, especially fingering and hand position**.** The app allows pupils to learn pieces without using western staff notation, leading to a slower development of **sight-reading** skills.

AR changes the way pupil and tutor interact

Several tutors stated that the AR gave the pupil more **autonomy** both within lessons and at home. Some tutors felt this led to a lack of tutor control over the learning process, and reduced the ability of tutors to give instant **feedback** while pupils were playing.

AR does not increase overall pupil progress

The data does not indicate that pupils who had access to AR made more progress over the ten week period than those without. However, this may partly be due to the acclimatisation period to the headset for both tutors and pupils in the early stages of the research.

AR is more useful for some pupils than others

Tutors stated that some pupils showed significant engagement and progress when the technology was introduced, but that others preferred and seemed more suited to traditional lessons. They also suggest that AR may be particularly useful for pupils who have already acquired basic technique and/or those that may struggle with staff notation and/or traditional teaching methods, for example those with specific learning difficulties.

Conclusions

The research has identified key areas of challenge and potential for music hubs, technologists and individual tutors who are interested in using augmented reality as a teaching tool.

For tutors, the research has identified the areas that AR can currently support teaching: increased engagement; more rapid development of both beginner repertoire and more complex, familiar pieces; increased autonomy over the learning process for some pupils. It has also identified the limitations of the technology and areas that still require a traditional, tutor led model.

For music hubs, the research suggests that there is significant potential for this technology, but that further development needs to take place before AR matures into a technology that will be taken up more consistently.

For the research community, several areas of further study have been identified, including using the technology with non-beginner pupils and those who may find traditional lessons less accessible.

For the developers of AR instrumental teaching products, the research offers an extensive list of suggests for future features and areas of pedagogical focus.

For both the education and technology sectors, this research demonstrates that piano tutors have much to offer the developers of music education technology. It is the aim of the research team to promote the voices of educators during the conception and development of future technologies.

2. Introduction

Context

The period between 2014-2021 saw a significant decline in the number of young people aged 14-16 taking instrumental lessons, a trend accelerated by the pandemic (ABRSM, 2021). The same period saw an increase in digital learning tools that claim to offer new ways to develop keyboard and piano skills. The exploration of the role that digital learning tools can play in the retention and progression of instrumental pupils is a priority for the UK music education sector (DfE, 2022).

One area that has received significant attention in recent years is 'augmented reality (AR)'. An augmented reality is a hybrid environment within which a user is able to perceive "the real world, with virtual objects superimposed upon [it]" (Azuma, 1997) (fig. 1). In 2019 the first consumer-facing virtual reality headset with augmented reality capabilities, the Oculus Quest, was launched. By March 2023 the Oculus Quest and its successor, the Meta Quest 2, had been purchased over 20 million times (Wöbbeking, 2023). The first half of 2023 also saw the launch of two free software apps that claim to use AR to 'teach' the piano (Rogerson, 2023).

The relative affordability and accessibility of AR technologies has made it more feasible for instrumental tutors to use AR as part of their teaching.

Figure 1: Simulation of augmented reality piano learning system. Both the piano itself and the coloured blocks would be visible within the headset. Source: Kaiser (2022)

Project Development

A partnership of four music education hubs initiated this project in order to provide insight and guidance to the music education sector by gathering evidence on the potential function and perceived value of AR systems within in-person instrumental lessons and pupils' home practice.

The research focuses on an app called Pianovision in the context of beginner piano lessons over a ten-lesson period. It investigates how tutors respond to the incorporation of an AR piano application in their lessons, how the use of the application changes their pedagogical approaches, and how the application could be developed to better support teaching and learning.

The primary research question was:

How do music tutors perceive the use of the 'Pianovision' augmented reality app to teach beginner keyboard pupils aged 13-16?

The primary research question is supported by three sub-questions:

1. How do tutors' perceptions of AR change over time?

2. In what ways does the incorporation of AR affect pedagogical approaches?

3. In what ways could the AR software be developed to better support teaching and learning?

By exploring these questions with a group of 6 instrumental tutors in 4 areas of England over a ten-lesson period, the research aimed to identify potential areas of strength and challenge, explore how tutors adapt their teaching approaches to best use the technology, and recommend improvements and additional features to the Pianovision software. It also sought to identify areas of further research and support the sector by increasing the effective deployment of AR technology in instrumental lessons.

3. Methodology

Focus on Tutor Experience

The research team chose to focus on tutors' *perceptions* of AR technology in their lessons within a naturalistic setting, supported by limited data gathering on the impact AR on pupil engagement or rate of progression. There were two main reasons for this. Firstly, there are multiple factors that affect engagement and progress, for example previous music-making experience, input from other adults, and rapport between teacher and pupil. It would be extremely difficult to create a research environment that could control or mitigate these variables.

The second reason to focus on tutor perceptions was based on existing research that suggests that AR can enhance, but not replace, traditional in-person piano tuition (Turchet et al., 2009; Deja et al., 2022). The tutor serves as gatekeeper to the technology for many pupils and would need to perceive the technology to be of value in order to incorporate it into their wider pedagogy. Understanding factors involved in the creation of that perception, how that perception might change over time, and how it might affect their existing teaching methods, would allow conclusions to be drawn that would be of most use to the wider sector.

Research Paradigm

Every tutor, both in this study and the wider world, has a unique set of subjective and socially constructed opinions about all aspects of teaching and learning (Hammersley & Atkinson, 2007). Therefore, the research used a narrative, interpretivist paradigm, attempting to draw meaning from tutors' evolving experience of reality. The focus on gathering data over time was particularly appropriate as the tutors were both teaching (the piano) and learning (to use the AR) simultaneously, with each element impacting the other.

Recruitment

The researchers used the following criteria to recruit tutors:

1. A minimum of 5 years of experience of teaching the piano, with at least some experience of teaching piano to 13-16 year olds
2. Willingness and enthusiasm for the aims of the research project
3. Capacity within their teaching schedule to take on 4 pupils for 10 weekly lessons
4. *Note: Being 'tech-savvy' should not be a factor in the recruitment process*

Teacher #	Sex	Years Teaching	Primary Teaching Resource
T1	F	16	Piano Time
T2	M	12	Piano Time
T3	F	21	Piano Time
T4	M	6	Benjamin's Beginnings
T5	M	9	Benjamin's Beginnings
T6	M	8	Piano Time
Mean years teaching		12	
Male- Female Ratio	2:1		

Table 1: Piano Tutor Participant Demographics and Overview

Once participant recruitment was complete, individual hubs worked with local schools to select pupils for the participants to work with. Informal discussions with tutors highlighted two notable areas of diversity. The first variation related to instrumental experience. Several pupils reportedly already played another instrument to an intermediate level, whilst others had no experience of playing any instrument. The second was socio-economic backgrounds, with a significant minority of pupils attending fee-paying schools.

This variation in pupil background increased the range of perspectives on the technology and may have strengthened the research, in line with the principles of maximum variation sampling (MVS) (Palinkas et al., 2015). Future research could incorporate a more intentional approach to MVS when recruiting participants.

Preparatory Work

How-to videos

The research team created three 'how-to' videos for tutors:

1. How to set up the headset for the first time.
2. How to upload the bespoke scores onto the app;
3. A guide for first-time users of the headsets

Some tutors chose to show the final video to pupils at the beginning of their first lesson.

Data Collection & Rationale

Over the course of the research period each of the six piano tutors completed between 6 and 10 30-minute lessons with four pupils, two of whom had access to an AR headset with the piano learning app both in lessons and at home (*see Table 2*). A total of 130 lessons took place. 67 lessons included the use of AR. 63 lessons did not use AR. They were held in both schools and tutors' homes.

Tutor Code	*Hub Area*	*Lessons with AR*	*Lessons Without AR*	*Total lessons*
T1	*Norfolk*	*16*	*16*	*32*
T2	*Norfolk*	*17*	*12*	*29*
T3	*Lincolnshire*	*18**	*18*	*18*
T4	*Leicestershire*	*8*	*9*	*17*
T5	*Wiltshire*	*13*	*24***	*13*
T6	*Wiltshire*	*13*	*8*	*21*
Total:		*67*	*63*	*130*

Table 2: Lessons completed by each tutor with/without use of an AR headset.

* *One of T3's non-AR pupils used a headset in their final lesson*

** *One of T5's AR pupils stopped using their headset after 3 lessons*

Data was collected via:

1. *Lesson diaries*
2. *Focus groups*
3. *Tutor & pupil surveys & questionnaires*
4. *Pupil case-study interviews*

4. Results/Findings

The focus group interviews and tutor diaries were coded into 457 codes using an inductive, semantic approach. These were grouped into five overarching themes and 26 sub-themes (fig.5).

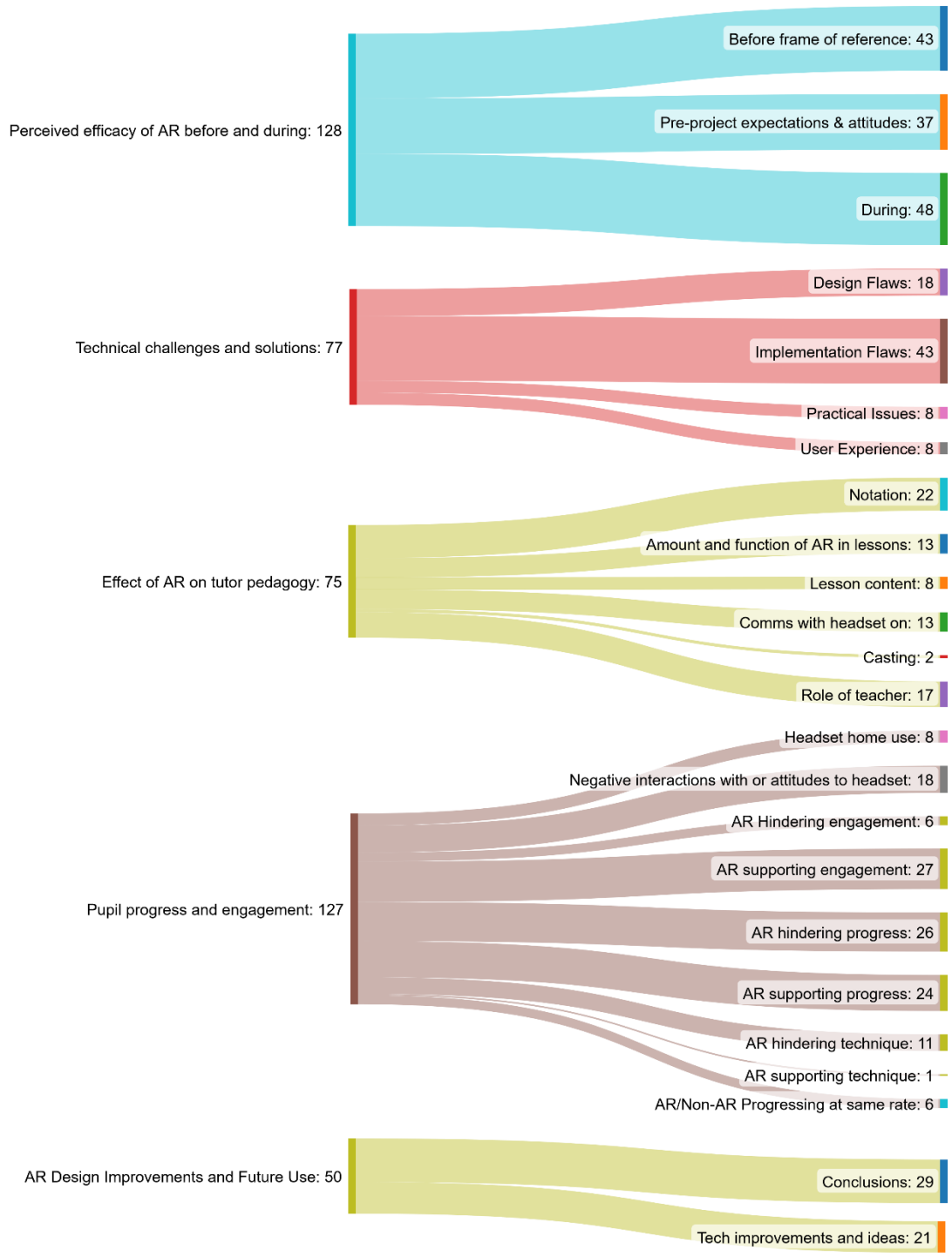

Figure 2: Sankey diagram of themes and sub-themes

The overarching themes are:

1. Perceived efficacy of AR before and during the research period
2. Technical challenges and solutions
3. Effect of AR on tutor pedagogy
4. Pupil progress and engagement
5. AR Design Improvements and Future Use

4.1 Perceived efficacy of AR before and during the research period

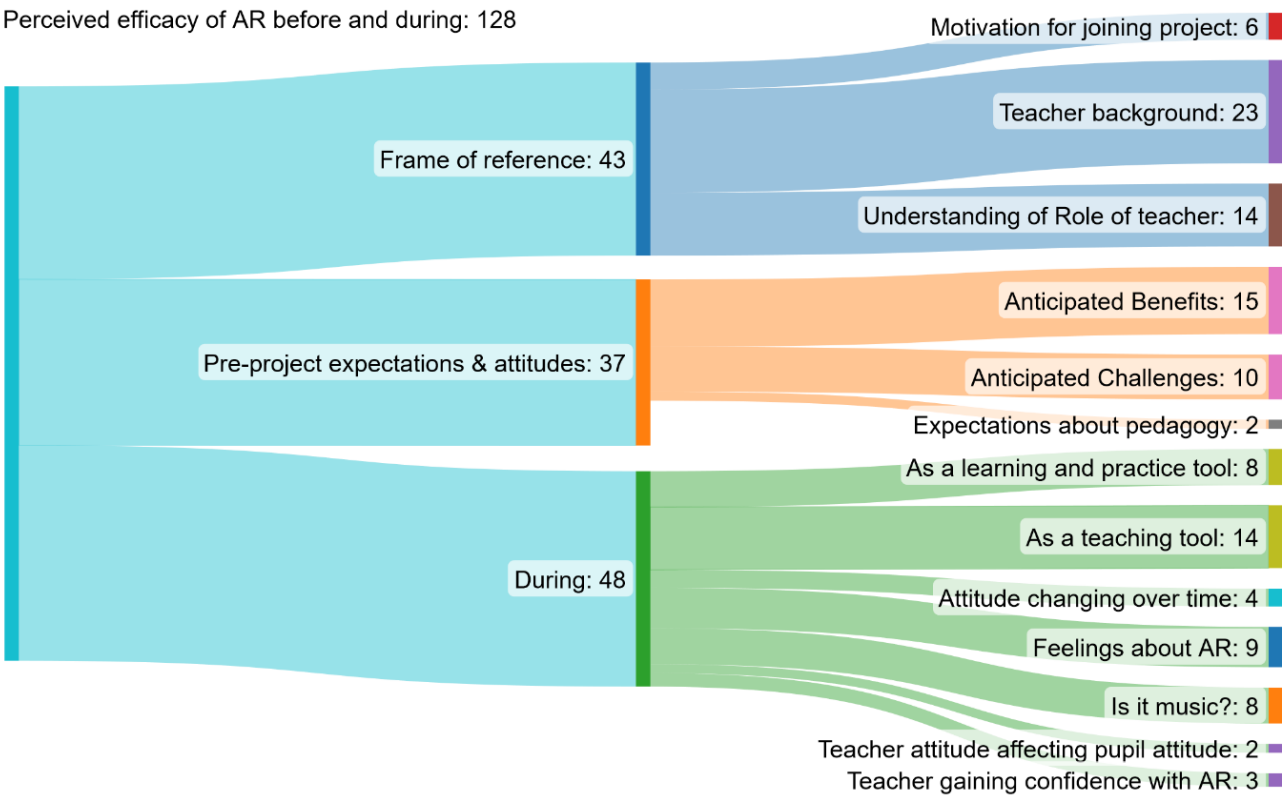

Figure 3: Perceived efficacy of AR before and during the research: Subthemes and code groups.

4.1.1 Pre-Project

The first tutor focus groups took place in the week immediately before teaching was due to begin. Tutors anticipated both benefits (n=15) and challenges (n=10) of using AR their lessons. In terms of benefits, tutors anticipated that the AR would add 'variety' to lessons, enable pupils to play complex rhythms more quickly, and creat "more equilibrium and an equal footing" (T4) in the learning relationship between tutor and pupil. Several tutors pointed to the gamification potential of the technology, noting that gaming technology is "in the DNA now for that generation" (T1) and anticipating that the use of AR would lead to "extra engagement and extra practice and wanting to try [it] out at home a bit more" (T3). In the longer term, two tutors who

identified as having more “traditional” teaching methods hoped it would help them “look outside the box” (T1) and lead to a more consistent use of technology beyond the project.

Anticipated challenges centred on both technical setup and teaching approaches. Three tutors felt that onerous headset setup could take time away from teaching. They stated that the headset could create barriers to communication and rapport building between teacher and pupil, a loss of control over the teaching process, and the fear that the headset might be a “turn-off” (T2) for pupils if they struggled with it in the early stages.

Despite these anticipated challenges, five of the six tutors expressed excitement towards the project, intending to “embrace it and see where it goes” (T3)

4.1.2 During the Project

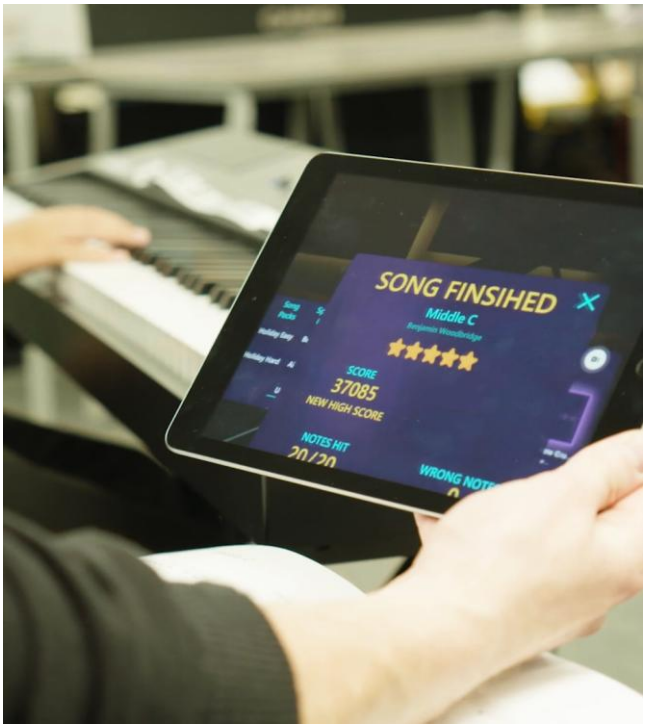

Figure 4: An example of gamification within the Pianovision app. At the end of each song, the app gives the user a score based on the accuracy of their pitch and rhythm.

The remaining four focus groups took place over the ten-week teaching period at weeks 2, 5, 7 and 10. Perceptions of the efficacy of AR as a teaching and learning tool were mixed during this period, with more overtly negative comments than positive ones. The main stimulus of negative comments concerned how perceived flaws in the design (n=18) and implementation (n=43) of the technology affected pupil engagement and progress (see fig.9). These technical issues are described in section 4.2. They left four of the six tutors feeling “stressed and frustrated” (T3), believing that the technology issues were “eating into teaching time” (T3) and meant that the AR was “largely flawed as a teaching tool” (T1). The peak of negative comments came between weeks 3-6 of the project. However, comments in weeks 7-10 suggest that some of these four

tutors' perceptions improved over time as they overcame technical challenges and gained more confidence with the tech after "that initial phase of troubleshooting" (T6).

A second perceived negative aspect centred around the question of whether the use of AR allowed the learning of 'music' or just "reaction and memorisation" (T3). One tutor felt that the AR did not allow pupils to learn music "in its truest sense" and that "in essence… they're learning to play a computer game which just happens to be on the piano" (T3). Another tutor stated that their pupil had been able to play more complex songs using the headset, but "that… grates on me. It doesn't feel like what [they] should be learning. I need them to be learning to read music and to be managing their fingers and all this sort of stuff really." (T2)

Tutors observed that AR use hindered pupils' development of technique (n=11). This included an inability to learn correct fingerings, poor posture and hand position, and a lack of understanding of staccato and legato articulations. Several tutors stated that the piece *sounded* okay on the headset, but that the poor technique employed to make this sound created a bad foundation for further development.

In contrast, positive comments often related to enjoyment, engagement and focus levels of pupils when using AR. A large amount of comments (n=27) stated that the AR increased pupil engagement, with one tutor stating that "I feel like without [the AR] she wouldn't be coming to lessons" (T6)

Figure 5: Virtual Concert Hall mode on the Pianovision app

Pupils enjoyed having a go at more complex pieces: the "spontaneity of just being able to click on something and play along and it sounds like what it should be without too much effort being put in." (T3). Pupils also engaged well with the gamification element of AR (fig. 7), which "pushes [pupils] to improve" (T1). Several tutors mentioned positive pupil reactions to the "magical" virtual concert hall mode (this mode places the user within a virtual concert hall. See figure 8)

4.2 Technical challenges and solutions

Discussions about challenges with both the AR hardware and Pianovision software were a feature of all focus groups (fig. 9). These in turn led to the discussions about potential solutions and improvements to the technology that I describe in the 'design improvements' section below.

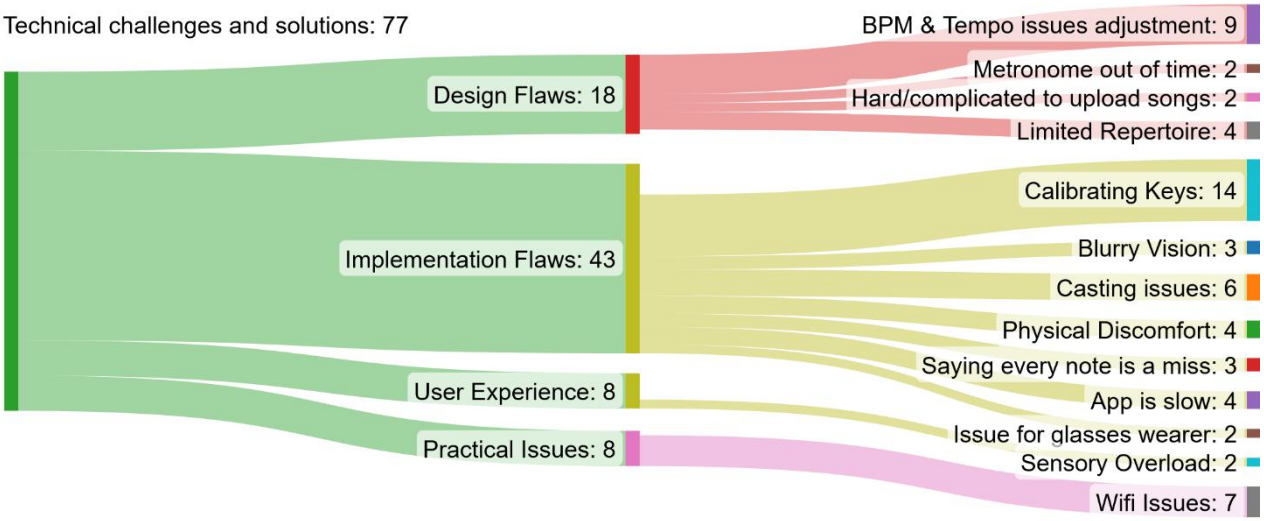

Figure 6: Technical Challenges: Subthemes and code groups

4.2.1 Headset calibration & casting

The most common technical issues mentioned (n=14) concerned 'mapping' the virtual keyboard in the app onto the physical keyboard or piano in the room, a process known as 'calibration'. Getting this right is a necessary first step in the setup process. All six tutors reported significant problems with this process: "it's just always slightly off and as a teacher, you can't manage that" (T1). Some tutors found that they had to "recalibrate the keyboard between every piece" (T3). This led to repeated "long and faffy" (T1) setup times that had removed the "immediacy" associated with gaming and discouraged several pupils from using the headset for home practice.

The second most common technical issue reported related to 'casting': the sharing of images from the headset to an iPad or laptop so that the tutor could see what the pupil was seeing (n = 6). Issues included problems with school wi-fi systems (n=3) and the casting lagging or dropping out. This led to tutors "blindly telling [pupils] what to do from memory" (T6) and pupil disengagement because "he doesn't have my full attention … when I am trying to sort out the casting". Two tutors were able to mitigate casting issues by using their own wi-fi dongles in sessions.

4.2.2 Tempo

Though it was possible to adjust the tempo of any piece to 25%, 50% or 75% of the original speed, tutors felt that adjusting to a specific beats per minute (BPM) would allow for a more graduated learning process. Several tutors found that the metronome click was sometimes out of time with the notation. They stated that the design of the app did not allow for musical expression using tempo: "a bit of expression, a little bit of a *ral* here or there, [and] the notes have gone. You've missed." (T2)

4.2.3 Interface and uploading songs

Several tutors felt the app interface "felt clunky" (T6) and "lacked intuitiveness" (T2). They reported difficulty with moving between different sections of the piece, unclear naming of songs, and a complicated process of uploading new songs: "it shouldn't be that difficult to just put some tracks onto it, but it is at the moment so we end up with quite limited repertoire" (T2). The researchers attempted to solve the problem of song uploads by creating written instructions for the upload process and, in one instance, sharing specific song files with a tutor, but the complexity of the process and unresolved technical issues meant that these songs were not uploaded.

4.2.4 Gamification Difficulties

The main gamification feature involved the app assigning points and scores based on the amount of notes played at the correct time. This required a wired connection between the headset and a keyboard with a specific USB port. Not all tutors and pupils had access to this type of keyboard, leading to the app giving scores of zero, with every note marked as a 'miss': "It told me I got every note wrong and I knew I hadn't." (T2) Tutors believed that this would "annoy kids... because they need that instant gratification" (T1).

4.2.5 Hardware

Tutors reported issues with the headset hardware (n=5), noting the "discouraging" heavy weight of the headset as well as pupils experiencing mild pain (n=2) and disorientation (n=1) when using the headset. There were also some issues with the headset vision being blurry and out of focus (n=3) and difficulties adjusting the headset for glasses wearers (n=2). Halfway through the project some of the headsets required a software update that pupils were unable to complete themselves due to security settings. Pupils had to bring their headsets to tutors to update, leading to the loss of several days of potential practice time.

4.3 Effect of AR on Pedagogy

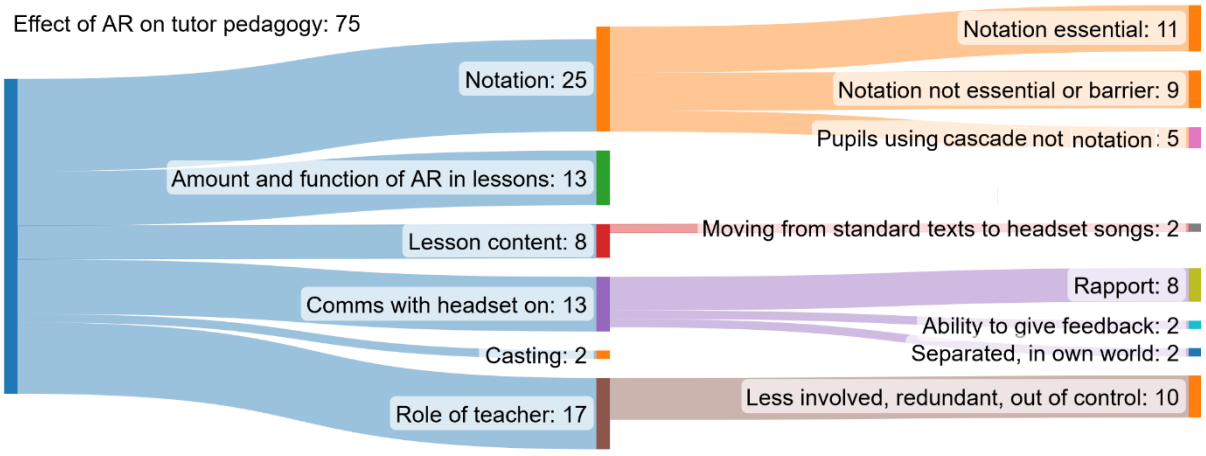

Figure 7: Effect of AR on Pedagogy: Subthemes and code groups.

4.3.1 Lesson Content

Tutors used the headsets in different ways and at different points in the lessons. One tutor began by using the headset throughout the whole lesson, with "no formal introduction of sightreading or rhythm knowledge". He reported in the first few weeks that "pieces are played with relative accuracy" but reported from week 8 that he had started teaching some musical elements without the headset on in response to pupils finding more complex pieces increasingly difficult to play using the headset.

By the middle of the project, most tutors were using a mixture of AR and non-AR methods within each lesson. One tutor would "teach a bit from the book and then stick the headset on and see how they get on." (T3). Another tutor would 'bookend' each lesson with the AR:

> *I started with the headset because the technology does excite them … then troubleshooted on the piano … and I set them homework on the headset … between the lesson, it's all headset, and then there's a small portion where you can really kind of technically focus on hand position and how to do it with the book. (T1)*

Concerning repertoire, all six tutors began using the two schemes of work uploaded to the headset: Piano Time 1 (n=4) and 'Benjamin's Beginnings' (n=2). Some would teach pieces in these schemes exclusively using the headset, remarking that "the process of trial and error seems sufficient enough for this pupil's progress using AR" (T5). Others would use a combination of both methods, beginning on the headset and then moving to the book. Over time, all tutors began to explore some of the in-built repertoire in the app. Tutors stated that this was because it included well known songs for pupils and seemed "designed to be a bit more user friendly" (T3). By the final weeks of the project, pupils working with at least two tutors were continuing to use the Piano Time book to learn technique and notation skills while also accessing more complex repertoire within the headset.

4.3.2 AR leading to reduced teacher involvement

The majority of tutors commented that the use of AR in lessons led to the reduced involvement of the tutors. Some tutors framed this positively: "AR tends to lead the way with occasional interaction/explaining from me… " (T4), "it is quite nice not having to be active" (T5), and as a shift in leadership from tutors and pupils.

Others felt negatively impacted. One tutor felt "out of control":

> *Once they start that page, you've had it for the next thirty seconds unless you get them to try and stop, which tends to [lose the] flow, and then they get confused (T3).*

The same tutor later reported feeling "a bit redundant. This was all quite simple so I wasn't really needed". Another tutor suggested that it was the lack of pedagogical detail that made the teacher less active: "they could just do this on their own, really. And I could not be here. Or if I'm meant to be teaching them with it, it needs to have more sort of detail to it." (T6)

4.3.3 Feedback, communication and rapport building

Despite the general perception from tutors that they were providing less input, all tutors noted the necessity of providing feedback. This concerned both "how to respond to the app interface

(grid and note lengths etc) and more formal tips on technique and position playing" (T5). This led one tutor to consider the amount of feedback he gave:

> *You're sort of watching trying to notice [things to feedback], but then also trying to monitor yourself like how much do you feedback, you [don't] want to put the pupil off. There's this constant dialogue going on internally* (T5)

This tutor was able to give feedback while the pupil kept the headset on. However, another tutor noted the issue of not being able to point to specific places in the music when giving feedback.

Several tutors observed that the headset created a "feeling of separation" and becomes an "obstacle" to the tutor/pupil relationship: "I find it hard to interact with what they're doing when they have got the headset on ... they're in their own worlds" (T2). Another tutor stated that:

> *there is maybe twenty percent less personality going on in terms of your relationship with the pupil naturally, ... without the AR headset there's a lot more discussion going on, a lot more interaction going on between pupil and teacher (T5).*

In contrast, other tutors stated that a shared engagement with and excitement about the technology led to increased rapport.

4.4 Pupil Progress

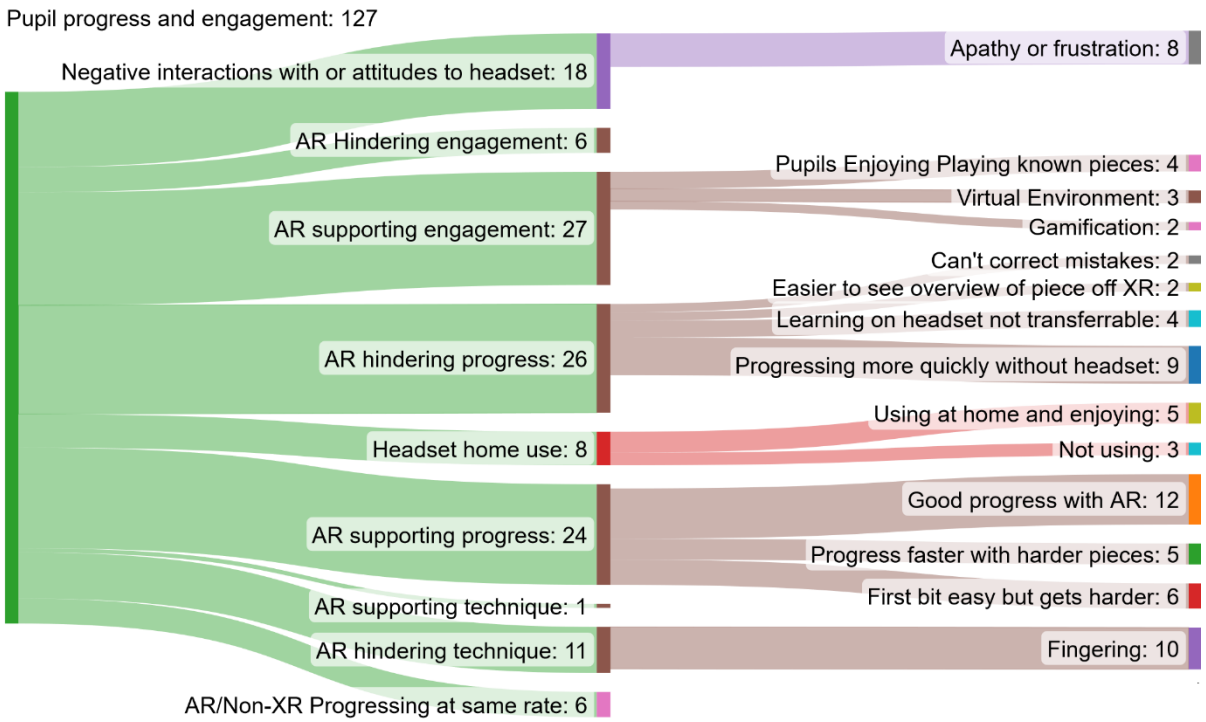

Figure 8: Pupil Progress: Subthemes and code groups

Tutors' perceptions of pupil progress are likely to have a strong influence on their overall perceptions of the efficacy of AR as a teaching tool. The amount of positive and negative comments about the influence of AR on progress speed were almost equal (positive n=23, negative n=24).

There was general agreement that, assuming that the technology was working, AR made it easier to learn more simple pieces. Tutors believed that this was because it is “a lot less daunting” to play along to cascade notation than staff notation in the initial phase of learning, and that there was “more playing and less teaching” time using this method. However it seemed that, with some exceptions, more complex pieces and also scale exercises required additional teaching with the headset off, and that attempting them with the headset on could led to “sensory overload”:

> *The last quarter [of the project] I was doing a lot more actual sort of tutoring whereas in the beginning … pupils were just sailing ahead and I didn't have to give much feedback. But when it got to the end, I wasn't even able to teach the last two pieces in the book (T5)*

Over the course of the whole project, the majority of tutors felt that the pupils who did not use a VR headset were progressing at a faster rate than those with the headsets. In addition to the above, reasons for more rapid progress for non-AR pupils included:

- Being able to see, conceptualise and discuss pieces in their entirety (n=3) outside of AR supported progress: “If I didn't have VR, I'd explain it. We’d visually look at it and say, ‘it's a bit like a sandwich, isn't it?’” (T1).
- Being able to correct mistakes immediately: “having that flexibility [to] quickly go back and do that now”, contrasting to using AR where “as soon as they make a mistake they can't correct it.” (T1)
- Being able to see your own hands more clearly, as opposed to through a visual representation in AR: “[pupils can] engage with the hand shape and finger shape … [you can’t] see if your fingers are flat because [AR] doesn't perfectly track every single finger movement.”

Two of the 12 pupils that used the headsets were exceptions to this and were able to progress onto much more complex pieces using the headset. Their tutors encouraged them to stick with the cascade system, rather than ensuring that their knowledge of staff notation kept up with the repertoire they were playing in the headset. Both of these pupils “really enjoyed using the VR” both at home and school and appeared to overcome the many technical challenges reported by tutors.

One tutor had a “magic moment” where the pupil was able to intuitively incorporate legato and staccato phrasing in their playing based on the block-based visual representation in the app.

Quantitative tutor surveys relating to the perceived progress of pupils were completed by tutors. Pre-project survey data were collected from six tutors describing 21 pupils, comprising 10 using the XR technology and 11 not using it. Follow-on data were provided by four of the tutors describing 15 pupils (7 of which used the technology). Therefore, pre-post analyses could be conducted on 15 students. Repeated measures mixed ANOVA were conducted with use of the technology as a between-groups independent variable and pre-post timing as a repeated measures variable.

Analysis were conducted with overall scores for quality of repertoire, fingering, posture, and sense of progression. The data collected supported the results of the focus groups and questionnaires: No significant differences in interaction effects were found, indicating that, within the constraints of the quasi-experimental study, the technology neither enhanced nor hindered learning progression in comparison with the control.

A significant and large main effect of pre-post measurement was found in the repertoire variable ($F_{1,11}$ = 13.02, p < .005, n^2_p = 0.542) in which the quality of the repertoire learned was found to improve across both groups, with no meaningful difference between whether students were using the AR technology (see figure 12). No main effects were found across the other variables, suggesting that the time period was too short or measurement scales not sufficient to capture change using these measurements.

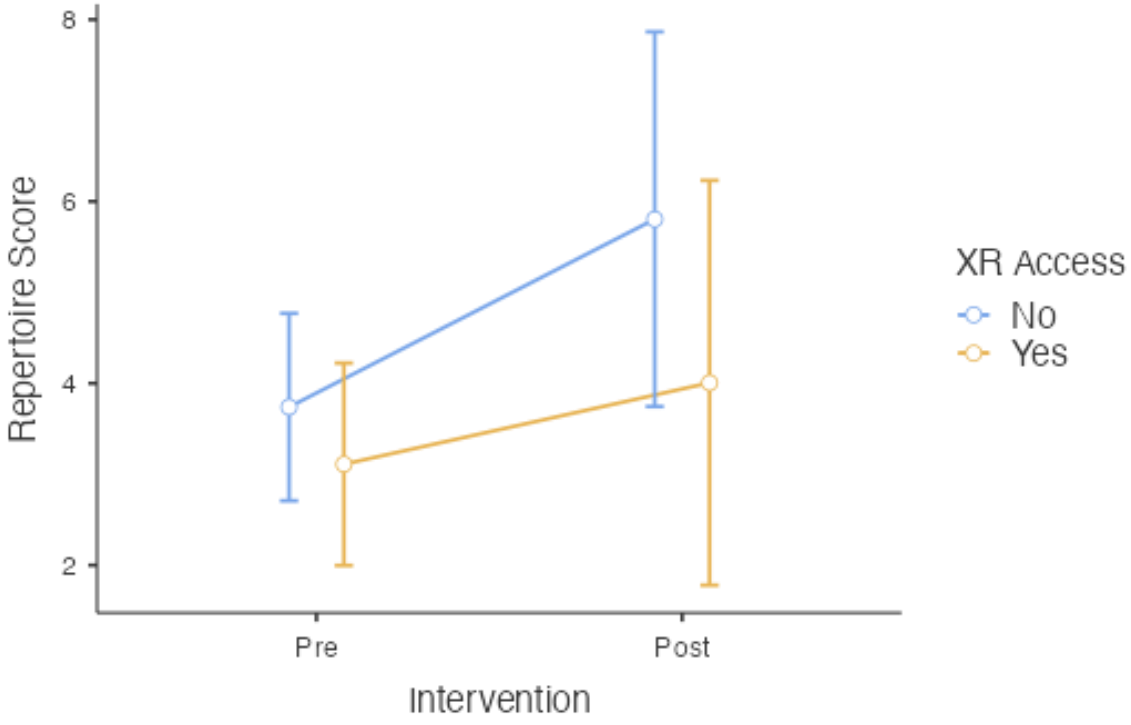

Figure 12: A significant increase in Repertoire ratings across both intervention groups

4.4.1 The Importance of Notation

The 'sidestepping' of the need to learn notation that led to greater progress in some areas was, paradoxically, also identified as a fundamental flaw of the technology. The headset display offers both 'cascade style' and traditional staff notation. Several tutors reported that the pupils were choosing to follow the cascade notation (n=5), with no pupils reported to be using the staff notation. This reliance on the cascade system presented a significant barrier to for pupils when they were asked to take the headset off and play using traditional staff notation.

> *I took him off the headset because he's playing something wrong and put him on the book. He couldn't play because he couldn't read it. So I was like 'ohhhh, so how do we get round that...' (T3)*

Several tutors had a strong negative reaction to this, feeling that pupils were learning individual pieces rather than 'how to play music', and that 'not learning how to read music' was equivalent

to ‘not learning music’. One tutor articulated this in terms of “longevity of learning” (T6): sheet notation allows you to “take that away and learn it across so many more things rather than being able to play one showy hard piece straight away to show off to your mates.”

Other tutors took a different view, noting that many musical styles (for example pop and rock) do not use staff notation as their primary means of communicating music: “I don't personally believe not having that education will stifle the a pupil in any way... and I do think it's possible to pick up site reading at any point in your life.”

4.5 AR Design Improvements and Future Use

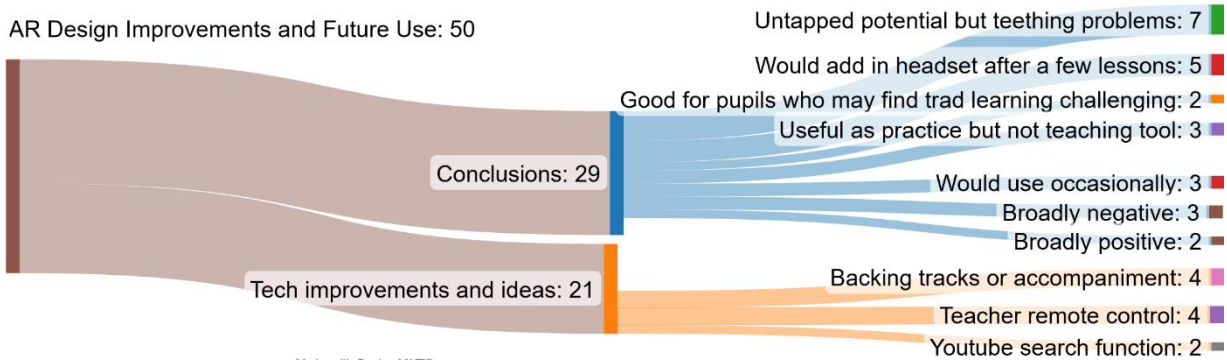

Figure 3: Design improvements and future use: Subthemes and code groups.

4.5.1 Design Improvements

Tutors engaged enthusiastically with discussions about how the app could be improved. Two discussions explored the idea of shared control of the app between tutors and pupils. This would allow tutors to temporarily take control of the app to select repertoire, pause and rewind the music remotely, and somehow point to specific parts of the music to provide feedback without the pupil needing to take the headset off. One teacher noted “if we could control the app then we would be controlling the learning which is more what we're used to, isn't it?” (T1)

Tutors also discussed the need for a more straightforward way of selecting a broader range of repertoire. One tutor suggested integrating the app with YouTube, allowing the numerous existing ‘cascade’ style videos to be mapped automatically onto a pupil’s piano using the app.

There were several other ideas for improvements raised and discussed in the focus groups:

- Add backing tracks/accompaniments to pieces in order to create a stronger sense of pulse;
- Automatic tempo recognition of imported tracks;
- A more detailed visual grid system, with representations for quaver and semi-quaver units of time in addition to crotchets;
- “Dialogue and text” within the app to explain musical elements and aid learning;
- An easier way of moving through different sections or bars of music using physical gestures, similar to the physical act of turning a page, or by ‘grabbing’ the notation display with a hand and moving it backwards and forwards;

- Mute audio on the device being cast to in order to reduce the effect of casting latency;
- A second linked device that displays a copy of the staff notation.

4.5.2 Future use of Augmented Reality

Despite the significant challenges reported, all six tutors felt AR had potential as a practice tool and that, assuming improvements in the technology, they *would* continue to use AR in their teaching in some contexts. One tutor summed up by stating:

> *I think it's got a load of untapped potential. I think it's just teething problems. I think it could be either really good as like a self-learning tool or if I'm meant to be teaching them with it, it needs to have more sort of detail to it. (T6)*

Another teacher said:

> *There's a lot of potential with it. It just needs to be better. [It] needs to be less glitchy, [there] needs to be much more repertoire and [it] needs to be easier to interact with it.* (T2)

Given the difficulties of teaching basic technique using the headset, two tutors suggested that the AR might be best deployed with non-beginners. One pupil tried it successfully with an intermediate pupil:

> *…he is already grade 2 standard… From sort of 10 minutes of using it, he was by far ahead of any of the pupils in the study with using it… [he] knows what he's doing with his hands. He knows the keys. It's kind of just a new way of interacting with the music*. (T6)

Other tutors suggested waiting several lessons before introducing it to complete beginners. This would allow basic elements of technique to be covered, for the rapport between pupil and tutor to be established, and for the tutor to have a better idea whether a particular pupil is likely to benefit from the technology. This was evidenced by the fact that two tutors felt that some of their pupils *with* access to AR didn't need it, but others that didn't have access to AR would have benefitted from having it.

One tutor stated that he was most likely to use the headset with pupils who were "the kind of people which would normally find traditional lessons a little bit dry, a little bit off-putting" (T4). They felt that the headset could act as a novel tool of engagement at the beginning stages of learning but were unsure as to the use of AR even with these pupils in the longer term.

5. Discussion

This first half of this discussion section addresses the initial research questions. The second half discusses the possible impact of the results on the future of AR in instrumental tuition through an adapted version of the Technology Acceptance Model (TAM) (Davis et al., 1989). Seven factors are identified that may influence the extent to which the technology will continue to be used and recommendations are offered for future research and development.

5.0 Addressing the Research Questions

The primary research question is: *How do music tutors perceive the use of the 'Pianovision' augmented reality app to teach beginner keyboard pupils aged 13-16?*

Overall, tutors' perceptions of the app were mixed. There were some perceived benefits to the AR technology. A majority of tutors believed that the AR increased pupil engagement, including through the gamification of their learning and the ability to play melodies from well-known, more complex pieces quickly and without the need for sheet music.

Some pupils learnt basic pieces more quickly and were able to play the melodies of more complex but familiar pieces almost instantly. Two of the 12 pupils overcame technical barriers that they encountered and were able to effectively learn complex pieces using the headset. Tutors emphasised that the technology is more suited to some pupils than others, including those with basic technique and those for whom the learning of staff notation may be a more significant barrier. Several tutors suggested that the technology should be introduced after the tutor has established an understanding of an individual pupils' needs, and once initial technique has been internalised.

The results also showed that the AR rarely supported, and in some cases inhibited, the development of correct playing technique, sight reading and development of rapport between pupil and tutor. There was no consistent increase rate of progress for the pupils using the headset compared to those receiving traditional lessons, though the technology did increase the speed of repertoire acquisition for some pupils in the first weeks of learning.

By the end of the project, a majority of tutors agreed that this application, or one like it, could in principle enhance their teaching, but that the software as it exists now is not technically reliable enough, and does not have the required teaching features, to be a consistently useful teaching tool for beginner pupils.

Sub-question 1. How do tutors' perceptions of AR change over time?

Before the teaching period began, most tutors acknowledged the importance of trying out new technologies in order to develop their own pedagogy and better meet the needs of pupils for whom AR and similar technologies are increasingly prevalent. Tutors anticipated that benefits would include adding variety to lessons, creating more 'equilibrium' in the learning tutor/pupil learning relationship, and increase engagement and practice time.

Tutors anticipated challenges with the technology itself and a potential negative impact on rapport within the lessons. These concerns were strengthened in the first 5-6 weeks of lessons, as many tutors struggled with perceived design and implementation flaws to the technology, leading to feelings of frustration and an increase in negative perceptions of the technology. Several tutors noted that pupils were not developing correct technique when using the headset, in particular the areas of fingering and articulation.

In the final 3-5 weeks, tutors reported an increase in confidence when using the technology and an increased understanding of how it could best serve their signature pedagogy. For example, some tutors found success experimenting with the inbuilt songs on the app, allowing pupils to explore more complex, familiar pieces.

By the end of the project all tutors stated that they would, given the opportunity, continue to use it as part of their wider teaching toolkit, but that in its current form it would not become a core part of most lessons.

2. In what ways does the incorporation of AR affect pedagogical approaches?

Tutors began the teaching period using the AR in a variety of ways in their lessons; some used it to 'bookend' the lessons while others used it for most or all of each lesson. By the end of the teaching period, all tutors were using a mixture of AR and non-AR teaching methods in each lesson.

The use of AR in lessons led to tutors have a less active role in the lessons. Some saw this as a positive aspect, believing that it gave autonomy to pupils. Others felt 'redundant', but suggested that the app could be developed to support new ways of tutor participation. Some tutors were able to give pupils feedback with the headset on, though some felt that the headset created a feeling of 'separation' between tutor and pupil.

There were mixed opinions about whether not needing to learn staff notation in order to learn repertoire was a positive or negative aspect of the technology. Some tutors felt that the technology was less of a tool for learning music and more of a 'game that happens to be on the piano', based on reaction and memorisation rather than developing musicality. Some tutors chose to take time away from the headset to develop sight reading skills. Others allowed pupils to acquire more complex repertoire without the concomitant sight-reading skills.

3. In what ways could the AR software be developed to better support teaching and learning?

Tutors identified several flaws in the technology and offered multiple suggestions about how the technology could be improved to better meet their needs. Limitations including issues with calibration of the keyboard, 'casting' to another device and physical discomfort with the headset. As well as mitigating these issues, suggestions for improvement included a stronger emphasis on learning staff notation within the app, more tutor control over the app itself, built-

in accompaniments or backing tracks, an explanation of musical concepts within the app, and easier access to a wider range or repertoire.

5.1 Future use of AR in instrumental tuition

In the final focus groups, tutors discussed if and how they might use AR technology in the future. There was a clear relationship between perceived usefulness of the technology as a teaching tool (its ability to engage and progress pupils' musicianship) and its perceived ease of use (reliability, design), and whether or not tutors intend to use the technology in the future.

This relationship is theorised Technology Acceptance Model (TAM) (fig. 14). The research team created an adapted version of the TAM (fig.15) to incorporate key findings from research and demonstrate how they relate to the likelihood of continued use of the technology.

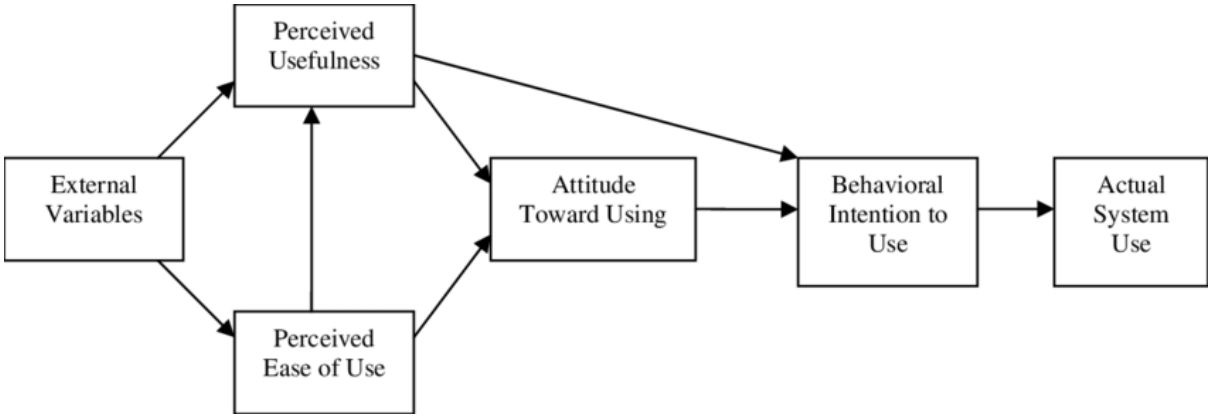

Figure 14: Illustration of the original Technology Acceptance Model (from Miller & Khera, 2010:3)

Three adaptations have been made to the original TAM model. Firstly, the 'external factors' section has been replaced with seven factors that the data show are likely to have influenced tutor perceptions of the technology. Four factors relate to perceived usefulness, while three relate to perceived ease of use. They are:

Perceived Usefulness

1. *Tutor attitudes relating to staff notation*
2. *Repertoire acquisition*
3. *Technique development*
4. *Pupil engagement*

Perceived Ease of Use

1. *Software design and reliability*
2. *Acclimatisation period*
3. *Headset use within lessons*

The second adaptation is the addition of 'pupil selection' as an additional mitigating factor. The data suggest that the AR was perceived to be more valuable for some pupils and less for others. Tutors suggested that they would use the technology with pupils who may benefit the most from it, including those who already had some basic technique, and those who may struggle with traditional teaching methods. This is made explicit within the model, highlighting the need for pupil selection to be a key factor when designing future research in this area.

The last adaptation of the model replaces 'behavioural intention to use' and 'actual system use' with 'continued use in lessons'. This aligns the model more specifically with this area of research.

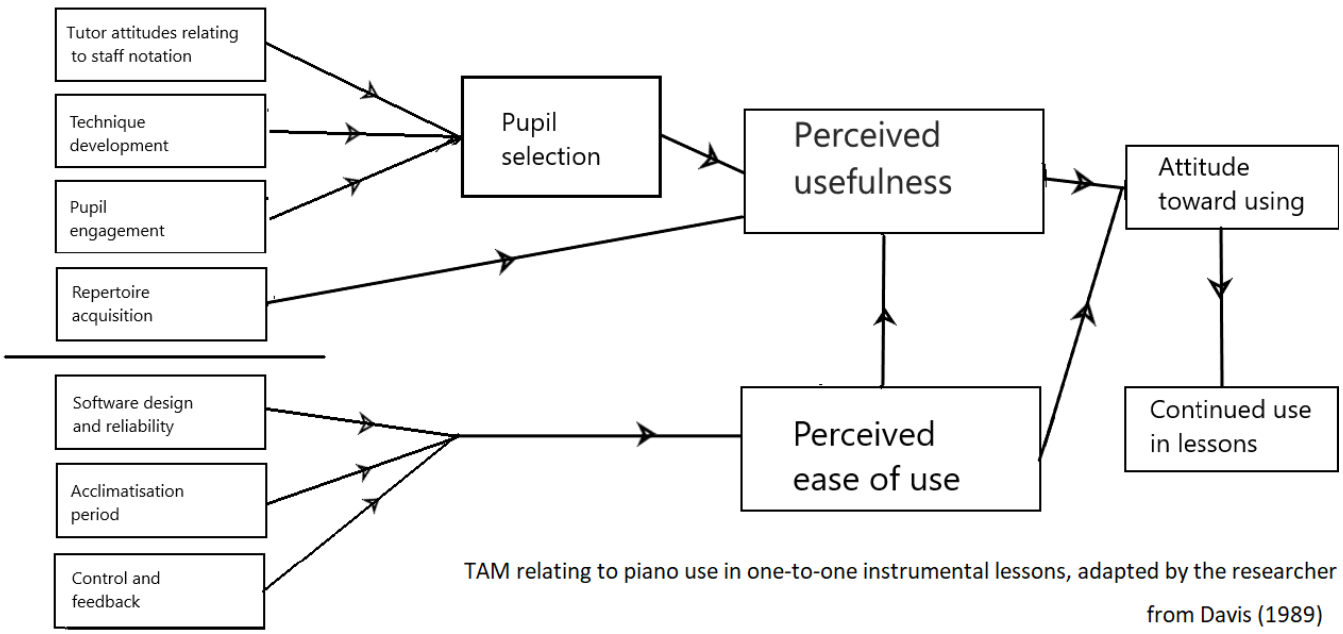

Figure 15: A contextualisation of research results within an adapted version of the TAM

5.2 Perceived Usefulness

5.2.1 Tutor attitudes relating to staff notation

Tutors' attitudes and beliefs around the nature of musical learning play an important role in their perception of the usefulness of AR technology. One clear example of this is around attitudes towards the relative importance of learning staff notation.

It became clear in the first half of the research period that, echoing Chow's (2013) study, pupils were choosing to focus on the cascade notation, rather than the staff notation, within the application. This led to tutors either teaching staff notation away from the headset and/or putting less emphasis on the development of notation reading within the lessons.

For some tutors this demonstrated the inherent limitations of the technology, and was an indication of its lack of function, as previously reported by Deja et al. (2021). Others contextualised the 'sidestepping' of notation within a belief that an understanding of staff notation was not an essential requirement of a student musician's skill set and would not be required to play some styles of music. Two tutors also identified the possible benefits of AR for pupils who may struggle with notation, for example pupils with specific learning difficulties e.g. dyslexia.

Recommendations

Incorporating these contrasting perspectives into possible future research and technology development, the following recommendations are made:

- Future AR systems could place greater emphasis on staff notation, for example by overlaying traditional note lengths above individual cascade notes. Previous studies identify various ways to do this (Birhanu, 2017, Cai et al., 2019).
- Future research could focus on the value of AR for pupils for whom staff notation is creating a significant barrier (rather than opportunity) to musical learning. This could include individuals with a specific learning difficulty.

5.2.2 Technique Development

Tutors reported that beginner pupils using the headsets developed poor fingering technique, posture and articulation skills. Several tutors stated that pupils who had moved beyond beginner stages and already learnt fundamental technique would benefit more from the AR technology.

Recommendations

A study that focussed on pupils who have already acquired fundamental technique would be a clear next step for this research.

5.2.3 Pupil Engagement

The effect of AR on pupil engagement was mixed. Tutors reported that the gamification elements, when operating correctly, as well as the virtual concert hall mode, significantly increased engagement (see also Molero et al., 2021). Others stated that the visual barrier of the headset decreased teacher-pupil rapport and, ultimately, engagement. However, it is likely that advances in augmented reality, which will allow the AR user to see both their tutor and the additional virtual information, will be commonplace in the coming years (Turchet, 2021).

5.2.4 Repertoire Acquisition

Tutors reported that many pupils picked up both simple pieces and well-known, more complex pieces more quickly when using the AR headset. This was identified as one significant benefit of the technology. However, they also stated that the process of uploading and finding new pieces felt complicated and convoluted.

Recommendations

Alongside streamlining the upload process on the software, one tutor suggested integrating the AR app with existing YouTube piano cascade style videos.

5.3 Perceived ease of use

The data clearly show that initial difficulties around setting up the technology and using it as a teaching tool, combined with a lack of reliability around headset calibration, influenced perceptions of ease of use and impacted teacher attitudes and pupil use of the headset for home practice. Related to this, one tutor reflected that their own negative attitudes that were expressed to one pupil may have influenced that pupil's attitude, and therefore their decision to use it for home practice.

5.3.1 Software design and reliability

The researchers considered the software application, Pianovision, that was used for the experiment, to be the most technically advanced and suitable software for the project. However, it is a very new system and was still in its development stage during the research period. Four of the six participants were able to test the headsets for a period of between 4-8 weeks before the teaching period began, but none were able to test the reliability of the software within a teaching setting. This meant that many limitations of the technology, as documented in the results section, were only discovered during the research period.

Recommendations

A longer and more rigorous pilot phase should be implemented with a new technology before data around efficacy within lessons is collected.

5.3.2 Acclimatisation to technology

The research results show that many tutors' acclimatisation to the technology lasted for several weeks. Tutors reported significant challenges with the set up and use of the technology during the first 3-6 weeks of the project, as well as a period of experimentation with how best they could utilise it within their lessons.

Recommendations

Future experiments could include an additional pre-teaching period of acclimatisation with the technology within a teaching context. This would allow tutors to be more confident with both the technical aspects of the technology and the areas in which it could support their teaching. This may lead to increased pupil engagement and progress and a more positive perception of the technology.

5.3.3 Control & Feedback

Some tutors reported feeling 'out of control' and unable to give timely feedback when pupils were using the headsets. Others appreciated the chance to 'sit back' and have more time and space to observe pupils' playing. Considered through the lens of transformative pedagogy in piano tuition (Coutts, 2019; Chmurzynska 2012), it could be argued that a tutor's loss of control is concomitant with pupils gaining control, allowing a redefinition of the power relationship between pupil and tutor and an increase in pupil self-efficacy.

Recommendations

- Future research on AR in piano tuition could focus on the impact of the technology on pupil self-efficacy.

- New features of the software, such as allowing the tutor to pause playing, move more easily between sections and be able to virtually ‘point’ to specific areas of the music were suggested by tutors as ways to increase tutor control.

6. Conclusion

This research investigated how tutors responded to the incorporation of an AR piano application in their lessons, how the use of the application changed their pedagogical approaches, and how the application could be developed to better support teaching and learning.

Though limited in scope, the research has identified key areas of challenge and potential for music hubs, technologists and individual tutors who are interested in using augmented reality as a teaching tool. By framing the discussion within an adapted TAM, the research has drawn links between the findings and the research's wider goal of providing insight and guidance to the music education sector.

For individual tutors, the research has identified the areas that AR can currently support teaching: increasing engagement; more rapid development of both beginner repertoire and more complex, familiar pieces; increased autonomy over the learning process for some pupils. It has also identified the limitations of the technology and areas that still require a traditional, tutor led model.

For music hubs, the research suggests that there is significant potential for this technology, but that further development needs to take place before AR matures into a technology that will be taken up more consistently.

For the research community, several areas of further study have been identified, including using the technology with non-beginner pupils and those who may find traditional lessons less accessible.

For the developers of AR instrumental teaching products, the research offers an extensive list of suggests for future features and areas of pedagogical focus.

For both the education and technology sectors, this research demonstrates that piano tutors have much to offer the developers of music education technology. It is the aim of the research team to promote the voices of educators during the conception and development of future technologies.

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