KAiKU MUSIC GLOVE TRANSFORMS MUSIC EDUCATION: EXPLORING NEW AND NOVEL MUSIC TECHNOLOGIES IN THE MUSIC CLASSROOM

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Tiivistelmä – Abstract

The concept of using one's hand to learn music dates back over 1000 years to The Guidonian hand, which used the palm and fingers to indicate note names. The Guidonian method was effective in teaching musical structures and is one of the primary concepts behind KAiKU Music Glove. KAiKU Music Glove is a wearable device designed for music education. This thesis explores how iPad and KAiKU Music Glove technology affect academic performance in elementary school children by testing both technologies in the music classroom. The study gathers attitudinal responses, a test of knowledge and includes qualitative observations of students using the technology. The study was conducted in an elementary classroom with two classes. Motivation levels to use the two technologies scored high in both classes, showing non-significance when compared with one another. The hypothesis that KAiKU Music Glove users will respond higher in motivation than iPad users is not supported. Ease of use response levels scored high in both classes showing non-significance when compared with one another. The hypothesis that KAiKU Music Glove users will respond with higher variance than iPad users in ease of use is not supported. The students viewed the technologies as musical instruments similarly with non-significance reported, however a close to significant result is registered, suggesting a distinction in how the technologies appeared to the students periodically during the study. Qualitative findings suggest technical problems experienced by KAiKU Music Glove users influenced how the technology appeared to the students. Overall, iPad scored comparatively higher in total attitudinal response and registered a 2% margin of improvement in the test of knowledge compared to KAiKU Music Glove. This confirms iPad to affect academic performance in elementary school children with greater magnitude than KAiKU Music Glove. KAiKU Music Glove's promising performance indicate it is achieving the balance in learning and innovation many educational technologies strive for.

Asiasanat – Keywords Music technology, music education, user testing, interaction, praxis	
Säilytyspaikka – Depository	
Muita tietoja – Additional information	

JYVÄSKYLÄN YLIOPISTO

CONTENTS

1 INTRODUCTION

Musical traditions are positing toward change. The role of the teacher is transforming and how a teacher acts, responds and orally conducts oneself varies in a technologically mediated classroom. Thus, the role of technologies becomes of great influence, impacting the quality of teacher classroom interaction. The responsibility of useful practice with technologies in the classroom will increase as more innovations are used there. In the US it is widely reported that student-centred, technology-driven devices are being put into the classroom yet teachers are slow to adopt them as teaching tools. According to author Herold (2018), schools in the US do not realise the full promise of educational technology. On the contrary, research in the Nordic countries shows high adoption rates of technology between the teachers and students (Jorgenson, 2012).

Placing new technology into present educational settings may be seen as challenging the traditions of formal music education (Jorgensen, 2012). It is argued that established formal approaches are too restrictive in how they teach, disregarding the technological environment students grow up in (Jorgensen, 2012; Leman, 2008). However, if the range of formal education is too restrictive, concerns arise regarding innovative education methods being too broad in scope for effective learning to happen (Green, 2017). A balance in learing strategy and innovation must be found for a device to be an effective tool in the classroom.

An increasing number of devices are being made to make music an interactive endeavour in education. Many of these devices succeed in engaging users with the intention of new methods of interaction, yet such devices do not achieve a specified learning method in their engagement. KAiKU Music Glove looks to achieve this, being a new interactive education technology. It is an innovative wearable device with a definitive learning system placed around the fingers.

KAiKU Music Glove is a technological invention designed for use in the classroom that produces musical data. It has touch sensors across each of the fingers which produce sound. The sensors on the fingers correspond to the notes of a first octave C, D, E, F, while the thumb includes the touch sensors A and B. This system of playing is rooted in musical pedagogy and underlines the specified nature of the technology. In addition, the device can be reprogrammed for use as a musical controller, for performance use, effect use and other functionalities.

This thesis aims to explore how an existing and prototype technology affect academic performance in elementary school children, by testing iPad and KAiKU Music Glove hardware in the music classroom. The study focuses the gathering of attitudinal responses and a test of knowledge before and after both technologies are used, as well as highlighting qualitative observations of how students used the technology. The study aims to connect broad concepts of praxis, user experience and prototype design to the collected data and also to further device development. Given the above, this thesis explores how educational activities manifest themselves in a real-world setting, as using this new technology in the classroom is not yet fully understood.

The following thesis gives an account of the theoretical concepts which are at the root of the device invention and a practical experiment is complete that is comparative by nature. The practical experiment compares the use of KAiKU Music Glove and the iPad in a music classroom. The comparison investigates device performance to its related learning outcomes and further attempts to connect theories pertaining to the empirical nature of the experiment for device development.

2 LITERATURE REVIEW

2.1 Literature Review Introduction

This literature review defines and discusses background concepts associated with music technology and music education. First, it accounts for the fundamental role that praxial philosophy presents when combining music technologies in education. User experience is covered with reference to how the technology is interacted with. Historical music educators Guido D'Arezzo and Zoltan Kodály are discussed providing a pedagogical background to the KAiKU Music Glove device. Wider theories of embodied cognition and constructivist psychology are discussed with reference to music technology. Music technology in the classroom is covered with specific reference to the iPad. Finally, music device use in therapy and special needs education are discussed.

2.2 Praxis

Praxis is informed action and the foundational theory to this thesis study. Praxis is action incorporating certain qualities to help someone make a wise, rational and practical decision. Where theory is often seen as a collection of abstract ideas about phenomena, praxis is the informed action that comes from theory. Gadotti (1996) states that praxis in Greek literally means action. In an Aristotelian context the word praxis literally means right action, as author Elliot (2005) argues, human activity which is goal directed and complete with focused attention toward activities, norms and functional standards be understood as praxis. However, one must be aware that the meaning of praxis is explicitly different from practice. Praxis is the practical nature of completing a task armed with the underlying theory associated with the task. Relating to this thesis, praxis is often a process of reflection. One carries out informed action, reflects on the process, creates new concepts following reflection and finally carries out a new set of informed actions. Brazilian philosopher Paulo Freire (1972) explains the nature of praxis in the classroom, stating that theoretical frameworks influence a teachers practice, yet the teachers lived experience further shapes their theoretical framework and that both theoretical framework and experience cannot be separate.

In the broad context of music, praxis puts an emphasis on doing rather than what is done. Reimer (2003) argues that praxis in music is best defined as the description of those who bring musical sounds into being and how they go about doing what they do. In addition, practice and praxis are acknowledged as separate concepts by King and Himonides (2016), considering how music technology tends to operate in educative scenarios. When implementing technology into the practice of education King and Himonides (2016), clarify that there may be no distinction in completing the creative activity and learning how to do it. Both activities are often part of the same of process.

Moreover, praxis is the bedrock of KAiKU Music Glove's conception and use. This is to put theoretical education into practice by use of technology. This notion is supported further by the KAiKU Music Glove aim to comprehensively remodel the hand. During the technologies prototype stage it was created to be a transformative educational technology (Myllykoski, Tuuri, Viirret and Louhivuori, 2015) aspiring to remodel the hands into musical instruments. Gadotti (1996) supports this concept of praxial creative potential in education, stating that transformative praxis is the "creative, daring and reflexive," (Gadotti, 1996, p. 24).

To summarise, using KAiKU Music Glove in education is an idea influenced by praxis, as it attempts to have students and teachers practically act out theoretical concepts commonly taught in education. The device encourages a pick up and play approach first, from teachers and students. The experience of playing KAiKU Music Glove as a musical instrument and then understanding how the notes are placed on the fingers shapes how the technology may be used, and this tension between use and theory is praxis.

2.3 User Experience

The authors (Myllykoski, et al., 2015) outline that in the KAiKU Music Glove prototype design, ease of use may lead to a transformation and embodiment in learning. Birnbaum, Fibrink, Malloch and Wanderley (2005) further support that device design is of vital importance to the users needs and goals when using interactive music technology. It is suggested that if something musical is difficult to learn when using a device, it is perhaps not only the content of the music being taught but also a flaw in device design (Birnbaum, et al., 2005).

The idea of making music technology easy to use and intuitive by design is also supported by authors Levitin, McAdam and Adams (2002) who state that a devices success often rests in its balance in ease of use and ongoing challenge to use. Additionally, authors Levitin and Adams (1998), Wanderley and Orio (2002) state that devices made too simple to interact with provide poor experiences and devices too complex often alienate the user. Ware (2000) makes the example of a violin having an extraordinarily difficult user interface to master virtuosity and achieve transparent expression, yet it has been used for centuries. The author continues, stating that it is an easy trap for designers to become focused on the problem of making an interface easy to use by a novice and insufficient for an expert (Ware, 2000).

The notion of using the hands as an instrument is not a new one (Myllykoski, et al., 2015; Mitchell, 2011; Torre, 2013) with several instruments having been developed over decades using the hands for performance means. However, little or next to any device has been made with such focus on music education. Interestingly an analysis was performed by Birbaum, et al., (2015) on a relevant performance device, which aimed to highlight its practical use and how it communicated with the user. The analysis was performed on a device known as The Hands. Notably, The Hands is a musical controller designed as a glove. The analysis indicated that The Hands required a high amount of user expertise to interact with that was highly dependent on the device mapping (Birnbaum, et al., 2015). In support of this analysis, KAiKU Music Glove's mapping may be indicative of how easy or not it is to use.

The layout of the mappings on KAiKU Music Glove may determine how easy it is to interact with. How these mappings generate sound is also key to its overall usability. Mapping is said to be the linkage between gestures or control parameters and sound generation (Kantowitz and Sorkin, 1983; Cadoz, Luciani and Florens 1984; Winkler 1995, Paradiso 1997; Hunt, Wanderley and Kirk 2000; Wanderley 2001). Mappings are stated to be as intuitive to the user as functionally possible (Norman, 1988). Supporting this premise, authors Birnbaum, et al., (2015) state that the best mapping strategies will represent a property of the musician’s mind, making a gesture or movement tightly connected with the intention of the musician.

Modern ideas regarding mapping and sound production relate to concepts such as harder means louder, (such as striking), gestural wiggle means pitch wiggle, (such as a vibrato effect), and tighter means higher in pitch (Birnbaum, et al., 2015; Shepard, 1994; Shepard, 1995). Such ideas are said to be the product of having evolved brains which assimilate specific physical principles of the world around us (Shepard, 1994, 1995). It is said to be a challenge in the design of computer music controllers to accommodate individual expressivity and musical nuances of musicians (Levitin and Adams, 1998).

Efforts to refine user experience by analysing the interface being used is said to be extremely important for developers (Ware, 2004). Ware (2004) states that it is a common goal of development teams to tighten the loop between human and computer, making access of information via interfaces efficient. Making an interface as efficient as possible to interact with is seen as crucial to user experience and delays in the amount of time it takes to interact with a piece of information said to drastically reduce the rate of information uptake by the user (Ware, 2004). Field and Spence (1994); Cutrell, et al., (2000) also agree that research on the effect of interruptions drastically reduce cognitive productivity and are typically negative elements in user experience.

It can be concluded that user experience is a highly complex concept, incorporating all of the above, dealing with a vast number of phenomenon, such as the interpreter, experience and object, forming experience (Rousi, 2013). User experience is further said to be of a practical nature for development teams to consider, as its method of device analysis applies to real world and industry use (Rousi, 2013). The more that is known about how specific user experiences can be designed for, the more likely it is that products *speak* to consumers (Rousi, 2013).

2.4 Guido d'Arezzo and The Guidonian Hand

There is a foundational theory which inspired the KAiKU Music Glove mapping system that is grounded in music pedagogical history. These theoretical concepts help to inform how KAiKU Music Glove intends to be used as an educational tool in the classroom.

This theory traces back to medieval history, approximately 991 – 1033 AD (Miller, 1973), specifically to a music educator known as Guido d'Arezzo. Guido d'Arezzo used the hand as a tactile application for visualizing, hearing and singing with clarity, specifically to identify the distances between successive pitches (Miller, 1973). Additionally, Guido d'Arezzo used the human hand as a pedagogical tool to aid in teaching and memorizing music (Miller, 1973; Beckstead, 2001).

The Guidonian Hand is all of the tones from G through to E, assigned to the palm and finger locations on the left hand, and the index finger on the right hand. These would be touched by Guido d'Arezzo and his respective students to demonstrate the precise tones to be sung (Miller, 1973). Guido d'Arezzo is said to have first introduced the use of Sol-fa syllables with concrete pedagogical application (McNaught, 1892), and since his application of such a system, over a thousand years ago, solfege syllables are said to have remained commonly applied in modern music education (Brown, 2003).

The Guidonian Hand is more symbolic to KAiKU Music Glove's genesis rather than a concrete indicator of how it practically functions. The Guidonian Hand's strong theoretical link to the KAiKU Music Glove demonstrates how the use of solfege could work on the hand and helps to display how mappings can be combined with theoretical effectiveness on KAiKU Music Glove. In addition, it outlines a pathway of how the KAiKU Music Glove device be practically used when teaching music notation.

2.5 Kodály Method

Building on the foundational theory of Guido d'Arezzo and The Guidonian Hand, KAiKU Music Glove is also a proponent to the Kodály method of teaching music. The Kodály method is a teaching practice in music education that was created in Hungary during the mid-twentieth century, approximately during the 1940s (Choksy, 1988), by Zoltan Kodály. Choksy (1988) associated musicianship with being musically literate and supported Kodály's method promoting such outcomes in music education. Kodály's method is outlined by author Sinor (1997):

> 1) Use of the highest quality of music, 2) Music for everyone, not only for an elite, 3) Initial grounding in the folk style of the culture, 4) A cappella vocal foundation for music learning, 5) Literacy as the primary means for musical independence, 6) Use of relative solfege, 7) Experiences before notation, 8) A child-centred learning sequence. (p. 34)

KAiKU Music Glove does fit with all of author's Sinor's (1997) criteria regarding the outline of the Kodály method. It does this by using high quality sounds, produced from a digital soundbank; is aimed at users who have abilities of all ages; uses technology found in Western culture; works in an A cappella style; promotes musical independence through the engagement of musical theory notation and practice; incorporates relative solfege within its notation system; focuses on user experience prior to engaging in the device notation; aims to educate child learners (Myllykoski, et al., 2015).

The Kodály approach to composition and improvisation developed out of music making and listening experiences, with composition following improvisation. It is in such a pattern of performance, composition and listening that the Kodály approach is argued to come closest to a paraxial curriculum (Elliot, 2005).

2.6 Embodied Cognition

The idea of engaging in musical experience before operating with its notation system is illustrative of the embodiment of sound. Myllykoski, et al., (2015) state that to master any musical instrument, the external physical instrument become part of the player's musical consciousness. Author Leman (2008) supports the notion of integrating a technology so that it becomes seamless to the musician. Leman (2008) calls this "transparent technology" (Leman, 2008, p. 2) which attempts to completely remove the feeling that the technology is even there. It should aim to disappear when it is used (Leman, 2008).

For instance Leman (2008) states that playing a musical instrument is an interactive activity, and the instrument is potentially viewed as the technology which intervenes “between mind and sound” (Leman, 2008, p. 138).

The notion of KAiKU Music Glove focusing on the bodily integration of the hand as physical instrument is part process in reducing the need to master any external instrument. Authors Myllykoski, et al., 2015 claim the device can potentially strip years away from the learning process, as one simply knows their hand best. This is the practical implementation of embodied cognition in relation to the KAiKU Music Glove and is tightly related to user experience. If one is unaware of the apparatus in front of them the experience is total immersion.

In relation to embodying various types of musical experiences, sound toys enable player’s access to more methods of composition (Collins, Kaparlos and Tessler, 2014). The term toy hints toward playful interactivity and pertains to the KAiKU Music Glove’s accessibility for the user. Sound toys are stated to provide the player with a scope of musicking (Small, 1998; Small, 2011) which presents different degrees of compositional input, control, influence, or decisions inside of a device structure. While the terminology, sound toy, has implications of what may or may not be a meaningful composition, it is a matter of personal perspective to constitute this (Collins, et al., 2014). The notion of inclusivity is something shared in common regarding sound toys and KAiKU Music Glove. However, it should be restated that KAiKU Music Glove has an identity outside of being a sound toy. KAiKU Music Glove has a learning strategy which is grounded firmly in history.

2.7 Constructivist Psychology

Leman (2008) proceeds to state that action plays a key role in how a subject can embody music. The author (Leman, 2008) adds that the concept of action allows for taking into account subjective human experience and cultural circumstance, as well as biological and physical processes (Leman, 2008). The notion that such actions are subjective (in the sense that actions are learned based on the biomechanics of the human body combined with cultural circumstances) support the idea of actions forming a link between mental and physical worlds (Leman, 2008). This concept of how mental and physical space correlates is supported by authors Nanjappa and Grant (2003), who state that learning takes place in contexts and technology refers to the designs and environments that engages learners. This is said to be an essential feature of constructivism (Nanjappa and Grant, 2003).

Nanjappa and Grant (2003) state the theory of constructivism originated from the works of Piaget (1970), Bruner (1962), Vygotsky (1962, 1978) and Papert (1980, 1983), and is additionally the combination of both philosophy and psychology. Constructivism assumes that a person's behaviours and environments are dependent on each other (Nanjappa and Grant, 2003). Authors Witfelt (2000) and Richards (1998), state that the role of the teacher is seen as most important in a constructivist environment. Nanjappa and Grant (2003) support this notion, arguing that a teacher creates the social and learning context where either collaborative or independent learning methods are supported. Jonassen (1999) acknowledges that using technology to teach in classrooms encourages constructivist learning and teaching strategies, as students collaborate new knowledge with old knowledge.

Wynne (2010) states that student-centred classrooms are constructivist and this means that the students create their own meanings and apply them to new pieces of knowledge. Wynne (2010) additionally states that student-centred classrooms encourage students to remain active in the learning process. The author (Wynne, 2010) supports these claims by outlining a constructivist model in which students learn. The model is said to have four stages. These are the following (Wynne, 2010):

> 1) The learner creates knowledge, 2) The learner constructs and makes meaningful new knowledge to existing knowledge, 3) The learner shapes and constructs knowledge by life experiences and social interactions, 4) In constructivist learning environments, the student, teacher and classmates establish knowledge together on a daily basis. (p. 4)

Wynne (2010) elaborates further stating that within such a model, the classroom becomes a place where students are supported and encouraged to interact by applying new ideas to old theories. Despite much of this research on constructivist theory being theoretical one can easily recognise how placing technology in current day Finnish classrooms would be well suited for learners. It is acknowledged (Lipponen, 1999) that the Finnish classroom adopts constructivist strategies of teaching and learning. Placing and using novel technologies in the classroom may be complementary to such modes of teaching and learning.

2.8 Music Technology in Education

King and Himonides, (2016) argue that placing music technology within education often puts the tools first, before an individual's educative needs. The authors (King and Himonides, 2016) continue that as music education has developed, curriculums developed with music technology in their background - the technology largely regarded as a tool to aid and assist in classroom teaching, but not used as an instrument to lead in the teaching. Despite the theoretical support of technology in constructivist learning, King and Himonides (2016) research indicates that at both higher and lower education levels, music technology and music education may exist in their own space with minimal intersection.

On the other hand, Nordic countries report to have successfully introduced music technologies into their music education curriculums as early as 1970 (Clements, 2008). In contrast, research focused on analysing K-12 schooling programmes within the USA and the United Kingdom (Clements, 2008; Zagorski-Thomas, 2016) have reported increasing difficulty when introducing music technologies to assist in a formal learning platform. The research consulted suggests Nordic countries are adaptive when introducing music technologies to their educative programmes. Interestingly, the body of research made in the music technology and education context is dependent on where it is complete. Indeed, the location of the research tends to inform its outcome when assessing the goals of the educators as well as assessing the use of technology in education. In addition, the notion of informality (Jorgenson, 2012) may be based on location. An informal education context is likely more relative to the Nordic countries especially when compared to the USA or United Kingdom.

Generally, educational technology strives for the inclusion of technology into mainstream educational systems in order to support various educational objectives (Roblyer and Doering, 2012) and since the emergence of educational technology, researchers, educational psychologists and technology specialists have often taken conflicting views on the role of educational technology in an educational system.

For example, while education researchers have advocated the approach of curriculum-based integration, technology specialists have stressed technology-based integration (Clements, 2008). Similarly, some educational psychologists described educational technology as potentially distracting and promoting time wastage (Clements, 2008) while others have called it a support to learning and a useful tool for user engagement (Henderson and Yeow, 2012).

As of recent, the educational technology sector has witnessed the emergence of new technological devices such as smart-boards that promote touch-based instruction through tactile feedback and tablet devices, such as the iPad. Among these, especially the iPad, is considered an ideal tool for performing different actions required in any education context due to its screen size, multimedia support, lightweight and long battery life (Churchill, Fox, and King, 2012). Research examining the use and integration of the iPad for educational purposes is still scarce (Churchill, et al., 2012) and a recent study (Hutchison, Beschorner, and Schmidt-Crawford, 2012) emphasised that iPads are relatively unexplored educational tools. Even though devices like the iPad are accessible for teachers to incorporate into a traditional educational system, it is perhaps not an easy task, as doing so may require combining new and relevant teaching strategies.

Interestingly, iPad use and integration into educational settings is not without criticisms. On the one hand, it is argued that the iPad supports learning and educational goals; on the other hand, studies have reported time wastage and the technology being used by students as an entertainment tool with almost no role in learning, (Churchill, et al., 2012).

The general consensus among motivation scientists is that technology should help students understand meaningful connections between what they do and learn in school. This is said to connect students with challenges concerning them in their everyday lives resulting in the promotion of academic achievement, (Jeffrey R. Albrecht & Stuart A. Karabenick, 2018). With relevance to technology, students in Finland are within a rich multimedia environment everyday, connected to technology with phones and tablets from a young age. For the researcher, the hope of using a new technology in their learning environment will be to motivate students and make music lessons relevant to their rich day to day multimedia environment.

2.9 The iPad in Music Education

The use of the iPad in the music classroom as well as music education is relatively widespread. Increasingly high rates of accessibility for educative practitioners as well as learners to engage with the hardware are now prominent (Clark and Luckin, 2013). In 2013, three years after the iPad was officially launched, Clark and Luckin, (2013) state a rapid increase in use of iPads in the classroom as well as additional tablet device use in schools, with specific reference to the United Kingdom and the USA. In addition, a study conducted by Henderson and Yeow (2012) demonstrated that in a New Zealand primary classroom, the portability of the iPad along with its tactile rotatable surface-screen, vast selection of apps and overall ease of use, gave learners a better opportunity for collaboration that was not ever possible historically.

Further, Clark and Luckin (2013) report positively regarding student use of the iPad in a teaching and learning environment with specific reference to the student's learning engagement. In support authors, Saenz (2011), Henderson and Yeow (2012) and Clark and Luckin (2013) report positive findings on increased student motivation, enthusiasm, interest, engagement, independence, self-regulation, creativity and improved productivity in the classroom when using the iPad. In addition, Rowe, Triantafyllaki and Pachet (2016) explicitly state that the playing and working with interactive technologies develops a positive approach towards learning, by increasing children's self-esteem and confidence. Rowe, et al., (2016) report positively regarding the creative use of the iPad, stating that learning in combination with the playfulness of using technology transfers, somewhat easily, into the experimentation which directly creates music.

However, authors Henderson and Yeow (2012), and Clark and Luckin (2013), state concerns regarding iPad use in the classroom relating to the device's overuse, misuse and a lack of user confidence found in students using the technology. Rowe, et al., (2016), also argue that not all children use their chosen technology equally, with some children possessing higher levels of aptitude, fluency and enthusiasm; in addition, motivation levels will be of differing degrees amongst children. On the other hand, it should be made certain that the literature consulted is overwhelmingly positive regarding the findings of iPad use in the classroom.

Teacher training is stated to be necessary for best use of the iPad and its effective integration into the classroom (Henderson and Yeow, 2012). The authors (Henderson and Yeow, 2012) continue to argue that this would address the technical and pedagogical aspects when using the device. In contrast, Burden et al., (2012) argue that the requirements for the formal training of teachers when using iPads should be minimal, with teachers learning instead through the lens of experiential learning and practice. This echoes the outline of the Kodály method previously discussed in this body literature (Sinor, 1997). However, the authors (Henderson and Yeow, 2012) agreed that some form of familiarisation with the device was important in helping teachers begin to use the technology.

Rowe, et al., (2016) similarly observed that teachers in the USA welcomed the opportunity for training in the use of music technology. This helped produce effective, long-term teaching improvements after training, with teachers knowing how to best use the technology. Rowe, et al., (2016) state that the availability of software at home helped to increase teacher's confidence in the USA when learning to teach with music technology.

Heinrich (2012), reports that a majority of recent studies show that observed students find the iPad easy to use, and this premise is used to argue against the notion of negative learner confidence. However, the author (Heinrich, 2012) states that young students may require initial support or familiarisation to cope with the iPad's features and functionality. This would also mean that a process of familiarisation be made available to students before attempting to use the iPad in the classroom.

Rowe, et al., (2016) overall, support iPad use in the classroom, reflecting that children have grown-up in a multimedia rich, multi-sensory environment and integration of such a device would theoretically be seamless. Rowe, et al., (2016) state that a child's eyes, touch and ears are sensitive to development at a young age, and the iPad device is a relative multi-sensory stimulant.

2.10 Therapeutic Device Use and Special Needs Education

Additionally, there is a therapeutic overlap which both the iPad and other hand-based technology intersect. Rand, et al., (2013) found improvement in patient's rehabilitative hand function, post-stroke, using iPad technology combined with apps, measuring motor ability when compared to normative rehabilitative measures. Notably the authors (Rand, et al., 2013) stated enjoyment being a key factor for the improvement in the rehabilitative process, highlighting the potential of using the iPad as a motivating tool for therapeutic intervention. Similarly, a study using a hand-based device, MusicGlove, recorded positive results when compared to conventional hand-therapy treating post-stroke patients (Friedman, et al., 2014). Motivation was recorded as the key factor in maintaining patients to engage in their therapy consistently over time, as opposed to other methods (Friedman, et al., 2014).

Further positive use of technology has been documented within special needs education and a comparative study between iPad and computer use showed an increase in higher participation during lessons as well as overall improvement in academic score (Arthanat and Knotak, 2013). Interestingly such studies reflect the breadth of music technologies multidisciplinary nature. Such studies demonstrate effective devise use within a medical, educative and therapeutic setting simultaneously.

3 KAIKU MUSIC GLOVE

3.1 Device Overview

KAiKU Music Glove is an invention with the aim to be a wearable control device. It is a hand-based device, equipped with touch sensors. KAiKU Music Glove has been intentionally created to meet the needs of music theory. The touch sensors on KAiKU Music Glove are operated using the fingers on the opposite hand. From a pedagogical and theoretical perspective, it is important to understand that the touch sensors on KAiKU Music Glove be arranged in a practical order.

The touch sensors on KAiKU Music Glove are arranged in two rows. The touch sensors are organised in the order across the fingertips from the index finger to the little finger, consecutively ranging from C, D, E and F. The thumb includes the touch sensors A and B. The semitone E-F is found between the ring finger and the little finger. The semitone B-C is found between the thumb and index finger. This a preferential mapping setup and can be changed by the user. The users in this study will embody this original mapping.

The placement of two rows of touch sensors is focused for teaching scale, interval and chord structure. Relative to music theory, the semitone steps in a seven-step scale are organised relative to the fingers.

The touch sensors are capacitive sensors, and thus the velocity of the push, touch or stroke will emphasise the volume of the sound output (or lack of). How these sensors can be used is additionally versatile, as each touch sensor can be played together to create a chord, as well as using the device to control musical sequencers, entering text or as a game controller.

The final input to output flow of KAiKU Music Glove is presently as follows. The device is connected to a host apparatus (PC, tablet, mobile device). The electrodes, wiring, circuitry, Bluetooth and USB connection will then be active. The host apparatus will produce sound to an assigned output as the software decodes MIDI-information to sound. A Digital Audio Workstation (DAW) or additional third-party software can be used to export musical data to external devices as well as musical applications. Refer to Appendix 1 for schematic of KAiKU Music Glove (Taction Enterprises Inc., 2018).

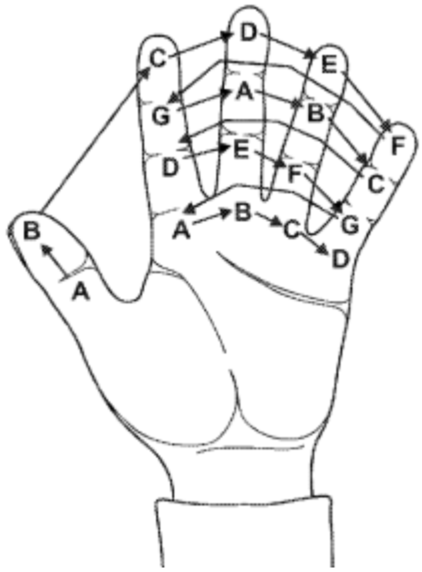

FIGURE 1. The progression of a scale on the hand. The arrows show the location of the notes in the adjacent fingers. This a concept sketch, as the sensors and technological units are not presented. (Taction Enterprises Inc., 2018).

3.2 KAiKU Music Glove Software: Taction Control

Taction Control software is a software component specifically designed for use as KAiKU Music Glove is connected to a machine host. The connection is either USB or Bluetooth assigned. It should be noted that KAiKU Music Glove has been designed with standard MIDI functionality, thus it can be used as an interface with most MIDI standard enabled software, (capable of functionality in operating systems and digital audio workstations with MIDI protocol).

Taction Control enables the user to configure the KAiKU Music Glove input parameters. These input parameters are: (1) Velocity. (2) Control Scaler. (3) Default Control. (4) Attack. (5) Delay. (6) MIDI Channel. (7) Threshold.

1. Velocity refers to the measure of how rapidly and forcefully a note is pressed when the player presses the key. When we think of the sensors placed on KAiKU Music Glove, velocity measures how forceful a note is pressed when the player presses a sensor.

2. Control Scaler refers to how sensitive the MIDI Aftertouch expression is set. For example, moving a finger to produce a trilling effect on the sensors.

3. Default Control refers to the selection of saved settings. This can be used to load a preset configuration which the user had saved from a previous time.

4. Attack refers to a measurement of how long it takes for a sound to go from zero to maximum loudness.

5. Delay refers to the time it takes for an active MIDI circuit to handle the signal.

6. MIDI Channel refers in a general sense, to a route of communication or access. A MIDI port or a MIDI channel can define MIDI messages. General MIDI standard has 16 channels.

7. Threshold refers to the overall loudness of the Taction Control software output volume.

There are additional parameters which usefully relate to KAiKU Music Glove's use. These are in relation to MIDI Velocity and Aftertouch control parameters. In MIDI protocol, a velocity value is transmitted with a note on message. Aftertouch is the force used to press down on a key after it has been initially struck. This can be thought of as pressure sensitivity. Like velocity, Aftertouch ranges from 0 to 127 (Guérin, 2006).

There may be a critical difference in playing styles between children and adults, and this could be observed intuitively by how the device will be held. Children may hold the device or glove facing sideway, playing with the fingers facing east or west - dependent on if one is left or right handed. In contrary, adults may hold the glove as if looking directly opposite the palm of their hand with the fingers facing north. This difference in play style could potentially affect the mapping and notation configurations on KAiKU Music Glove and may potentially lead to the requirement for multiple pre-set (saved) mode settings to effectively compliment both modes of play.

The Taction Control software lets the user configure notational mappings across each finger of the device, thus making this preparatory task novel. It would be a case of choosing the correct notes across the fingers. For example, if one were to choose the C Major Scale across the fingers, one could do this using the Taction Control software. Also selecting a new scale to base a pre-set mode on, Taction Control will re-position (re-map, re-assign) notes around on KAiKU Music Glove.

To manually move notes around the fingers, this can be done in the Taction Control software, through transposing notation higher or lower (up or down). This is done by selecting the arrow keys toward the top of the screen. The arrows will change the values on Taction Control (12 notation steps higher, or 12 notation steps lower) to output an associated sound. Transposition will move notation around the KAiKU Music Glove device.

It is also possible to individually select a note to edit a specific finger. This is done by selecting one sensor by left clicking it and changing its numerical MIDI value by selecting up down and keys. Additionally, one can make this control change, selecting a sensor, and in the ‘type’ box, choosing ‘Control Change’. This lets the user add MIDI effects, such as modulation, (pitch bend).

4 THE CURRENT STUDY

4.1 Research Questions and Hypotheses

The current study explores how existing and prototype technologies affect academic performance in elementary school children, by testing iPad and KAiKU Music Glove hardware in the music classroom. The test involves gathering attitudinal responses before and after the technology is used and an academic test of knowledge test before and after the technology is used. The data will be compared to conclude which device performed strongest during class. The attitudinal ratings are gathered from Likert-scale self-report questionnaires. The self-report questionnaire records responses from motivation, ease of use and viewing the technology as an instrument.

It is hypothesised that KAiKU Music Glove users will respond with a higher attitudinal rating in motivation than iPad users on the self-report questionnaires. This is due to the novel nature of the technology.

It is hypothesised that KAiKU Music Glove users will respond with higher variance in ease of use than iPad users on the self-report questionnaires. This is due to the KAiKU Music Glove being a prototype instrument at the time of writing, with different versions given to different students in comparison to the iPad being a product with consistent hardware design.

Similarly, it is hypothesised that KAiKU Music Glove users will respond with greater variance in viewing the technology as an instrument than iPad users on the self-report questionnaires. As described, this is due to the KAiKU Music Glove being a prototype instrument when compared to the iPad being a ready product.

Regarding testing participant’s academic performance, comparisons made between KAiKU Music Glove and iPad class test scores will show if there was one technology more effective to learn with than the other.

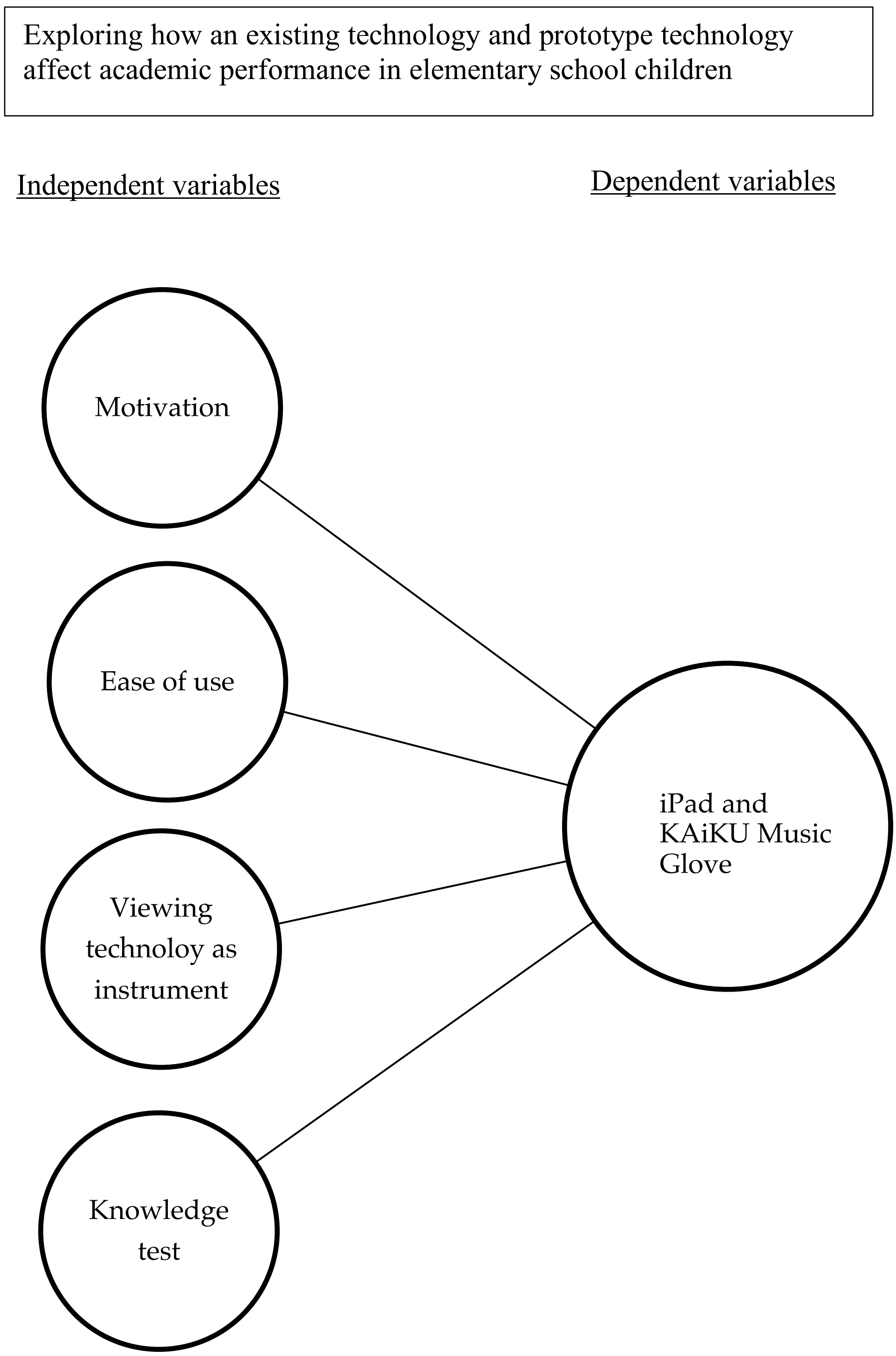

FIGURE 2. The Research Model used in the current study adapted from described research questions and hypothesis.

5 RESEARCH METHOD AND MATERIALS

5.1 Action Research

Action research is defined with little constraint. It is stated to be a robust practical research methodology and as such a wide range of definitions are available to it. Lewin (1946) defines action research as a process of preparation, action and searching. Ferrance (2000) defines action research as a cycle of presenting questions, collecting data and deciding on a suitable research plan. Therefore, it is simple to assume action research is a cyclical process. One starts with the research problem, creates a study design, completes actions relative to the design, captures and reflects on the process and the process is repeated.

The research thus far presented in the literature review is mostly theoretical, however the results from the current study are from a real ecological setting. The stated studies found in the literature review use ethnographic and qualitative measures as their chosen research methodology (Gaspirini and Culen, 2012; Churchill, Fox and King, 2012) yet a study focusing on how technology is interacted with employed a technically distinct framework (Birnbaum, et al., 2005). Thus, there is ample room for experimentation. Considering that there is no published data available regarding KAiKU Music Glove's use, the possible methodological choices make for interesting options regarding the current study.

Multiple sources of data should be collected and analysed to test the device's use in the classroom. As the KAiKU Music Glove is made as a pedagogical tool for teachers and students, measuring how the device be experienced phenomenologically as well as technically, across a set of students may prove challenging. This points to a relatively complex experiment design.

There will be two researchers present during the data collection phase. As researchers we would place ourselves into the classroom environment to provide accurate observations. This allowed for observation of the setting from the inside, giving way to experiencing events similar to that of the participants. Further, this method of naturalistic observation requires that researchers completely immerse themselves in the situation (Cozby and Rawn, 2012).

The current study aims to explore how an existing and prototype technology affect academic performance in the classroom. It replicates some of the methodology in the literature which used the iPad in the classroom (Gaspirini and Culen, 2012; Churchill, Fox and King, 2012), using similar observatory measures to record participant behaviour. In addition, we wanted to investigate KAiKU Music Glove's use as a pedagogical tool for teachers. We arranged for a subject matter expert interview with the teacher and device inventor to happen after the data collection phase was complete. Further, we wanted to compare attitudes toward the iPad and KAiKU Music Glove device, asking all of the students to self-report.

The study would be comparative in design between the iPad and KAiKU Music Glove. This would let us observe for technical differences between the technologies as well as measure academic performance while using them. We would assign the iPad and KAiKU Music Glove to separate classes of students. A baseline test of knowledge would be given to the two classes before and after using the technologies, as a measure of academic performance. The study would take place over multiple weeks. Different versions of KAiKU Music Gloves would change over the weeks of study. This was due to the ongoing manufacture of the prototype technology and also a process of the action research.

The intention for selecting action research as the methodology to complete this study is due to the context and prototype hardware available for research. Accordingly, the setting and materials available to the researchers held influence on this decision. An action research framework is said to help the researcher engage in multiple processes at once. These are stated as the development of a technology, the practical nature of education and the development of theories resulting from the practice (Gadotti, 1996; King and Himonides, 2016).

Costello (2007) notes that any action-research model used in education should lead to the improvement of educational practice. Hopkins (2002) reflects that action research is an attempt at understanding while engaged in a process of improvement and reform (Hopkins, 2002). When applied to the classroom and in particular, teaching a class, the General Teaching Council for Wales states that action research “is a term used to describe professionals studying their own practice in order to improve it” (Costello, 2007, p. 15). Further, Costello (2007) argues that when action research is applied to classroom pedagogy it involves the gathering and interpreting of data to best understand and improve its teaching practice. The essential characteristics of action research models are stated to be prepared, discreet, systematic and reliable methods of investigation and deepening understanding (Costello, 2007).

5.1.1 Intuitive proactive action research

An intuitive-proactive approach in action research is considered to be based on an individual or group evaluation for improvement, established on intuitive grounds (Wragg, 2002). It follows that in this context, the data collection was conceptualised intuitively. The researchers conceptualised the KAiKU Music Glove device goals by their own use and reference to the device patent (Taction Enterprises Inc, 2018). The researchers also observed both classes prior to the data collection phase. This was planned to be a familiarisation session for the researchers and students to be familiar with one another. It also helped to conceptualise how the data collection will practically happen. A suitable research plan was made from this to test the KAiKU Music Glove device features and student academic performane.

The practical tasks of the research were to make classroom observations while the class were being taught and assist students who experienced technical problems while using their device. All measures remained the same for both iPad and KAiKU Music Glove classes. This would then, theoretically, give us a control group (students using iPad) and an experimental group (students using KAiKU Music Glove) of which to focus our data collection and potentially base our comparative results on.

5.1.2 Action research: potential limitations

Wragg (2002) discusses the potential limitations of using an action research methodology using comparative measures to form conclusions. Admittedly a problem when completing action research is that the research conducted by the innovators or researchers themselves rarely has the control group *win* in such circumstances - the experimental groups often *beat* control groups. Costello (2007) accounts for this problem often found in the data collection phase, as the “sheer drive, energy and enthusiasm,” (Costello, 2007, p. 120) of the researchers or innovators engaged with the new product, influencing the rigour to execute their research methodology programmatically.

As researchers we were aware of this literature before implementing the methodology. This helped us to maintain a rigour in our research approach. We choose action research as the primary methodology to complete the study due to its robustness in practice. We aimed to test the KAiKU Music Glove educative application in a natural setting and measure its effectiveness as a pedagogical tool. Accordingly we would compare it to an established music education technology, the iPad. One could then apply theories and concepts from cognitive science, user experience and embodiement to the data.

We would collect multiple sources of data which we would triangulate with one another. Further, we would complete a subject matter expert interview with the classroom teacher and weekly consult with our project supervisor. We would reflect twice per week with our project supervisor, to discuss the data collection as it was ongoing. These discussions were often recounts of technical difficulties experienced as the class used KAiKU Music Glove. In addition, we would discuss verbal feedback given by the students, teacher or observations by the researchers (these would be compared by an observatory log between both researchers) during the classes. This material would be collected each week and discussed between the project supervisor and researchers, relfecting on improvements to be made for the KAiKU Music Glove in development. This resulted in updated versions of the prototype, amending a sensor or strap placed around the glove to be made ready for the following session. Further, amendments to the music curriculum itself to assist with the use of the technology was often discussed between the classroom teacher and researchers.

Before executing this action research plan we as researchers are aware of its limitations. Academic rigour is often discussed as a concern and challenge upon the choice to use action research. Typically, action research studies, like the one outlined in this thesis are often of small-scale and the results presented should not be generalised outside of the individual context of the study.

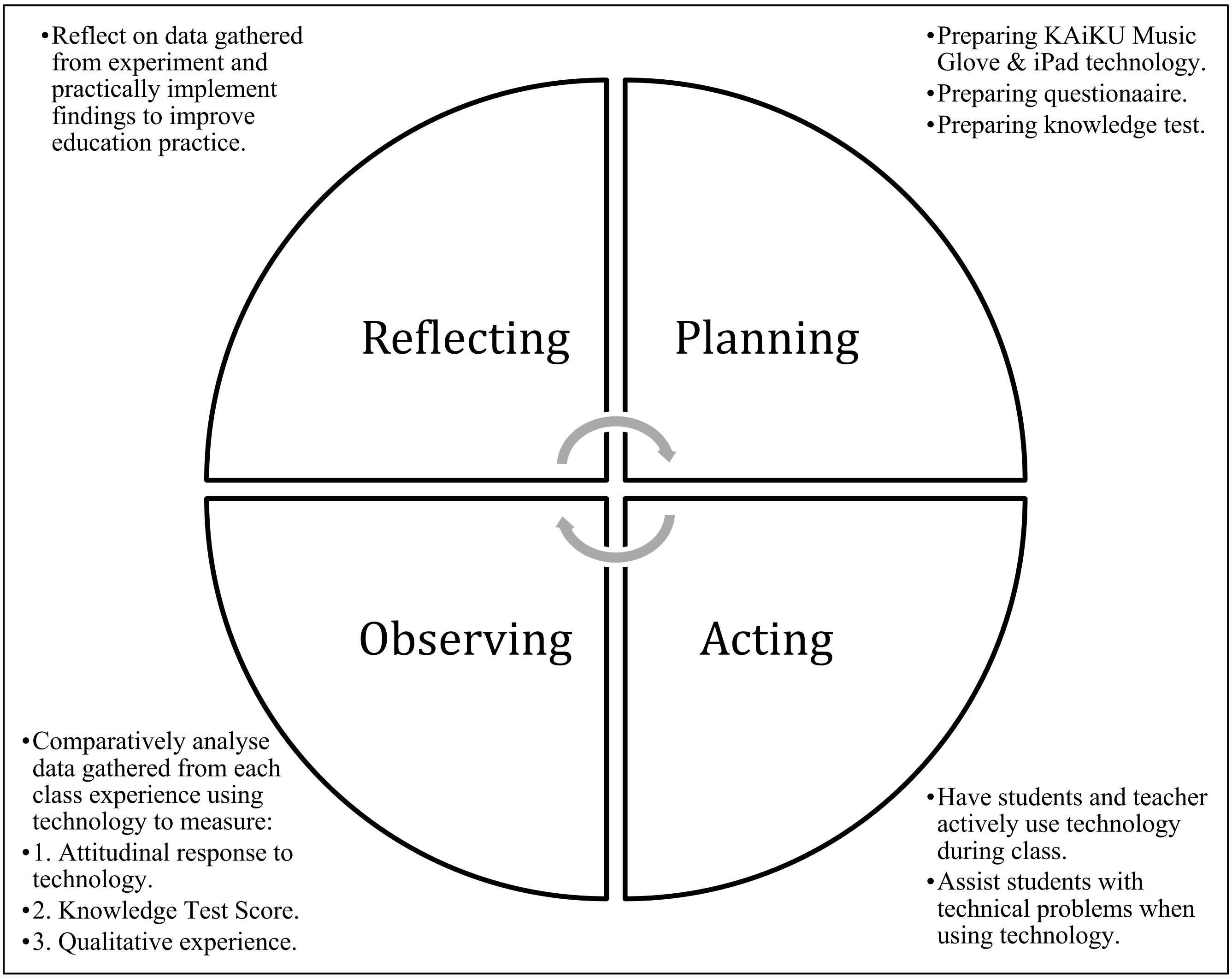

FIGURE 3. The Action Research model used in the current study. It is adapted from Costello (2007) and Ferrance (2000) in an attempt to understand and improve the technologies affect in the elementary classroom.

5.2 Setting

The study was conducted in a classroom setting at the Jyväskylän Normaalikoulu School located in Jyväskylä, Finland. The school provides comprehensive education for students ranging from grades 1-9. Normaalikoulu additionally arranges experimental and collaborative research with multiple faculties of the University of Jyväskylä and is available as a research field for university students. The iPad is a common learning modality used in the Jyväskylän Normaalikoulu music classroom.

Ensuring ethical clearance to conduct research in a school setting is necessary to complete this study and was complied with before completing the proposed methodology. Ethical clearance was obtained through partnership between the University of Jyväskylä and Normaalikoulu. This association between university and school allows consent for our attendance, collection of data and future analysis of data. The data management and its preservation in this study is adhered to the principles of research data management at the University of Jyväsklyä.

5.3 Participants

The participants were two classes consisting of twenty-one students in both classes. All of the participants are students enrolled at the Jyväskylän Normaalikoulu school between the ages eight and nine. In consideration of broad educational abilities in the classroom, prior musical knowledge was assessed by completing a baseline test before using the technology. This was to help evaluate participant curriculum knowledge in the two classes. The same baseline test will be complete after the participants have used the technology. This will evaluate participant curriculum knowledge after they have used the technology. One class of students is assigned the iPad technology as the instrument to engage in the academic curriculum. The other class is assigned the KAiKU Music Glove as the instrument to engage in the academic curriculum. All participants were required to complete a self-report inventory before and after each lesson. The self-report inventory is the same for each class. The study duration using the technology will last for six weeks.

5.4 Materials

5.4.1 Technology

iPad for play and interaction in one class for all participants of that class and teacher. iPad was further used as connecting apparatus in KAiKU Music Glove class for all participants and teacher. KAiKU Music Glove for play and interaction in other class for all participants of that class and teacher. Additional versions of KAiKU Music Glove were made available to class using older version of KAiKU Music Glove as the device continued to be developed. GarageBand software used by all participants to create sound with. GarageBand sound presets were loaded before classes began by the teacher and researchers. Sound presets loaded in GarageBand were Classic Electric Piano and Glockenspiel. Headphones given and used by all participants to hear and playback created sounds triggered in GarageBand. Projector used to show lesson instructions and plan to all participants in both classes. Video camera set at a fixed angle for all lessons used by researchers to record observatory data for reference purposes. Electric keyboard used by teacher to play aloud during oral portion of lesson with students.

5.4.2 GarageBand software

GarageBand is a musical software program that was used in this project acting as a musical synthesiser. Specifically, GarageBand's soundbank will be used to emulate different musical instruments via MIDI or sample playback. This means that the iPad and KAiKU Music Glove will act as a *controller* triggering data within GarageBand as the software outputs sound.

GarageBand is easy to setup for MIDI controllers such as iPad or KAiKU Music Glove and is widely available. Its simplistic set-up, deep soundbank and prominent use in Normaalikoulu are the primary factors in choosing GarageBand as a practical component in this experiment.

5.4.3 Baseline test of knowledge and post-test of knowledge

All participants were required to complete a baseline test of knowledge before using the technology. This would establish the student's academic performance before using the technology to engage in their musical curriculum. Participants were then instructed to use the technology for six weeks.

After using the technology for six weeks the participants would then complete the same test to evaluate their knowledge on the musical curriculum after using the technology.

5.4.4 Self-report inventory

A self-report inventory was included to assess how participants experienced the experiment before and after the class. This self-report inventory consisted of three questions before using the technology and six questions after using the technology. Their response was recorded on a 5-point Likert scale. This self-report inventory is included in Appendix 2.

5.4.5 Pictorial Likert-scale creation: student self-reports

The participant self-reports are purposefully designed pictorial Likert-scale inventories, with thumb-finger pictures positioned downward indicating a negative response to the proposed statement and a thumb-finger picture positioned upward indicating a positive response to the proposed statement. The more negative the response, the more thumbs available for selection and the more positive the response, the more thumbs available for selection. This increases to a total of two for negative and positive responses. The pictorial scale was validated consulting literature by authors Kano, Horton, and Read (2010). In the stated study Kano, et al., (2010) indicate that thumb-scale frequency during self-reportage of children's computer experience was used effectively with children as young as seven years old.

Additional literature was consulted (Reynolds-Keefer and Johnson, 2011) which assisted in the creation of a suitable self-report for children. Specifically, Reynolds-

Keefer and Johnson (2011) state they are creating functional attitudinal instruments for young children, researchers and reviewers through the application of response scales which use pictures or images as anchors. We as researchers had two clear objectives in making our self-reports as visually accessible to the children. We aimed to maintain an interactivity for the children to engage with the study materials, and we also aimed to make the materials simple for the students to engage with. This was an informed intuitive decision, with the aim to reinforce the interactive behaviours of the potential constructivist (Lipponen, 1999) influenced classroom.

5.5 Procedure

5.5.1 Hawthorne effect

The Hawthorne Effect is the perceived change of behaviour by the participants of a study, as they know they are being observed (Croucher and Cronn-Mills, 2015). We wanted to minimize this potential effect on the participants by being present in both classes. In addition, we would introduce the KAiKU Music Glove to the class, which were going to use it.

5.5.2 Familiarisation sessions

Familiarisation sessions took place over two sessions. These two sessions began before the baseline test of knowledge was administered as well as the procedure of testing the technology in the classrooms. The aim of these sessions was to informally introduce the KAiKU Music Glove technology to one group of students as well as introduce ourselves as researchers to both groups, minimising the potential Hawthorne effect. The familiarisation sessions were also recorded by video camera.

The familiarisation sessions were structured similarly to each other. Both sessions had the researchers informally introduce one another to the class. One class was given five KAiKU Music Gloves to play with. The other class would use iPads and completed their class as normal. The class given the KAiKU Music Glove would have five students at a time using the technology. This was timed closely, with four sets of students in total using the technology for approximately 10 minutes as a group (total= 40minutes). The iPad group used their technology for the entirety of the class. Both researchers took observatory notes during this session. Additionally, there was content taught in the familiarisation session. The content contained students playing four bar simple rhythms, whole notes, half notes, quarter notes, and whole rests using one note.

5.5.3 Weekly lessons

Students enter the class. All students complete a self-report inventory before using both the iPad and KAiKU Music Glove. The students then collect their technology along with headphones. The class using only iPads, collected an iPad each and then plugged their headphones into the iPad. The class using KAiKU Music Glove, would each collect a KAiKU Music Glove and iPad. This would then be followed by plugging their headphones into the iPad and having the KAiKU Music Glove connected to the iPad. Both the iPad and KAiKU Music Glove class used GarageBand to generate sounds. Both classes are given an overview regarding the content of the lesson and asked to play and practice independently by the lesson teacher. Both the iPad and KAiKU Music Glove class are asked to play together during their lessons, by unplugging their headset from the iPad and either playing the iPad or KAiKU Music Glove with other students. Both classes of students receive feedback from the teacher and are then instructed to play independently. The class ends with all students returning their technologies and completing a self-report inventory.

Table 1. An overview of observed lesson format.

Lesson Format
Students enter class
Complete pre-lesson self-report questionnaire
Collect technology/headphones
Teacher gives instructions
Individual practice time with headphones
Group instruction and practice without headphones
Return technology/headphones
Complete post-lesson self-report questionnaire

5.6 Learning Outcomes

In week 1, the students incorporated three notes, ‘C-D-E’, into four bar simple melodies. During week 2 the students learned about different note names on the stave. Week 3 saw the students rehearsing the melody and harmony of Twinkle, Twinkle, Little Star. This was accompanied with the teacher playing Twinkle, Twinkle, Little Star on the electric keyboard. Week 4 saw students rehearsing the melody and harmony of a traditional Finnish Christmas Carol (Joulu on Taas). The students sang to accompany the melody and harmony of the Christmas carol. This was the first-time students accompanied the use of their technologies with singing. Within Week 5, the students learned about time signatures, ¾ time playing, and incorporated two new notes to their repertoire, including ‘low H’. They continued to rehearse the Finnish Christmas carol piece (Joulu on Taas). The students also sang and played the technology at the same time. In the final week, week 6, the students continued to rehearse the Christmas carol (Joulu on Taas) and were accompanied by the teacher on the electric keyboard.

6 RESULTS

Both the results from the Likert-scale self-report questionnaire data and results from the test of knowledge are presented here. First, reliability analysis was conducted on the self-report inventory statements to ensure the statements were testing what they should. Second, differences in the class self-report response before and after using the technology are presented, across six weeks using the technology. Third, differences in class score in the test of knowledge before and after using the technology are presented. Statistical analysis was performed on the self-reports using an independent samples *t*-test to compare the iPad and KAiKU Music Glove responses. Further, a Mann-Whitney U test was used as responses to the self-report statements formed skewed distributions in the data.

6.1 Likert-Scale Self-Report Responses

6.1.1 Likert-scale reliability analysis

Cronbach's alpha was used as a measure of reliability to test the internal consistency of the Likert-scale items. Cronbach's Alpha measures how closely related a set of items are as a group. The self-report inventory was found to be highly reliable (27 items; α = .939).

Table 2. Inter-item correlation matrix showing coefficient reliability for Likert self-report statement "I think the iPad / KAiKU Music Glove will be easy to use today." The decrease in coefficient scores from weeks 1 to 3 suggest these items have less covariances with one another and the potential to measure different underlying concepts.

		"I think the iPad/ KAiKU Music Glove will be easy to use today."		
		Week 1	Week 3	Week 6
"Today, I found the iPad/ KAiKU Music Glove easy to use. "	Week 1	.701		
	Week 3		.524	
	Week 6			.525

Table 3. Inter-item correlation matrix showing coefficient reliability for Likert self-report statement "I view the iPad/KAiKU Music Glove as a musical instrument, just like the recorder and piano." The high coefficient scores from weeks 1 to 3 suggest these items have high covariances with one another and are likely measuring the same underlying concept.

		"I view the iPad/ KAiKU Music Glove as a musical instrument, just like the recorder and piano."		
		Week 1	Week 3	Week 6
"Today, I viewed the iPad/ KAiKU Music Glove as a musical instrument, just like the recorder and piano."	Week 1	.730		
	Week 3		.800	
	Week 6			.777

6.1.2 Student response before using the technology

An independent-samples *t*-test was conducted to compare student motivation in the iPad and KAiKU Music Glove class before lessons began across the six classes. The tables 4 and 5 show there was not a significant difference in the scores before lessons began across weeks 1 and 6. These results suggest that the comparison between using the different technologies did not affect the student's motivation before classes began across weeks 1 and 6.

Table 4. *t*-test Results comparing student motivation in iPad and KAiKU Music Glove classes before lesson started, week 1.

	n	Mean	SD	t	df	*p*
iPad	19	4.84	1.12	1.36	37	0.181
KAiKU Music Glove	20	4.30	0.98			

*$p < .05$.

Note. n = Amount of students present. SD = Standard Deviation. df = Degrees of Freedom. t = t-value. p = Statistical Significance. Likert-scale ratings range from 0 (Not at all) to 5 (Very much).

Table 5. *t*-test Results comparing student motivation in iPad and KAiKU Music Glove classes before lesson began, week 6.

	n	Mean	SD	t	df	*p*
iPad	17	3.80	1.25	-0.162	35	0.872
KAiKU Music Glove	20	3.70	1.74			

*$p < .05$.

Note. n = Amount of students present. SD = Standard Deviation. df = Degrees of Freedom. t = t-value. p = Statistical Significance. Likert-scale ratings range from 0 (Not at all) to 5 (Very much).

As shown in table 6, a Mann-Whitney U test indicated that the level of motivation was similar for the iPad class across weeks 1, 3 and 6.

Table 6. Mann-Whitney U Results comparing student motivation in iPad and KAiKU Music Glove classes before lesson started, week 1, week 3 and week 6.

	Week 1			Week 3			Week 6		
	Median	U	p	Median	U	p	Median	U	p
iPad	4	139.5	0.129	4	171.5	0.416	4	162	0.800
KAiKU Music Glove	4.5			4			4		

Note. U = Used to determine statistical significance. p = Statistical Significance.

An independent-samples *t*-test was conducted to compare if the students found the the iPad and KAiKU Music Glove technology easy to use in the class before lessons began. The tables 7 and 8 show there was not a significant difference in the scores before lessons began across weeks 1 and 6.

Table 7. *t*-test Results comparing how easy the technology was to use in iPad and KAiKU Music Glove classes before lesson started, week 1.

	n	Mean	SD	t	df	*p*
iPad	19	3.90	0.74	-0.817	37	0.419
KAiKU Music Glove	20	3.65	1.10			

$^*p < .05$.

Note. n = Amount of students present. SD = Standard Deviation. df = Degrees of Freedom. t = t-value. p = Statistical Significance. Likert-scale ratings range from 0 (Not at all) to 5 (Very much).

Table 8. *t*-test Results comparing how easy the technology was to use in iPad and KAiKU Music Glove classes before lesson started, week 6.

	n	Mean	SD	t	df	*p*
iPad	17	3.65	1.22	-0.116	35	0.908
KAiKU Music Glove	20	3.60	1.23			

$^*p < .05$.

Note. n = Amount of students present. SD = Standard Deviation. df = Degrees of Freedom. t = t-value. p = Statistical Significance. Likert-scale ratings range from 0 (Not at all) to 5 (Very much).

An independent-samples *t*-test was conducted to compare if the technology appeared as an instrument to the students before lessons began in the iPad and KAiKU Music Glove class. Tables 9 and 10 show there was not a significant difference in the comparison of scores between the KAiKU Music Glove and iPad class before lessons began across weeks 1 and 6.

Table 9. *t*-test Results comparing how the technology appeared as an instrument to students in iPad and KAiKU Music Glove classes before lesson started, week 1.

	n	Mean	SD	t	df	*p*
iPad	19	2.84	1.07	-0.124	37	0.902
KAiKU Music Glove	20	2.80	1.056			

*$p < .05$.

Note. n = Amount of students present. SD = Standard Deviation. df = Degrees of Freedom. t = t-value. p = Statistical Significance. Likert-scale ratings range from 0 (Not at all) to 5 (Very much).

Table 10. *t*-test Results comparing how the technology appeared as an instrument to students in iPad and KAiKU Music Glove classes before lesson started, week 6.

	n	Mean	SD	t	df	*p*
iPad	17	2.53	1.55	-0.948	35	0.350
KAiKU Music Glove	20	2.10	1.21			

$^{*}p < .05$.

Note. n = Amount of students present. SD = Standard Deviation. df = Degrees of Freedom. t = t-value. p = Statistical Significance. Likert-scale ratings range from 0 (Not at all) to 5 (Very much).

6.1.3 Student response after using the technology

An independent-samples *t*-test was conducted to compare if the student found the technology easy to use in the iPad and KAiKU Music Glove class after lessons were complete. The data was collected at the end of each of the six lessons. Tables 11 and 12 show there was not a significant difference in the scores after the lessons were complete across weeks 1 and 6. The high scores suggest both technologies were easy for the students to use.

Table 11. *t*-test Results comparing how easy the technology was to use in iPad and KAiKU Music Glove classes after lesson ended, week 1.

	n	Mean	SD	t	df	*p*
iPad	19	4.47	0.612	-0.467	37	0.643
KAiKU Music Glove	20	4.35	0.988			

*$p < .05$.

Note. n = Amount of students present. SD = Standard Deviation. df = Degrees of Freedom. t = t-value. p = Statistical Significance. Likert-scale ratings range from 0 (Not at all) to 5 (Very much).

Table 12. *t*-test Results comparing how easy the technology was to use in iPad and KAiKU Music Glove classes after lesson ended, week 6.

	n	Mean	SD	t	df	p
iPad	17	4.06	1.029	-0.940	35	0.356
KAiKU Music Glove	20	3.75	0.97			

*$p < .05$.

Note. n = Amount of students present. SD = Standard Deviation. df = Degrees of Freedom. t = t-value. p = Statistical Significance. Likert-scale ratings range from 0 (Not at all) to 5 (Very much).

An independent-samples *t*-test was conducted to compare if the students viewed the technology as a musical instrument in the iPad and KAiKU Music Glove class after lessons were complete. Tables 13, 14 and 15 show there was not a significant difference in the comparison of scores between iPad and KAiKU Music Glove classes across weeks 1, 3 and 6. However, week 3's comparison (table 14) scored close to significance. This difference in result and high score for iPad may suggest students viewed the iPad as an instrument more so than KAiKU Music Glove.

Table 13. *t*-test Results comparing how the technology appeared as an instrument to students in iPad and KAiKU Music Glove classes after lesson ended, week 1.

	n	Mean	SD	t	df	*p*
iPad	19	3.05	1.18	-0.399	38	0.692
KAiKU Music Glove	20	2.90	1.21			

*$p < .05$.

Note. n = Amount of students present. SD = Standard Deviation. df = Degrees of Freedom. t = t-value. p = Statistical Significance. Likert-scale ratings range from 0 (Not at all) to 5 (Very much).

Table 14. *t*-test Results comparing how the technology appeared as an instrument to students in iPad and KAiKU Music Glove classes after lesson ended, week 3.

	n	Mean	SD	t	df	*p*
iPad	20	3.20	1.36	-1.864	38	0.069
KAiKU Music Glove	20	2.40	1.353			

*$p < .05$.

Note. n = Amount of students present. SD = Standard Deviation. df = Degrees of Freedom. t = t-value. p = Statistical Significance. Likert-scale ratings range from 0 (Not at all) to 5 (Very much).

Table 15. *t*-test Results comparing how the technology appeared as an instrument to students in iPad and KAiKU Music Glove classes after lesson ended, week 6.

	n	Mean	SD	t	df	*p*
iPad	17	2.53	1.42	-0.394	35	0.696
KAiKU Music Glove	20	2.35	1.35			

*$p < .05$.

Note. n = Amount of students present. SD = Standard Deviation. df = Degrees of Freedom. t = t-value. p = Statistical Significance. Likert-scale ratings range from 0 (Not at all) to 5 (Very much).

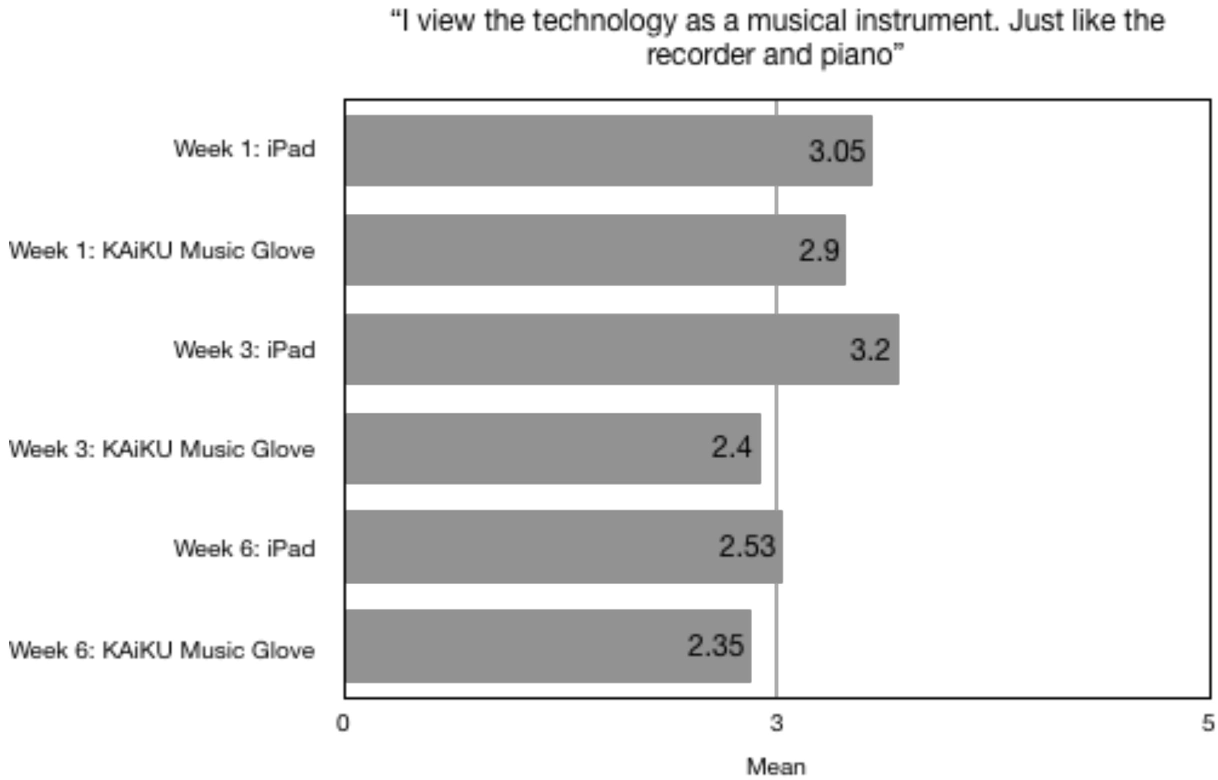

FIGURE 4. Means of responses the students gave to viewing the technology as an instrument over weeks 1 to 6. The iPad is shown to be rated consistently higher than KAiKU Music Glove.

As shown in table 16 a Mann-Whitney U test indicated that ease of use responses before and after lessons were similar for the iPad and KAiKU Music Glove class across weeks 1, 3 and 6.

Table 16. Mann-Whitney U Results comparing how easy the technology was to use in iPad and KAiKU Music Glove classes before and after lessons, week 1, week 3 and week 6.

	Week 1			Week 3			Week 6		
	Median	U	p	Median	U	p	Median	U	p
Pre-lesson	4	169	0.533	3.5	190.5	0.785	4	165	0.874
Post-lesson	5	189.5	0.987	4	192.0	0.816	4	136.5	0.285

Note. U = Used to determine statistical significance. p = Statistical Significance.

As shown in table 17, a Mann-Whitney U test indicated that viewing the technology as an instrument, before and after lessons were similar for the iPad and KAiKU Music Glove class across weeks 1, 3 and 6.

Table 17. Mann-Whitney U Results comparing how the technology appeared as an instrument to students in iPad and KAiKU Music Glove classes before and after lessons, week 1, week 3 and week 6.

	Week 1			Week 3			Week 6		
	Median	U	p	Median	U	p	Median	U	p
Pre-lesson	3	179.5	0.750	3	161.5	0.283	2	142	0.365
Post-lesson	3	177.5	0.714	3	134	0.068	2	154	0.609

Note. U = Used to determine statistical significance. p = Statistical Significance.

6.2 Test of Knowledge

The test of knowledge was complete by both classes before and after they used their technologies. This test would provide a basline of what the student's knowledge in the music curriculum was before using the technologies. After using the technologies the same test was given to the students to measure their academic performance in the curriculum. The test of knowledge is scored out of a total of 31.

6.2.1 Pre- and post- results: iPad class

Table 18. Pre- and Post- results of the iPad class.

	Mean	Median	SD
Pre-study	9.58	7.5	5.80
Post-study	16.17	16	7.80

Note. SD = Standard Deviation. Pre-study presents results before using iPad in the curriculum. Post-study presents results after using the iPad in the curriculum. Total test score is 31.

6.2.2 Pre- and post- results: KAiKU Music Glove class

Table 19. Pre- and Post- results of the KAiKU Music Glove class.

	Mean	Median	SD
Pre-study	12.52	10	9.30
Post-study	15.60	10.5	9.90

Note. SD = Standard Deviation. Pre-study presents results before using KAiKU Music Glove in the curriculum. Post-study presents results after using KAiKU Music Glove in the curriculum. Total test score is 31.

6.3 Qualitative observations

Qualitative video analysis was complete to better understand classroom behaviour. Two students from each class were selected to analyse their behaviours (M=2 F=2). This made a total of four students to analyse. All of these students completed both a pre- and post- test of knowledge. The students were selected regarding the proportion of their improvement margins found in their test of knowledge scores. In addition, both sets of students were present in class for the duration of the study to complete the analysis.

Videos recorded across lessons during weeks 1, 3 and 6 were played back for analysis. The analysis was complete over two weeks by the two researchers. We identified student behaviour patterns to investigate in the videos while consulting literature (Cozby and Rawn, 2012).

Coding parameters were made as off-task behaviour and student-teacher interaction agreed between the two researchers. Off-task behaviour was determined as the students being distracted and not interacting with their chosen technology in a single point in time. The students requesting assistance from the teacher determined teacher/student interaction. In the study setting, the video camera emerged as an important element to the experiment due to the angle of which it was recording video. This became a critical factor, as the participants had to be consistently in the video frame when completing the analysis.

The behaviour was coded by both researchers and results were compared at the end of the two weeks of video analysis. The codes were then tallied in agreement with each researcher.

6.3.1 Qualitative observations: iPad class

Table 24. Table showing tallied codes of both researcher's observation codes in iPad class. The total for the iPad class indicates more off-task behaviour than that of the KAiKU Music Glove class.

Week	Student	Off-Task Behaviour	Teacher/Student interaction
1	7	3	0
	12	2	0
3	7	0	0
	12	0	0
6	7	1	0
	12	4	0
TOTALS:		10	0

Note. Student refers to number assigned to students in class (range from 1 to 22). Selected student number 7 and 12 for analysis.

6.3.2 Qualitative observations: KAiKU Music Glove class

Table 25. Table showing tallied codes of both researcher's observation codes in KAiKU Music Glove class. The total for the KAiKU Music Glove class indicates more teacher/student interaction than that of the iPad class.

Week	Student	Off-Task Behaviour	Teacher/Student interaction
1	3	0	0
	10	0	0
3	3	0	0
	10	0	0
6	3	0	3
	10	0	3
TOTALS:		0	6

Note. Student refers to number assigned to students in class (range from 1 to 22). Selected student number 3 and 10 for analysis.

7 DISCUSSION

7.1 Discussion Introduction

This section will provide explanation of the main results within the context of the project's research questions and hypotheses. It does this by examining Likert-scale response ratings provided by the students and the baseline test of knowledge scores of the two classes.

7.2 Motivation Likert-Scale Self-Report Responses

Motivation response levels to use the two technologies remained high in both classes, showing similar response scores across weeks 1 and 6 and non-significance when compared against each other across weeks 1 and 6. Further, the Mann-Whitney U test showed non-significance. Comparatively there is not a significant difference in motivation between using both technologies. Overall, the users high scoring response indicate both technologies are motivating to use. As non-significance is reported in the difference in motivation before using the technologies, the hypothesis that KAiKU Music Glove users will respond with higher satisfacion in motivation than iPad users due to the novel nature of the technology is not supported.

The high score in this attitudinal response may have caused increased engagement levels for both sets of classes, potentially beneficial toward the students learning outcomes. Increased engagement in the classroom while using technology reinforces some of the findings in the literature consulted (Saenz, 2011; Henderson and Yeow, 2012; Clark and Luckin, 2013), however, these authors did not specifically measure motivation. Moreover, motivation levels remaining high in both classes suggest the technology was viewed positively by the students.

The practical relevance of measuring motivation when using technologies in the classroom is an important point to consider. Echoed in the literature review, among motivation scientists the general agreement is that helping students create meaningful connections between what they do and learn in school and the issues that concern them in their everyday lives should promote academic motivation and achievement, (Jeffrey, et al., 2018). Correspondingly, the children scoring high in motivation before using the technologies may show that technology is viewed as relevant to their needs in school and everyday life.

7.3 Ease of use Likert-Scale Self-Report Responses

Ease of use response levels remained high in both classes showing similar scores across weeks 1 and 6 before classes began and after classes finished. In addition, non-significance is recorded before using the technology, across weeks 1 and 6 before and after using the technology. Further, the Mann-Whitney U test reported non-significance. While the difference in ease of use response is highly marginal, the higher response in standard deviation for iPad users does not support the hypothesis that KAiKU Music Glove users will respond with higher variance than iPad users.

The responses indicate that both technologies were easy to use. This suggests the students found the technologies accessible and accordingly, the technology was not an obstacle for them to use in the music classroom. Both technologies scored higher after the students used them. The overall high score in ease of use among both classes may confirm positive experience when using both technologies in the classroom.

Corresponding to the literature review, ease of use in device technology is linked with user experience, usability and embodiment (Leman, 2008; Rousi, 2013). Equally covered in the literature review, the classroom teacher facilitated a student-centred classroom environment (Wynne, 2010), with the students given autonomy to collaborate with one another while using the technologies. The high response in ease of use with high amounts of class collabration suggests the technology was a practial tool for the students to use in the music classroom.

On the contrary it is difficult to assess both technologies ease of use with accuracy from these scores. The features and in particular, user interface of GarageBand are acknowledged to have influence on ease of use response levels. Determining how much influence the hardware and product design of both technologies held on the response scores, in contrast to how much the user interface and features the GarageBand software held is not fully addressed by the self-report.

7.4 Viewing the technology as an instrument Likert-Scale Self-Report Responses

When asked to respond if the students viewed the technologies as musical instruments, similar scores are observed across weeks 1 and 6 and non-significance reported before and after device use. In addition, a Mann-Whitney U test reported non-significance. The hypothesis that KAiKU Music Glove users will respond with higher variance than iPad users is not supported.

The responses in week 3 after the students used the technology show a close to significant result (*p=0.069).* The high score of the of the iPad and low score of the KAiKU Music Glove in week 3 may suggest a distinct difference in how the technologies appeared to the students. This response may be indicative as to how the technology performed during this session, particularly as the in-session observation notes recorded unstable Bluetooth connections of KAiKU Music Glove. The students experience of this technical problem when using the KAiKU Music Glove may hold influence on the response being close to significant.

The low response score from KAiKU Music Glove users suggest that the students perception of the hardware as a musical instrument was not easily understood. In contrast, the higher response score from iPad users suggest the students perception of the hardware as a musical instrument was more easily understood.

Refering to the literature review, Ware (2000) discusses that when a user must stop thinking about a task and focus attention to the computer interface the effect can be devastating to the overall thought process. Field and Spence, (1994); Cutrell, et al., (2000) correspondingly state the effect of interruptions drastically reduce cognitive productivity. Such interruptions were experienced in the technical problems with KAiKU Music Glove's Bluetooth connection repeatedly failing. As a result it is considered to have held the majority of influence on this response.

7.5 Test of Knowledge Scores

Before using the iPad, the students who would use that technology in their class produced an average score of 9.58 with a total of 20 students completing the test. After using the iPad, the same students produced an average score of 16.17 with a total of 19 students completing the test. Before using the KAiKU Music Glove technology, the students who would use that technology produced an average score of 12.52 with a total of 21 students completing the test. After using the KAiKU Music Gove technology, the students produced an average score of 15.60 with a total of 20 students completing the test.

These results show that the majority of students improvement in test score with the exception of one student, who decreased by one point after the six lessons. After 6 weeks of using the iPad, the respective class improved their baseline score by 21%. After 6 weeks of using the KAiKU Music Glove the respective class improved their baseline score by 10%.

Comparisons between the iPad and KAiKU Music Glove classes baseline and post-test score indicate an 11% difference, showing a higher margin of improvement for the iPad class. When completing the baseline test of knowledge, the class using the iPad registered a lower average score when compared to the KAiKU Music Glove class. This suggests the KAiKU Music Glove users had a stronger understanding of the music curriculum before they used the technology, as they scored higher than the class using iPad in their baseline test. Yet, after completing the post-test, the iPad users registered a higher result than the KAiKU Music Glove users. Accordingly, the results indicate the class using the iPad finished strongest, completing the six-week experiment with a higher post-test result and greater margin of improvement. When both classes post-test results are compared with one another, there is a 2% difference favouring the iPad class.

The iPad class performed stronger post-test despite registering a weaker baseline result than the KAiKU Music Glove class. This may confirm the iPad to be a superior technology within this portion of the study. Yet, how much the abilities of the users, software, hardware and test influenced the scores is difficult to state with accuracy. Admittedly, the contribution of these factors uncontrolled for may have influenced post-test scores for both classes.

Further, a limitation should be acknowledged with the post-test itself. The post-test tested for a question found specific to the iPad and this same question was given to students using KAiKU Music Glove. This was an error in the study's data collection phase. The students who used KAiKU Music Glove were asked to draw and place notes that were learned in the form of a hand during their post-test, still this was not counted in their final scores. This suggests that the baseline test of knowledge post-test examined a musical syllabus optimised for iPad users.

7.6 Qualitative Observations of classroom activity

Classroom setup times were observed throughout the analysis and quantified. This was understood to be the length of time it took before the lesson began. The iPad class set up time was recorded as 26% of its overall lesson time across weeks 1, 3 and 6, while the KAiKU Music Glove set up time recorded as 43% across weeks 1, 3 and 6. Such difference in setup times may have had an impact on class behaviour and learning outcomes. This also hints at the different technical barriers between setting up the devices. The iPad appeared to be much easier to pick up and use quickly. One must also be aware that the students are more familiar with using the iPad consistently.

In addition there was an observation made regarding KAiKU Music Glove's general comfort and fit with one observed student removing the device from their hand and placing the device back on it. The student asked for further assistance from the teacher to fit the technology on the hand. This may be a fruitful area to refine the prototype design to better suit the childs needs.

Overall, the differences in the observation tallies are minimal. The iPad scored higher in off-task behaviour while the KAiKU Music Glove scored higher in student teacher interaction. This may suggest that students who used the iPad were not focusing all of their attention on using the technology, while the class using the KAiKU Music Glove were more engaged. This could be a difference between a novel and established technology. It also could be demonstrative of KAiKU Music Glove's wearable design compared to the iPad being an external device that you pick up. In addition the low score in the off-task behaviour of KAiKU Music Glove may be suggestive that it was not as shared in its use amongst the students while the iPad was.

The KAiKU Music Glove class was observed to be generally more disruptive in week 3 despite this not being reflected in the tallied scores. This may relate to the low score in the response to viewing the technology as an instrument. There were multiple students requesting help to reset the Bluetooth connection of the KAiKU Music Gloves as they repeatedky malfunctioned in the class.

Both classes were observed to be generally more disruptive and collaborative in week 6 which may also have influenced both classes low scores in viewing the technology as instruments. Both classes were not experiencing technical difficulties from the hardware and this may have been a reflection of the teaching material and tasks the class were completing.

8 IMPLICATIONS AND CONCLUSIONS

8.1 Implications

To summarise how existing and prototype technologies affect academic performance in elementary school children, the iPad scored comparatively higher in overall attitudinal response and registered a 2% margin of improvement in the test of knowledge compared to KAiKU Music Glove. Given the above this confirms the iPad to affect academic performance in elementary school children with greater magnitude than the KAiKU Music Glove prototype.

The current study tested a new prototype technology in the music classroom, KAiKU Music Glove and compared its results to an established technology, iPad. Test data based on attitudinal ratings and academic performance were obtained from two different music classes and the results compared with one another. Likert-scale questionnaires were given to both classes to record their attitudinal response before and after using the technology. Non-significance was reported across all responses as they were compared with one another. A close to significant response was recorded when comparing how the students viewed the technology, with significance favouring iPad. All tested hypothesis were not supported. The largest improvements in academic performance found in the test of knowledge came from the class using the iPad.

This study is the first documented for KAiKU Music Glove. It exists within a wide collection of studies using and testing technology in the music education field. Research into music technology and education have often studied the role of technology ethnographically (Henderson and Yeow, 2012; Gaspirini and Culen, 2012; Hutchison, et al., 2012; Ostashewski, et al., 2009; Rowe, et al., 2016) with little mention to areas in prototype research and education. However, the action research methodology used by Henderson and Yeow, (2012); Gaspirini and Culen, (2012) and Hutchison, et al., (2012) was applied with success in the current study to examine practice in music education.

Generally, it is hoped that as technologies are introduced into the classroom the students benefit with tools to increase their engagement during class. In this study motivation remained high to use both technologies. It is considered that the high response in motivation led to increased engagement during class activity. Accordingly, the technology was considered to be viewed positively by the students.

Using relevant technology in the classroom is stated to help students make meaningful connections between what they do and learn in and outside of school and as a consequence, technology is said to promote academic achievement (Jeffrey et al., 2018). Such relevance to the students personal life may have also impacted the high response score in motivation.

Similarly, ease of use response levels remained high in both classes. The responses show that both technologies were easy to use. This suggests both technologies were not a barrier for the students to play music with. The high score in ease of use rating from both classes suggest a positive experience when using both technologies relevant to their tasks.

Despite non-significance reported when comparing responses to viewing both technologies as musical instruments, a close to significant difference was reported during week 3. The low score of KAiKU Music Glove during this week may be due to the poor technical performance of KAiKU Music Glove. Interestingly, KAiKU Music Glove responses are consistently lower than iPad responses in how the students viewed the technology and further speculation into this may reveal how the design of the prototype was percieved compared to the ready industrial design of iPad. The design of such hardware could impact user perception.

Namely, the difference in response may be due to the interface that was used in both classes. The GarageBand interface would be used alone in the iPad class and the KAiKU Music Glove class would use both KAiKU Music Glove hardware along with the GarageBand interface. The demand in paying attention to both KAiKU Music Glove hardware and the GarageBand interface may have impacted the low response score.

The users field of view can be influenced paying attention to both the hardware of the KAiKU Music Glove and GarageBand software at the same time.

Further, the low score may reflect other inferences regarding device design. The GarageBand interface may have been perceived as fluid and supporting of eye-hand coordination. With KAiKU Music Glove scoring lower, the hardware may need further development into supporting eye-hand coordination. Ware (2000) discusses that interfaces should be made as fluid as possible to support eye-hand coordination and provide rapid, consistent feedback.

On the contrary, Ware (2000) presents a counter argument of a violin having an extraordinarily difficult user interface with the user having to master virtuosity to achieve transparent expression. The author continues stating that it is an easy trap for designers to become focused on the problem of making an interface easy to use by a novice and more difficult to create designs for an expert (Ware, 2000).

Even so, should a user stop thinking about the current task and change attention to the interface itself the effect is said to be devastating (Ware, 2000). The result is said to be the loss of almost all cognitive context and drastic reduction in cognitive productivity (Ware, 2000, Field and Spence, 1994; Cutrell et al., 2000). This may have been reflected in the low response for KAiKU Music Glove in this category.

The teacher played an important role in making the technology practically relevant for the students to use. This is particularly important for KAiKU Music Glove as it had never been tested in a classroom before. As previously described student autonomy and collaboration was a feature of the class when using both technologies. In a subject matter expert interview after the experiment was complete, the teacher stated “I made quite a lot of preparatory work with them (KAiKU Music Gloves) because I didn’t know what to expect. The whole teaching material was completely different,” Mikkonen, H. (12th February, 2018). SME Interview. In addition the teacher stated, “sometimes the kids just played by themselves which was working just nicely,” Mikkonen, H. (12th Febraury 2018). SME Interview. This central role the teacher played in preparing the classroom material while facilitating a student-centred mode of autonomy, supports the constructivist literature found in this thesis literature review. The literature states the teacher maintains a central role in a class structure, even as that means giving students practical freedom (Nanjappa and Grant, 2003; Witfelt, 2000; Richards 1998; Wynne, 2010). To summarise, it may be that when technology is used in the elementary classroom it rests on a constructivist premise.

The implications for KAiKU Music Glove as a product in development are great despite being out of reach for this current study. The study shows that KAiKU Music Glove is well engineered to function within its parameters as a pedagogical tool. Further study may branch into motion capture, to investigate movement patterns during device use and explore how these findings bare relevance to different prototype versions. Moreover, a study dedicated to analysing KAiKU Music Glove's pedagogical system, inspired by Guido d'Arezzo (Miller, 1973), may investigate how different arrangements mapping sensors around the fingers impact playstyle. In addition, exploration is needed for different versions of KAiKU Music Glove hardware design and analysis of which hardware is best suited for general comfort and fit.

8.2 Practical Application

Understanding that KAiKU Music Glove is a product in development makes this study not only an academic pursuit. The study has benefit to its development team and there is potential for the knowledge presented here to aid in overall product improvement. Pertinent to this study investing knowledge into the practice of development is a praxis influenced idea, (Gadotti, 1998; King and Himonides, 2016). Moreover, development of KAiKU Music Glove using the data in this study may foster improved pedagogical performance.

A product development framework could be used to analyse the data collected in this study, structuring its use for designers. The design of KAiKU Music Glove has a product-out strategy which means it is manufactured based on its own product strategy. A market-in strategy suggests a manufacture based on the consumer's desire and preference (Nagamachi, 1995). A framework which could be used to aid its product development is from the automotive industry, known as Kansei engineering. Kansei engineering aims to produce a product concerning four key points, (1) Grasping the consumer's feeling (2) Identifying design characteristics from the consumers feeling (3) Making the product as ergonomic as possible (4) Adjusting product design to current societal trends (Nagamachi, 1995). An immediate solution could be reviewing the video data collected and tallying which prototype version was most used by the students and then draw conclusions on the features from the most used prototype.

The multidisciplinary nature of user-experience is said to represent many approaches and definitions (Rousi, 2013) and it is difficult to know with accuracy how user experience reflects on the KAiKU Music Glove device in this thesis. Aesthetics (if the product looks like an instrument) and how the product is perceived by the user (excitement, motivation) are considered all part of user experience (Rousi, 2013; Hassenzahl and Tractinsky, 2006; Gaver and Martin, 2000). Studies in user experience are also said to be holistic in their approach due to their combination of many factors, coming together at once (Rousi, 2013). This is reflected in the nature of this study.

Applying this wide user experience framework to the KAiKU Music Glove prototype, user needs could be given ranking by the device developers to the senses of which KAiKU Music Glove aims to engage. Perhaps the senses be structured in such a way to pinpoint sensations in hierarchal form, in order of importance. As the device is a glove it is a device with a high degree of specificity where practical use and embodiment are related than that of the iPad. Analysing hand movement and sensations found on the hand with motion capture and skin conductance analysis may lead to an improved experience for the user.

8.3 Limitations

The sample in this study was a relatively small pool of participants and the results must be considered with caution when making generalizations outside of its population. In addition the comparative methodology used in the current study may be of limitation and it is reported by Emigh (1997) that such methods cannot support general theories as they are based on induction. The literature consulted regarding action research (Costello, 2007; Wragg, 2012) also supports this argument. Typically due to the large range of variables at play in the current study, it is difficult to find empirical evidence to make casual explanations about them due to the comparative method used (Emigh, 1997). Indeed, controlling for more of these variables may prove useful to make definitive arguments.

The students were allowed to self-select different prototype versions of the KAiKU Music Glove in each lesson and were observed to make such selections differently. This could not be consistently accounted for, as different prototype versions were made available for the researchers as the lessons progressed. Further, a student-centred classroom environment enabled this process (Wynne, 2010).

The materials used in the lessons need increased collaboration between developer, teacher and student in order to achieve practical educative outcomes. The teacher in the current study did not have detailed knowledge of what to include in the study and further coordination between developer and teacher is necessary to achieve empirical results.

In order to further understand how a student finds a device easy to use the current study may adopt a more technically distinct methodology and test relevant device features. In addition, qualitative analysis in observing the students using the product may better asses the technologies ease of use and user experience. Analysis could be made of what device features were used repeatedly as well as what challenges were often experienced.

Should a similar methodology be repeated, the baseline test of knowledge must be repeated with a test made fully attributable to the KAiKU Music Glove. The test of knowledge examined the same set of questions across each of the devices and this was an error made by the researchers and teacher. The test examined questions which favoured how the iPad was representing notation and gave this same examination to the KAiKU Music Glove class.

The video camera angle impaired the qualitative analysis and more angles or wider angled device would be better suited for the relative population.

Despite these limitations, completing the study in a real-world environment gave the present study firm foundations in ecological validity. Such a notion is supported by Rousi (2013), stating that real device usage in real environments shapes real device development.

8.4 Further Study

As previously mentioned there is much opportunity for additional analysis. Further analysis of the video data could be made to include more qualitative measures of behaviour. Isolating specific features of the device for analysis, such as KAiKU Music Glove's touch sensors and fit may prove useful. The sounds KAiKU Music Glove triggers may also prove a useful avenue to explore for future research, as touching a string sound in comparison to touching a percussive sound may make a subject interact differently with the technology and attribute the need for re-mapping. Integration of Taction Control software to a study may prove advantageous for the device developers as they can isolate hardware inputs for analysis with ease. A more technically distinct framework can be used to analyse the technology interaction. Further, a larger population recreating this methodology will also give more magnitude to the Likert-Scale attitudinal data as well as the test of knowledge scores.

Examination of device use in respect of the student's age could prove fruitful, to investigate potential variance in score when using the device, as age increases or decreases. This could be of great use to the development team, as they would empirically know what market age group their device is best suited for.

In addition, research into device use may benefit from the methods adapted from neuroscience. Any study such as this would likely remove ecological validity from its equation yet it may be better understood how embodiment is consistently experienced by user population when analysing which brain mechanisms are active during the process of device use.

Moreover, another area of potential investigation is device use for special needs education as an assistive learning technology. One may assume that the novelty of the device and its wearable nature will transfer over to special needs education with ease. A different critical framework of research for the device may need to be actioned before this could take place.

8.5 Conclusions

- High response levels were found in motivation to use the technologies before and after lessons. This may indicate increased engagement levels in students of both classes when using technologies. This may be beneficial toward the students learning outcomes and suggests that students viewed the technology positively.

- High response levels regarding ease of use of the technology were found. This may suggest that the technology is an accessible tool for students to use during class. In addition, high response levels in ease of use of the technologies may suggest that the technologies are an easy tool to learn with in the classroom. The teachers understanding of the technologies may have made them easier for students to use.

- KAiKU Music Glove's unstable technical performance potentially disassociated it being seen, used and embodied as an instrument. This was recorded in a close to significant repsonse during week 3. This was also observed in the video data as the KAiKU Music Glove class was more disruptive during the technical problems experienced by the students.

- In the test of knowledge score, the results indicate the class using the iPad finished strongest, completing the six-week experiment with a higher post-test result and greater margin of improvement. There is a 2% improvement difference favouring the class using iPad. This may confirm the iPad to be a superior technology within this portion of the study. Consistent improvements by many students were recorded in the iPad class. Larger improvements by few students were recorded in the KAiKU Music Glove class.

The current study explored how existing and prototype technologies affect academic performance in elementary school children by testing iPad and KAiKU Music Glove hardware in the music classroom. It suggests that motivation, ease of use and how the technology is perceived to be important components in how the technology affects academic performance. The attitudinal responses were reinforced by qualitative observations of the class who used the technologies. Video analysis provided qualitative evidence for the complex nature of these variables when making conclusions about device use.

The students responded high in motivation using both technologies and similarly in ease of use using both technologies. Viewing the technologies as instruments showed variance in score. When viewing the video recordings, technical difficulties of the KAiKU Music Glove device could be attributed to teacher and student interaction (the student asking for the teacher for help) or how disruptive the classroom was. The test of knowledge revealed a bigger increase for the class that used iPads as their learning modality. This may confirm the iPad to be a superior technology in this portion of the study. Yet it is important to note that both tests of knowledge examined a context familiar to the iPad class than to the KAiKU Music Glove class. A consistent pattern of test score improvement level is recorded by the students using the iPad, however larger test score increases by fewer students are recorded by students using the KAiKU Music Glove. The fluctuating nature of each device technical performance is perhaps shown in these final scores.

As this is the first study of its kind testing KAiKU Music Glove in the environment it is designed for, the current study adds empirical weight to KAiKU Music Glove's pedgagoical concept. The implications of the study give empirical weight to students experiencing KAiKU Music Glove as a positive device within the classroom. There is considerable support reflected in the test of knowledge scores, that how the notation is mapped on KAiKU Music Glove is a pragmatic and functional one. Additional research is required to support how the device be best used in the classroom and further development of the device is required. Increased control may be given to the set of variables in the current study and a more controlled experiment could be applied for future study of the device.

In this study, placing a new technology into a present educational setting was seamless and there was little challenge putting it into a formal music class (Jorgensen, 2012). As argued, formal pedagogical approaches may be too restrictive in their method of teaching, disregarding the technological environment students grow up in (Jorgensen, 2012; Leman, 2008) and the students in our study may have been familiar with technology in their day to day life, making them open to using a new technology in their class. This may have showed in a positive adoption rate of using the technology by motivation response, incidentally echoing research that in the Nordic countries, adoption rates of technologies between teachers and students is high (Jorgenson, 2012).

As described, KAiKU Music Glove aims to strike a balance in learing strategy and innovation. Despite the academic test scores favouring students who used the iPad, many of the students who used KAiKU Music Glove did find improvements in their test scores. For a prototype still in development, this shows promise, that with a high motivation score from students to use the technology and test score improvements, it is achieving the balance in learning and innovation that so many educational technologies are striving for.

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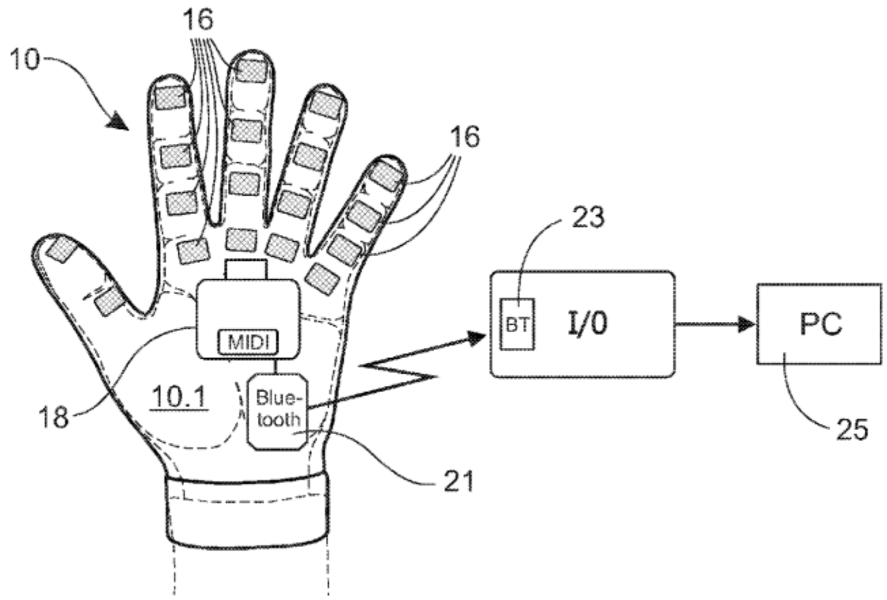
Appendix 1 – KAiKU Music Glove invention with sensors.



Appendix 2 – Likert-Scale Student Self-reports

(BEFORE THE LESSON)

Student Name: ____ Date: ___________________________

Assigned Student Number: ________________

1. I am very excited to use the iPad/Glove today. — not at all / no / maybe / yes / very much

2. I think the iPad/Glove will be easy to use today. — not at all / no / maybe / yes / very much

(AFTER THE LESSON)

Student Name: ____ Date: ___________________________

Assigned Student Number: ________________

1. Today, I found the iPad/Glove easy to use. — not at all / no / maybe / yes / very much

2. Making music on the iPad/Glove today was easy. — not at all / no / maybe / yes / very much

3. Today I viewed the iPad/Glove as a musical instrument Just like the recorder and piano. — not at all / no / maybe / yes / very much

4. I think I could teach my friends to play the iPad/Glove. — not at all / no / maybe / yes / very much

(AFTER THE LESSON)

Student Name: ______________________________________ Date: __________________________

Assigned Student Number: _______________

5. Today it was easy for me to follow directions while playing the iPad/Glove.

not at all | no | maybe | yes | very much

6. Today Henna helped me play the iPad/Glove.

not at all | no | maybe | yes | very much