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*Augmented reality: Examining its value in a music technology classroom.
Practice and potential*

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Augmented reality: Examining its value in a music technology classroom. Practice and potential

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Abstract

Augmented reality (AR) provides exciting opportunities for advancing the design and practice of classroom instruction. AR can facilitate unique opportunities for students to conceptualise, understand and recall learning content. AR offers students contextual learning experiences. These views suggest that AR can assist in reducing distances between learner's knowledge and what they need to understand. In my senior music classroom, I tested these ideas, wanting to see if students, through using AR, could visualise relationships between component parts, describe their function and use that knowledge in practice. The focus centred on students need to construct a sound system for performance in a Year 12 music class (16–17 years old). The project question was; Would AR aid the understanding and conceptualisation of content and develop the quality and retention of their learning? Through observation, interviews and a questionnaire, I used these data to understand levels of knowledge retention, conceptualisation and understanding of content. Findings indicate that while students displayed content conceptualisation skills, they also showed secure knowledge retention in line with previous studies. An encouraging finding suggests that in using AR, students retained what they had learned, remembering the function and use of various components after one learning experience. The potential impact of new and emerging technologies such as AR on student progress and instructional design is exciting, offering alternative ways of delivering and mediating learning content and concepts that connect with teaching and learning.

Keywords

Augmented reality; music technology; contextual learning; knowledge retention.

Introduction and background

This paper is structured as follows: The impact that digital technologies are having on the educational space. A description of augmented reality (AR). A description and context of the task. This is followed by Affordances of augmented reality; Methodology and study design; Findings: Discussion/conclusion.

Practices that are used to educate students are in a state of fundamental reconfiguration and transformation (Balkin & Sonnevend, 2016). Music technology in secondary education, in the form of

individualised computer tutoring of music theory, is an example of the rapid pace of this change. Digital technology is increasingly impacting how educational content can be delivered. Digital technology is also providing teachers with tools to innovate and experiment with development of pedagogy and practice in secondary education (McPhail, Thorpe & Wise, 2018).

AR is a technology that blends physical and virtual words. It primarily involves superimposing digital content over real world footage viewed on a screen such as an iPad. Virtual reality (VR), in contrast, immerses the user in a completely computer-generated environment via a headset. The main difference between AR and VR is VR seeks to replace the real word and AR aims to supplement the real world (Kesim & Ozarslan, 2012). AR can be described as a type of mixed reality where real-world content is overlaid and transplanted into a virtual environment. The distinguishing aspect of AR is its ability to seamlessly composite virtual objects onto a real-world environment in a way that is contextually relevant (Bower, Howe, McCredie, Robinson, & Grover, 2014).

My interest in AR stemmed from three aspects—how does AR work? Is it effective? Can I use AR in my teaching?

In planning for instructional responsibilities needed to support this project, I investigated the skill set and support I would need and the selecting of the AR content delivery system. Ottenbreit-Leftwich, Glazewski, Newby and Ertmer (2010) comment on key aspects needed to support investigative experimentation with emerging technologies, including specified time allowance to investigate the technology, motivation of the teacher and administrative encouragement and endorsement of the project. These three aspects played key roles in the implementation of the project.

The construction of the AR content and delivery did not need specific technology skills, e.g., the ability to write code. Video animations were constructed in a program called Moovely and loaded into an App called Aurasma installed on 15 school iPads. Neither of the programs required high level technology skills and were pitched at entry level ICT capabilities. An ongoing issue with using emerging digital technology in the context of meeting future learning objects in a sustainable way is the high iteration rate of products and services. For example, the Aurasma App used to deliver the AR content of this project has been purchased by an international company and reconfigured to reach a wider audience. This has resulted in a change to the way the App functions.

I teach in an urban secondary school. The students involved with this report are Year 12 with a mix of New Zealand European (9), Māori (2), Polynesian (1), Filipino (1) and Japanese (1) students. The gender balance was eight females and six males. The cohort was typical for the music technology class compared with previous years. This included student numbers (10–15) and a mix of students who had low (7 students), medium (6 students) and high (1 student) levels of confidence using technology for learning tasks. The students had no prior exposure to learning tasks using AR. The iPads used to deliver the AR content were owned by the school. The technical threshold needed for students was low and involved students using target images in the workbook to initiate the AR content facilitated by the iPad. Students were canvassed as to using AR for this task and resulted in all students being in favour of using the AR system. Consideration was given to students with specific learning needs which included extra support if needed and consultation with learning support staff. The task the students undertook was assembling and operating a public address sound system (PA). This included connecting amplifiers to speakers and a mid-sized audio mixing desk along with microphones. The task was conducted over six weeks in a music technology classroom. The students' learning experiences were recorded via questionnaire, observation and interviews with the teacher.

A persistent challenge in this music technology course is the teaching of relationships of componentry and their interrelated functions. Students find it difficult to visualise how component parts are connected and the process of assembling the system. An aspect of this is signal flow of audio data from the source to the speaker and the listener. In previous years, students have complained about the complexity of the information. Instruction resources produced by the teacher included a one-dimensional schematic of the connections of componentry and the direction of signal flow (Figure 1). I felt there was an added depth of learning and content knowledge that could be added to enhance student conceptualisation of content. As a master's project, I investigated how AR could be leveraged to develop student conceptualisation of content. One of the project's objectives was to gain insight into the experiences of the students and how they perceived the use of AR for instruction and learning.
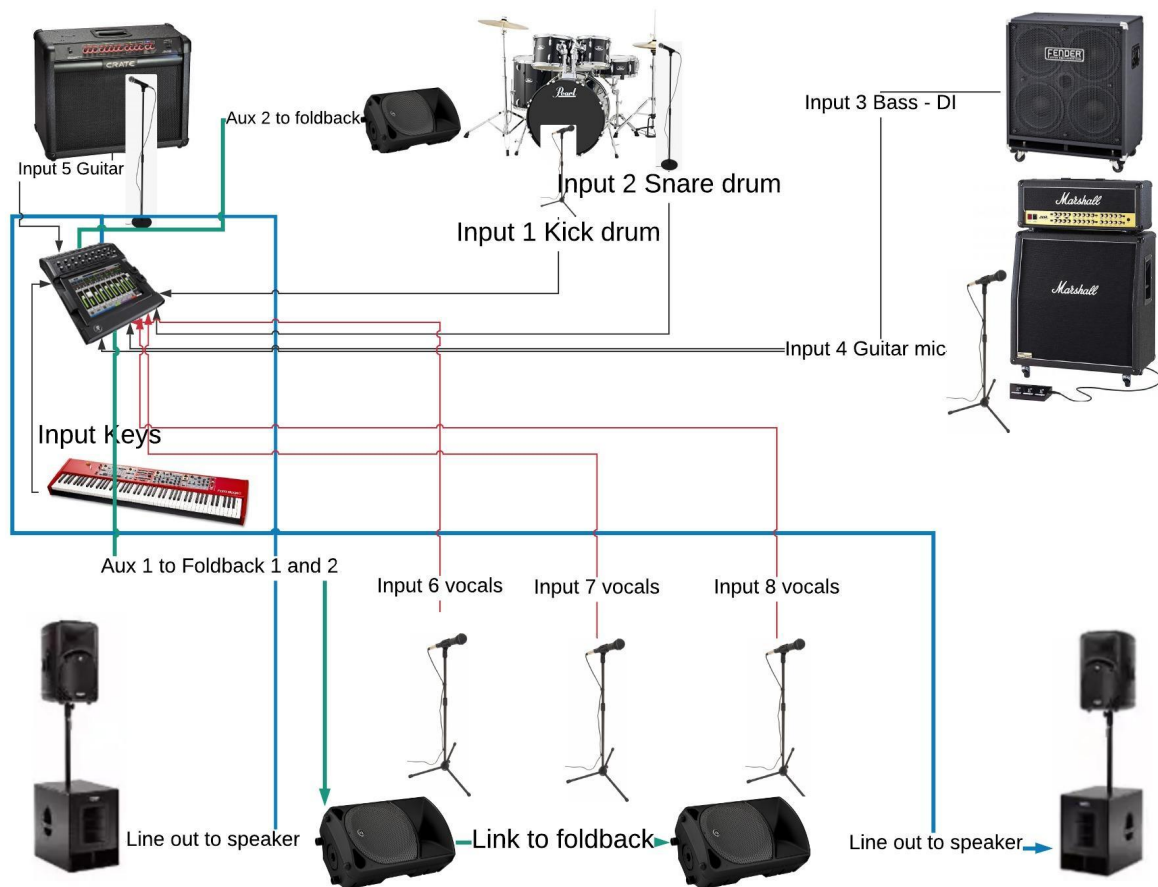
Figure 1. **Schematic of connections of componentry and direction of signal flow.**

Affordances of augmented reality

Develop content understanding

AR has been shown to develop content understanding and can be more effective when compared with books, videos or desktop experiences (Radu, 2014; Wu, Lee, Chang & Liang, 2013). Understanding a complex system setup with diagrams and cables represented on paper can be a difficult undertaking (see Figure 1). AR provides contextual scaffolding for the student to be able to view the relationship between different components of the system in a way that is not possible with paper. This includes being able to view components in 3D space and zoom in and out to discover detail (Billinghurst & Dünser, 2012; Diaz, Hincapié & Moreno, 2015). Research by Seo, Kim and Kim (2006) found that students who used AR to learn about volcanoes performed better than students who did not use AR on the same learning task. Similarly, a study by Sin and Zaman (2010) found that students learning about the solar system who used AR improved their pre-test scores by 46 percent compared to students who used textbooks improved by 27 percent.

Conceptualisation of content

AR has shown to increase students' conceptualisation of content. Lindgren and Moshell (2011) compared students' learning about astronomy. One group used AR within a mixed reality context while the other group used a PC application. Qualitative analysis found the group using AR to display how

the planets interacted together displayed a deeper understanding compared to the second group who seemed more focused on the visual look of the planets. This is an important aspect of why I selected AR as the content delivery method. In previous classes, students have commented on the difficulty of being able to understand the various componentry and how it was connected piece by piece. Additionally, there was a requirement of understanding of how the system worked in order to produce sound. Using AR, the students were able to directly engage with the content and this has had an impact on the way the students are able to conceptualise the information.

Contextual learning experience

AR can provide a contextual learning experience that combines complex problem solving together with teamwork which creates engaging educational experiences (Billinghurst & Dünser, 2012). AR can provide powerful learning experiences that are authentic, can take place in real time and are interactive (Chen & Tsai, 2012). This contextual learning was a key component of my teaching strategy. AR provided the means for this to take place. Billinghurst, Kato and Poupyrev (2001) describe the advantages of combining virtual and real-world data, "The process of combining virtual data with real-world data can provide users with access to rich and meaningful multimedia content that is contextually relevant and can be easily and immediately acted upon" (p. 6). Bower et al., (2014) comment on the capacity of AR to create a contextually relevant learning environment. This is due to the ability of AR to seamlessly composite virtual objects with real-word environments. Students are able to locate and discover important connections between components that may be difficult or not possible with paper-based one-dimensional systems. Radu (2014) describes the ability of AR to construct contextual learning experiences as in situ interactive visualisations, where students can manipulate and investigate interactions between components. AR has been shown to increase content understanding because of its ability to present multimedia content that is contextually relevant. This is represented by the student being placed contextually in the center of the learning environment and being able to reference and place new learning content in the real world (Lindgren & Moshell, 2011).

Memory retention

Radu (2014) comments that research indicates long term memory retention when using AR systems as superior to non-AR systems. In a study by Vincenzi et al. (2003), students were shown to recall content learned with AR significantly better compared with students who did not use AR. Macchiarella and Vincenzi (2004) found that students learning about turbines using AR outperformed students who did not use AR when tested one week later. A comparative study by Perez-Lopez and Contero (2013), looking at knowledge retention in students learning the digestive and circulatory systems, found a significant increase in knowledge retention. Students who used the AR system outperformed students who used a paper-based system in knowledge retention when retested.

AR offers a number of advantages over traditional teaching context. Diaz et al., (2015, p. 206) describe four affordances of AR:

i.   AR has an ability to encourage kinaesthetic learning, practical - hands on.

ii.   AR can support students by inspecting the 3D object or class materials from a variety of different perspectives or angles to enhance their understanding,

iii. AR increases the student's level of engagement and motivation in academic activities.

iv.   AR provides contextual information, that is, data about real objects of the scene related to the learning activity.

Methodology and study design

Project question: Would AR aid the understanding and conceptualisation of content and develop the quality and retention of their learning? Being investigated was the ability of AR to enrich the conceptualisation of content and develop the retention of learning over time. The research design is qualitative and utilised observation, interviews and questionnaires to investigate knowledge retention, conceptualisation of content, perceptions, and attitudes.

The primary orientation of the project was Interpretivism. Interpretivism is concerned with the experiences, attitudes and perceptions of subjects (Scotland, 2012). This approach provides the researcher with the information with which they can construct insight into actions and attitudes of the subjects. An advantage of Interpretivism is that it can afford a deep understanding of complex interactions between the subject, content and context (Scotland, 2012). A limitation of Interpretivism is that it views the subject's experiences through a subjective lens held by the researcher. This can introduce bias and findings which are affected by the researchers' own interpretations (Scotland, 2012). In order to help mitigate bias, critical discussions of findings were held with department staff and leaders of learning in the school.

A central tenet of the interpretive approach is constructivism. Constructivism asserts that students need to move from the role of a passive recipient of knowledge to active constructors of their own knowledge (Hacker & Niederhauser, 2000). Constructivism posits the importance of students gathering and exploring information from their environment and constructing their own knowledge and understanding of it. Students being able to construct their own knowledge through investigation, collaboration with peers, trial and error and experience, is an important component in students taking ownership of new knowledge. This, in turn, contributes to increased student confidence and self-efficacy (Bangert, 2004).

Situated cognition theory was used as the framework for the design of the learning activity. Situation cognition theory posits that knowledge is embedded in the activity and learning context (Aydede & Robbins, 2009; Brown, Collins & Duguid, 1989). Chao, Chang, Lan, Kinshuk and Sung (2016) describe the main philosophy of situated cognition as "the idea that knowledge is situated in an authentic context and that learning is an actively cognizing process that interacts with this context" (p. 2). AR provides an effective and powerful conduit for the process of conceptual content interacting with real-world content.

An important aspect of situated cognition is cognitive apprenticeship and is centred around the idea of students being nurtured by a tutor to develop professional competence (Lin, Hsu & Cheng, 2011). Cognitive apprenticeship is an established method of instruction focusing on observation and coaching and less on didactic methods (Collins, Brown & Newman, 1988). The teacher spent several sessions with students discussing the role of componentry and task objectives before using AR resources. Cognitive apprenticeship rests on the theory that people learn from each other through observation, imitation and modelling (Collins et al., 1988). This rationale was also used in the learning design of having two students using the AR system while being observed by the rest of the class. This concept was developed further by employing legitimate peripheral participation (LPP), in which learners observe and imitate what is being taught (Lin et al., 2011). This was the rationale for having two pairs of students involved in the process of setting up the sound system. While one group was learning how to use AR, the other two students had the opportunity to observe and imitate what the other students had experienced before them.

Selection of technology

I selected the iPad as the interface for the AR app because I needed portability and wireless connectivity. Students needed to be able to walk around the PA system in order to contextually view the content in-situ and be able to check and recheck their learning. The iPad provides an opportunity for students to interact with the content and promotes discovery learning. The affordances of the iPad for education are well documented and have a high engagement and enjoyment factor with students. This, combined with

portability and the ability to promote collaborative learning, made the iPad a secure choice for content delivery.

Churchill, Fox and King (2012) describe five affordances of the iPad:

1. Portability—handhelds can be taken to different locations.
2. Social interactivity—handhelds can be used to collaborate with other people.
3. Context sensitivity—handhelds can be used to gather and display real or simulated data.
4. Connectivity—handhelds enable connection to data collection devices, other handhelds, and to networks.
5. Individuality—handhelds can provide scaffolding for learners.

There were a few technical issues but the iPad's worked effectively. Occasionally an iPad needed to be reset or re-imaged but apart from that, there were no major issues using the AR system with the iPad. Having reliability of the technology enabled me to move forward with the project with confidence.

Selection of apps

The cloud-based app Aurasma (now known as HP Reveal) was chosen because of its ability to overcome the processing and resource constraints of the iPads. The processing and heavy lifting of the AR content were on cloud-based servers and this provided a seamless AR learning experience for the students.

An added advantage of the Aurasma app is the information is hosted in the cloud and is scalable. If I needed to amend content I could manage that in the cloud database of the app. Updated content was pushed out across all the iPads and the Aurasma App. If an app's content was locally hosted on the iPad it would have been a large amount of work if I needed to alter any of the content. This was because I would have needed to change each individual iPad. Cloud-based computing was a critical component in the design of the technology for this project because of scalability, lack of maintenance and computational power. The iPad simply would not have been able to deliver the learning in the form that I wanted if the content was loaded on the iPad. Access to the power of cloud-based servers to perform all the necessary calculations empowered AR to work in the classroom.

AR animation content was produced using the cloud-based App Moovly and then loaded onto the Aurasma website for access by the iPad Aurasma App. Further consideration of choosing a cloud-based app was that I wanted to have direct access to the process of changing the AR content without needing to go through the school IT support provider. Having the school IT support provider run the technical aspects of the project may have placed a significant drag on the design and application of the project. One advantage of cloud-based apps is that this can be avoided.

Students used a paper booklet with target images (Figures 2–6) to generate the AR content facilitated by the apps on the iPad. Students would move sequentially through the setup process. Students were able to revise and repeat the AR content at each point before moving on to the next section.

Design of AR environment

The AR environment comprised five sections of a task book which represented five learning tasks. Once recognised by the App, animated AR videos would play. The task book images (Figures 2–6) needed to be unique in order for the AR app to recognise, load and play the animated AR video. Cuendet, Bonnard, Do-Lenh and Dillenbourg (2013) acknowledge the importance of using an activity booklet to host and display the sequence of the AR content. I constructed a paper booklet which hosted the target images for each aspect of setting up the sound system. I put them together in a sequence that led the students to work through the setting up of the system in the correct order. This was important as students were able to become familiar with the sequence of the setup using AR and if they needed to go back a step all they needed to do was to go back one step in the booklet. Figure 7 details how the AR content is accessed by the App. The video linked to the target image contained animation which depicted how the XLR audio

signal cables connected to the componentry (figures 8 & 9). By moving the iPad closer or further away from the task book students were able to zoom in and out of the details of the componentry.

Foldback speaker

Mixer input
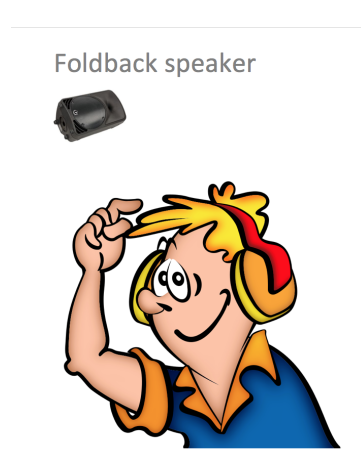
Mixer to FOH

Figure 2.

Figure 3.

Figure 4.

Top Speaker

Sub Speaker

Figure 5.

Figure 6.

To launch the Aura:

1. Open the HP Reveal app on your phone or tablet and log in using the same username and password as your HP Reveal Studio account.
2. Go to the "Auras" tab within the "Explore" section and drag the page downward to refresh the Auras.
3. Select the app's viewfinder and point your device at the Trigger image below to preview your Aura.

☐ Don't show me this again

Download HP Reveal   Focus on the image   Watch it come to life

Figure 7.   Aurasma (HP Reveal) App instructions of use. Poster is a target image.

Connect the left and right Sub speakers here

Figure 8.   Screenshot of animated AR content.
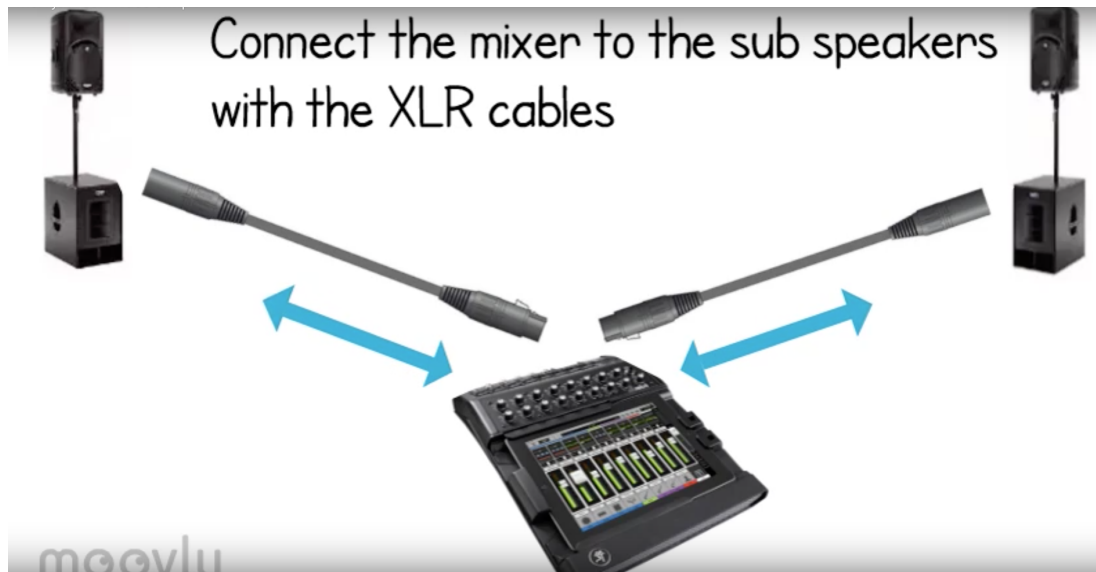
Figure 9.   Screenshot of animated AR content.

Data collection

I used a triangulation of observation, interview and questionnaire methods to assess the students' perceptions, performance and attitudes. Observation is an accepted method of complementing other research methods because it can triangulate with other data collection methods and strengthen the interpretation of the findings (Menter, 2011). A strength of the observation method is that it can use both visual and aural information to describe the particular context and who was involved. It can also be used to describe photographic evidence or video evidence. Observation needs to be systematic, as such, I reviewed observation notes after the sessions for themes.

Menter (2011) describes three affordances of observation:

- Observation is useful for confirming and corroborating information from interviews.
- Observation allows for detailed information to be gathered in a natural context—can be less intrusive than other methods.
- Observation also attunes the researcher to look for important behaviours and activities highlights what those things are.

Using observation, I was looking for increases in efficiency of the students' methodology and assembling of the sound system over the six weeks. Evidence of this was students being able to select different microphones and different instrument leads and being able to use the correct procedure for powering the sound system up and down (on and off). I was observing the students to see if they were making the same mistakes and how they would correct that mistake from session to session. I observed how the team dynamics were impacted by the learning process and how the students perceived their learning experience. Observation data was recorded and used to corroborate questionnaire and interview data.

Interviewing is a flexible qualitative approach to illuminating and discovering information that investigates what the students are thinking about and helps to understand their attitudes, motivation, perceptions and experience (Cohen, Manion, & Morrison, 2011). One aspect of the interview method is that it is able to complement the other qualitative methods I am using. The interviews helped me to interpret and understand what the students were talking about and describing.

Student interviews were captured on video at the end of the performance of the task. The interviews were then analysed to decode information that corroborated or contrasted the information from the other data collection methods. One advantage of the interview method is that students can put their views and understanding forward. I used the semi-structured informal interview method as the interactive nature,

and the pre-chosen topic of the interview allowed me to adapt questions in order to confirm what the student was talking about and to probe into information that the students were giving me.

The interviews were kept under three minutes in order to be able to minimise the amount of time of analysing the data regarding decoding the information. The interview questions focused on whether the student had used this kind of system before and ease of use of the iPads to deliver the content; the experience, how students found using the AR animations and if the animations helped or hindered their conceptualisation of the system.

Questionnaires were delivered by Google forms. The questions covered the students' perceptions of the ease of use of the AR system and their levels of confidence in using the iPads with the AR content. The questions were on a scale of 1–5, *How useful do you think AR will be in helping you understand the sound system setup? 1 = not very useful, 5 = very useful* and were delivered pre and post use of the AR system.

Findings

Conceptualisation of content

The AR system was able to provide students with a bird's eye view of the system (Lindgren & Moshell, 2011). The advantage of conceptualisation of content that AR affords has seen an increase in the quality of student comments compared to previous cohorts' comments recorded in task books at the same stage of the task.

Viewing the setting up and relationships of the different components within five different AR presentations enabled the students to conceptualise the content in a way that was much easier than trying to remember it from a schematic drawing. The results compared with previous cohorts were:

- Increase in in-depth and knowledgeable comments. Students were able to accurately identify componentry and explain the role of the components in the system.
- The speed of setting up the system had improved. In the past, some students have not completed the system setup in 1 hour. The average setup time with AR was 40–50 minutes, with some pairs of students achieving full setup in 30 minutes.
- Fewer mistakes. By the third practise, the level of mistakes had dropped with most student pairs being error free.
- Greater accuracy. Students were able to identify the correct cables and connection order of componentry correctly.
- Eleven out of fourteen students completed a successful system setup.

When asked if using the AR system contributed to a clear understanding of the PA system setup and operation students commented:

> *"The iPad told me where to put the cables and made the whole lot easier than reading off a piece of paper. It was easier to understand."*

> *"It was really easy to use the iPad ... Being visual was easy for me to learn, step by step."*

> *"I had no clue how to set these up, but with the iPad and the pieces of [trigger AR] paper I was able to figure out where all these cables go."*

Increased content understanding

Students were more able to describe the function and operation of the sound system (Radu, 2014). I have been teaching this standard for several years. The level of content understanding of the students using AR was more advanced and deeper than other classes that I have had at the same stage. Students were able to describe componentry, its place in the system and why it is important, without reference to

printed matter and directly from the experience of setting up the sound system. Increased content knowledge and understanding was evident after only one use of the AR system. Evidence included fewer mistakes, greater speed of setting up the system and in-depth and knowledgeable comments. The AR system was able to help simplify complex relationships. The students were able to describe the signal flow, comprehend and explain the importance of component parts and their use in the system.

Memory retention

This was the most encouraging aspect of using AR. Previous cohorts have struggled to recall what they had learned the previous week. All students displayed increased memory retention compared with previous cohorts after one week. This is in line with the findings of Macchiarella and Vincenzi (2004) and Vincenzi et al. (2003), who describe AR as impacting on long term memory by reducing the amount of information forgotten—in other words, simplifying the learning and reducing the amount learners need to remember. The researchers found that learners who used AR forgot less over time compared to those who did not use AR and that AR appeared to more effectively encode information into long term memory. Patzer, Smith and Keebler (2014) similarly found that students who used an AR system to learn scales on the guitar were significantly better at performing the scale after a two-week waiting period compared to learners who did not use the AR system. This apparent ability to more effectively encode information was displayed in my AR project. Out of the seven teams of two students, one team completed a successful set up of the sound system four weeks after using AR for the first time. Due to student illness and term holidays, the same two students did not re-engage with the AR system for four weeks. When asked to have a run through in preparation for an assessment of setting up the system, both students replied that they felt confident in setting up the system without the support of the iPads and the AR system. I was sceptical that they would be able to set up the system from memory without AR because they had not engaged with the content for four weeks. This was a test of the capability of AR to deliver learning that was instructive, comprehensible and durable. The students completed the setup successfully in 50 minutes completely from memory. This was an important outcome and highlighted the ability of AR to provide deep learning and knowledge retention via conceptualisation of content and increased content understanding.

Contextual learning experience

The affordance of AR to facilitate a contextual learning experience is an integral part of providing an engaging educational experience for students (Billinghurst & Dünser, 2012). Students were able to engage in complex problem solving facilitated and mediated by teamwork and AR situated within an authentic learning environment (Chen & Tsai, 2012). Students valued the combination of real-world data (information) and virtual data (AR animations) to construct working models of how the sound system was constructed and functioned. This learning experience was encompassed in a real-world learning environment—setting up for a band performance—and supported by virtual representations of connection of componentry and direction of audio signal flow facilitated by AR.
    One student commented,

> *"It [AR] showed you details on where to place the cables and having the cables animated from one connection to the next made understanding the setup much easier."*

International student

The cohort contained one Japanese international student. When the student was asked how easy the AR system was to understand on a scale of 1 = hard to 10 = easy, the student rated it a 7. The student explained that the visual animations were easier to remember than a paper schematic. The collaborative aspect of using the iPads helped the student to work with a partner and co-construct the information they needed to complete the setup. The student found reading the standard resource book about setting up

the sound system very difficult to decode. The student noted that the AR system was much easier to understand and use. The student's first experience of using the AR system was spread across two days and commented that it was easy to pick up from the previous day.

Table 1.   *Key Findings of the Augmented Reality Project*

Categories	Examples of evidence from AR Project	Supporting research
Increased content understanding.	All students were able to describe the setup, functioning and operation of the sound system using technical language.	Diaz et al. (2015). Lindgren & Moshell (2011).
Increased knowledge retention.	Four weeks after the initial lesson, students remembered what the AR had taught them and set up and operated the sound system without using AR. Out of 14 students 11 were able to set up and run the system without referring to the AR or diagrams.	Patzer et al. (2014). Vincenzi et al. (2003). Perez-Lopez & Contero (2013). Macchiarella & Vincenzi (2004).
Breaking down the complexity of the learning.	Students were able to break down the constituent parts of the learning and visualise the signal flow.	Billinghurst & Dünser (2012). Diaz et al. (2015).

Student questionnaire

After an introduction to AR and how it would be used in the task, students were asked to comment on their perceptions about how useful they thought AR would be in helping them understand the setup of the sound system. The questionnaire was also administered after students used the AR system to gauge if their perceptions had changed. While some students were away on the day of the post administration of the questionnaire, the results suggest that students found the AR system helpful in being able to understand the setup of the sound system.
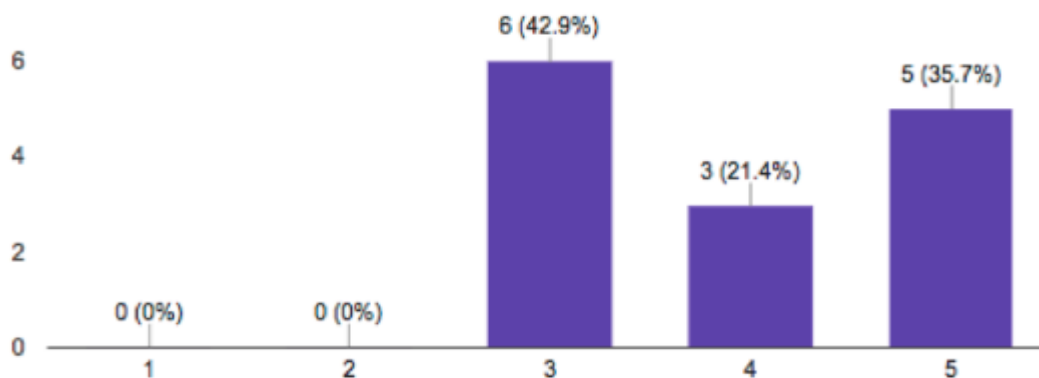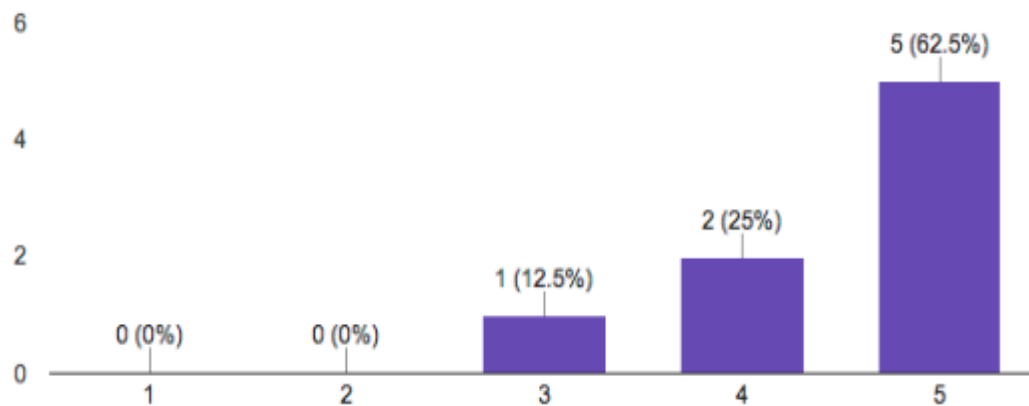

Figure 10.   Perceptions of students prior to the use of the AR system

Question: How useful do you think AR will be in helping you understand the sound system setup?
1 = not very useful, 5 = very useful.
14 student responses.

Figure 11.   Perceptions of student post use of the AR system.

Question; How useful did you find AR in helping you understand the sound system setup?
1 = not very useful, 5 = very useful.
8 student responses. Note: A number of students were away from school on the day of the post survey.

Discussion/conclusion

Situated cognition theory (Aydede & Robbins, 2009; Brown et al., 1989) was used as the framework for the design of the learning task. Situation cognition theory posits that people's knowledge is embedded in the activity and learning context. Aydede and Robbins (2009) describe situated cognition theory as emphasising that knowledge is constructed in the act and context of the activity. The design of the learning task focused on students being able to interact with resources which utilised a novel method of presenting information (AR). The learning context was engaging and interactive and provided opportunities for students to conceptualise information and, in turn, encouraged memorable learning which was durable over time.

The students' capacity to use the AR system generally increased during the course of the task. Diaz et al. (2015) describe how the use of dynamic content i.e., animations, can have a positive impact on students' conceptual and spatial skills. The progress and development of conceptual and spatial skills were evident in the students' development of conceptualisation and understanding of content. As a result of this, students were motivated to push the levels of their understanding and stay focused on the task.

An advantage of AR is its ability to increase knowledge retention. Patzer et al. (2014) found that using AR resulted in higher rates of knowledge retention compared to students who did not use the system. The results for my students were in line with the findings of Patzer et al. (2014). This was one of the key findings of the AR project and the most encouraging, in that the students' retention of knowledge was secure over time.

Diaz et al. (2015) discussed the increase in student motivation when using AR. While this may not be true for all students across various disciplines, a high level of student motivation was apparent in this project. Students were enthusiastic about using AR on the iPads. In interviews, students described feeling more motivated to engage with the task content when using AR compared to using the paper schematic.

A limitation of setting up an AR system for the classroom was the amount of time needed to research AR implementation. This included the construction of resources and field testing before rolling the system out in the classroom. Many classroom teachers are time poor, which may have an impact on the access to opportunities to experiment with new technology. I have worked with ICT in education for a number of years, which assisted me to work through setting the AR system logically. Added to this was a study support grant which provided me with time out of the classroom. This circumstance enabled me to work consistently on the project. Perhaps a greater emphasis by schools and education organisations on professional development opportunities and the deployment of emerging educational technologies, such as AR, could play a role in more widespread uptake.

The implications for other research disciplines considering course design and delivery is the ability of AR to enhance learning by combining digital and real world content to transform the learning experience. The types of learning best suited to AR are ones which need to present complex information in a mode which is readily understandable and memorable for the student and increases the student's conceptual understanding. An example of this is the visualisation of a 3D model of the solar system in which students are able to gain insight into the positioning of the planets not possible in a 1D picture and text. Other possible research areas include the skill sets needed by educators to conceive, develop and deliver AR resources and content. A further research avenue is the viability of commercial and educational partnerships in producing educational AR resources. This is important given the amount of time needed to develop AR resources—time that teachers rarely have. The affordances of using AR in the classroom are becoming more evident. Gains in content conceptualisation, knowledge retention and breaking down the complexity of learning signal the potential of AR to become increasingly embedded in classroom pedagogy and practice.

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