World Journal on Educational Technology: Current Issues

Volume 11, Issue 1, (2019) 38-47

www.wj-et.eu

Developing a haptic glove for basic piano education

Ferhat Kadir Pala*, Department of Computer Education and Instructional Technologies, Aksaray University, 68100 Aksaray, Turkey

Pınar Mihci Turker, Department of Computer Education and Instructional Technologies, Aksaray University, 68100 Aksaray, Turkey

Suggested Citation:

Pala, F. K. & Mihci Turker, P. (2019). Developing a haptic glove for basic piano education. *World Journal on Educational Technology: Current Issues*. *11*(1), 38–47.

Received from 10 November; revised from 15 December; accepted from 04 January

Selection and peer review under responsibility of Prof. Dr. Servet Bayram, Yeditepe University, Turkey.

Abstract

This study aims at developing a glove with integrated haptic interface to facilitate the learning of those who have just started playing piano and allowing them to perform without a need for a piano during daily activities. The steps of the analysis, design, development, implementation, evaluation model were used in the research. In the analysis stage, students' needs were analysed and problems were determined. At the design stage, practices oriented to resolving these problems were analysed and it was decided that haptic gloves might be appropriate for the solution to the problems revealed. At the development stage, evaluations were made directed to development of the product and formatting. The participants used the haptic glove for a while and have expressed their opinions, which are recorded by video camera. The recordings were analysed and it was found that the second version of the haptic glove increased the participants' recall level of the music.

Keywords: Music education, haptic glove, piano education, passive haptic learning.

* ADDRESS FOR CORRESPONDENCE: **Ferhat Kadir Pala,** Department of Computer Education and Instructional Technologies, Faculty of Education, Aksaray University, 68100 Aksaray, Turkey. *E-mail address:* fkpala@gmail.com / Tel.: +90-382-288-3422

1. Introduction

Ever since such concepts as student-centredness and active learning gained prominence in education, the demand for the use of technology use in educational contexts has increased and research on this subject has grown in importance. From past to present, such technological devices as televisions, radios and computers have been used for pedagogical purposes and how these technologies improve students' academic achievement, motivation and motor skills has been a focus of interest for researchers. Being one of the recent examples of these practices, haptics technology has also started to appear in education.

The origin of the word 'haptic' dates back to 1931. Its origin is in Greek and emerged from the words 'Haptikos' and 'haptesthai', which meant touch (Barfield, 2010). According to El Saddık, Orozco, Eid and Cha (2011), haptic technology is 'an interdisciplinary field that deals with the understanding of human touch (human haptics), motor characteristics (machine haptics), and with the development of computer-controlled systems (computer haptics) that allow physical interactions with real or virtual environments through touch'. This field provides the opportunity to touch and manipulate such features of these 3-D virtual objects as shape, weight, surface texture and temperature (Yadav & Krishnaiah, 2013).

Haptic technologies use haptic feedback that sends vibrations to a person's body or force or motion with similar effects. Enabling the body to feel touch, heat, pain and motion, the sensors identify force that is exerted by the actuators in the haptic system, thereby allowing the user to interact with the device she/he works with. In general, it can be said that haptics enables a person to feel the input from the device, in addition to the traditional methods of seeing and hearing (Anand, 2013). An investigation of the areas of the use of the haptics demonstrates that these areas vary and practices exist in a lot of fields such as commercial, medical, surgical, rehabilitation, military, entertainment, art and design (Eid, Orozco & Saddik, 2007). Pawluk, Adams and Kitada (2015) mentioned opportunities that the haptic technology offers for disabled people and they give examples of Braille reading, creating tactile graphics and applications for orientation.

When the practices of haptics in education are examined, it is seen that it is divided into two as active haptic learning and passive haptic learning. In active haptic learning, instant feedback is provided to the individuals through their senses and they receive stimuli in the learning process. On the other hand, passive haptic learning provides individuals the opportunity to perform other tasks such as reading a book and watching TV while the individuals are learning a psychomotor skill through a sense of touch.

Learning a new motor skill is a progressive learning process and practicing is at the centre of this process. For this reason, it is possible to achieve a better level of motor skill by repeating the skill. At this point, passive haptic learning activates muscle memory through repetition and helps the learning process (Huang et al., 2010).

When the literature was reviewed, it was seen that Barfield (2010) mentioned such examples as the creation of sculptures in art and the manipulation of geographic databases, the study of rock and surface models in terms of hardness, shape and structure and virtual excavations in anthropology. An investigation into the effects of their practices in education, Civelek, Ucar, Ustunel and Aydin (2014) researched the impact of haptic implementation on K12 students' physics achievement. The findings indicated that the implementation had positive effects on the students' academic achievement, motivation and learning quality.

Hamza-Lup and Stanescu (2010) addressed that kinesthetic learners' endeavour to learn concepts through reading and listening; therefore, haptic technology is a significant opportunity offered to those kinesthetic learners. Learning environment that is presented by means of visual and auditory methods can be enriched by including the sense of touch in the environment. In a similar vein, Barfield (2010) stated that haptics enables students to touch and explore objects actively, thereby helping the

learning process. With the help of haptics, students can feel objects tactually, thus it is possible for them to overcome conceptual barriers regarding mathematics and engineering.

It is seen that the areas of the uses of haptics are not limited to mathematics, engineering and physics and haptic implementations have been advanced in music education, as well. Huang, Do and Starner (2008) developed a glove in an attempt to help participants learn how to play piano during daily activities by activating passive haptic learning. Researchers indicate that the process of learning an instrument can be time-consuming for adults. For this reason, they express this implementation can be effective for individuals with respect to learning how to play the piano. Besides, researchers indicate that individuals who are exposed to passive knowledge in rich learning environments learn more. Therefore, they analysed users' passive learning processes by means of the gloves. The data yielded positive results. Similarly, Grindlay (2007) made use of a haptic system in piano education and specified that the system can be effective in teaching motor skills.

In the light of the studies conducted, this study aimed to develop a haptic glove with an integrated haptic interface for the purpose of facilitating learning of those who started playing piano and allowing them to perform without a need for piano during daily activities.

2. Methodology

Focusing on the development of haptic gloves to facilitate the piano learning process, this research is practical action research (Newton and Burgess, 2008). Practical action research is a kind of research approach that the researcher and the practitioner work in cooperation to identify and develop a plan for implementation oriented to a solution, that is flexible in that interaction with the practitioner may change the course of the research, and that is oriented to improvement of the practice (Yildirim & Simsek, 2006).

2.1. The development process

The purpose of this research is to facilitate the piano learning process and enable practice during routine activities without a need for a piano. Accordingly, a study called Mobile Music Touch that was conducted in Georgia Tech University provided the inspiration for the current research and a haptic glove was developed. Analysis, design, development, implementation, evaluation model was benefited, yet three steps of the model were mentioned in this research. The steps of the model and the activities performed are shown in Figure 1.

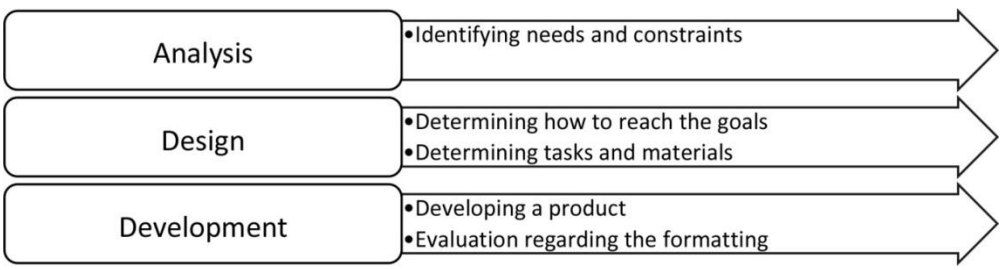

Figure 1. The steps of the haptic glove development

As shown in Figure 1, the process started with the *Analysis*. At this stage, analyses exist concerning why the developed context was needed. Every year, 40 students matriculate at Aksaray University, Faculty of Education, Department of Music Education.

Students receive piano education 1 hour a week until they graduate. They are trained by lecturers who work at the department and the specified compositions are played on the piano. However, each student needs to practice for these compositions to be played.

As a result of the interviews carried out with 23 freshmen and three lecturers at the Department of Music Education, it was determined that the number of the pianos were limited; therefore, the students who took courses practice within limited hours and at limited levels. That situation impedes students' improvement. Students expect additional pianos or different materials for practice. In addition, by means of the glove that would be developed within the scope of the research, development of a supportive material is valued not only for students at the department of music education but also for all those who would like to learn how to play the piano but cannot spare time.

Following the needs analysis, the *Design* process started and practices directed at solving this problem were analysed. Mobile Music Touch study (Huang, et al., 2008) was inspired; the writers were contacted and decided that haptic glove might be appropriate for the solution to the problem revealed. Because it was considered that by means of this glove, students could exercise and learn compositions passively which they need to play on piano even while they carry out their daily tasks. With the Arduino Uno and the vibration motors, it was decided to create the technical infrastructure and to code a specified piano composition.

In line with the Design process, the *Development* process started. In the haptic glove, vibration motors, Arduino Uno and power unit were located for each finger of the right hand. The vibration motors were programmed into the Arduino Uno with the assistance of the Arduino IDE software. Following the development of the product, evaluations were made regarding formatting with the participation of the students at the department of music education and other departments. Improvements were made in accordance with the participants' opinions. After that, evaluations were carried out again with respect to formatting with students some of whom were different while some of them belonged to the previous participant group. In line with the expressed opinions, upgrade and amendments of the product were completed.

2.2. Study group

Two different evaluation procedures were carried out while developing the haptic glove. For this reason, two different participant groups took part in the study. First group consisted of 10 students with six females and four males. The participants studied at the departments of Music Education, Computer and Instructional Technologies Education, Management Information Systems and Geomatics Engineering.

The second group comprised a total of 12 students, five of whom were also in the first group. The participants in this group studied at the departments of Music Education, Computer and Instructional Technologies Education, Psychological Counselling and Guidance and Industrial Engineering. In an attempt to find out whether improvements determined by five participants in the first group were accomplished or not, these students participated in the second evaluation process.

While study groups were being formed, the criterion was that the participant had never played piano before, except those at the department of music education. They are also agreed to participate in the research. However, music education students took part in both groups so that feedback could be received that would help the development process.

2.3. Data collection tool

During the course of the implementation, participants used the glove from 15 to 60 minutes; meanwhile, they were allowed to do other tasks. There was no time limitation during the implementation. The implementation was terminated when the participant declared that they learned and can perform the piano melody and rhythm. At the end of the process, the participants were interviewed faced to face and the data were collected. These interviews were video-recorded for the purpose of increasing the reliability of the interviews and enabling various researchers to reanalyse the data. Video-recordings were viewed, deficiencies were detected, the haptic glove was redesigned

in line with the participants' views and their opinions were received once again through the repetition of the implementation.

2.4. Data analysis

Video-recordings were viewed and transcribed by the researchers. Improvements regarding the haptic glove were determined and its development continued. Content analysis was used to analyse the recordings. Content was first coded by two experts whose expertise is piano education at the university and then the categories were created. The categories were divided into two parts; development required and development not required. The compatibility between the experts was examined. The alignment between the experts was calculated using the formula 'Consensus/ (Consensus + Disagreement) × 100' by Miles and Huberman (1994). In all analyses, it was seen that the reliability levels of experts were above 70% (Yildirim & Simsek, 2006).

3. Findings

3.1. Findings with regard to the development of the haptic glove (first stage)

Figure 2. First version haptic glove

To identify amendments to the haptic glove, two different evaluations were made at the stage of development. In the first stage, fitness (sports) gloves were used in order to grasp the users' hands easily. An electronic circuit and a 9 V battery—as the power supply—were placed on the glove. Arduino Uno card was used to program the haptic glove. Vibrations were placed on the third knuckles of the fingers. In Figure 2, there is a visualisation of the glove developed.

Table 1. Glove use times of the participants who participated in evaluations regarding the first version development

Sequence of practice	Department	Gender	Duration
Participant 1	Music Education	Female	20'
Participant 2	Music Education	Female	20'
Participant 3	Computer and Instructional Technologies Education	Male	30'
Participant 4	Music Education	Male	30'

Participant 5	Music Education	Male	40’
Participant 6	Music Education	Female	30’
Participant 7	Geomatics Engineering	Female	30’
Participant 8	Management Information Systems	Female	20’
Participant 9	Management Information Systems	Female	30’
Participant 10	Music Education	Male	30’

As shown in Table 1, the duration of the haptic glove use varied between 20’ and 40’. The majority of the students were from the Department of Music Education. In addition to that, students from Computer and Instructional Technologies Education, Management Information Systems and Geomatics Engineering took part in the study. Throughout the time that the students wore the haptic glove and the notes of the music were transmitted to the users’ fingers with the help of the vibrations. In this process, the participants were asked to be engaged in routine tasks and express their opinions to develop the glove. Accordingly, the following opinions were received from some participants within the scope of the first evaluation.

Participant 1
Before playing the piano, we do a certain exercise to warm up the fingers, this is like that. I feel as if I were exercising at this moment.

Participant 3
I feel like somebody tells me which keys to press. I can detect rhythm from vibrations. The vibration on my little finger was weak because the glove was a bit big for me.

Participant 4
It was like my fingers moved faster after the practice.

Participant 5
It plays a melody. When I was wearing the glove, I went to the canteen, bought chocolate. I sat at the canteen. I used a computer. I felt my fingers were a bit tired due to the vibrations. Since the same thing repeated continuously, I memorised it after some time. The vibrations mixed a little on my middle fingers.

Participant 6
The vibrations mingled because of the fact that the glove was a little big; I could not feel the vibrations, especially on the middle fingers. I believe that I can feel the vibrations better if they are close to fingertips rather than the first knuckles.

We can use the finger number while working. Our finger numbers are written on songs like the 5th finger and the 3rd finger. This glove can help us comprehend finger numbers. While I had the glove on my hand, I used computer, mobile phone and I did a lot of things that I normally do.

Participant 8
Vibrations are a bit irritating. It has a certain loop. Sometimes vibrations on the middle and ring fingers mingled when they were successive. The first time it mixes but after that, you get accustomed to it because it repeats.

Participant 9
I know programming. This has a specific algorithm too. The music is composed through vibrations.

Participant 10
Normally, I play baglama (an instrument like a guitar). I felt as if I were playing piano by means of this device.

When the participants’ views are examined, it is found that it would be beneficial and effective for them to practice with the haptic glove. However, the majority of the participants indicated that the

vibrations on the middle finger mixed. A student thinks that the transfer of vibrations to the first knuckles might prevent this mixing; thereby, letting them feel vibrations more clearly.

3.2. Findings with regard to the development of the haptic glove (second stage)

Opinions that were expressed as a result of the first evaluation were taken into consideration and the vibrations were moved to the first knuckle of the finger. Previously placed on the hand, the electronic circuit and 9 V battery were put on the wrist to allow users to act more comfortably. Instead of Arduino Uno card, a smaller one, Arduino Nano card was used to lighten the weight of the circuit and diminish the area and height that it covered on the wrist.

With the intent of enabling users to feel vibrations more clearly and to eliminate vibration mixing, an amplifier was added to the electronic circuit, thereby increasing the power of the vibration motors. The fitness glove was abandoned based on the participants' views in that the glove did not cover their hands directly. Instead, a patchwork glove was produced that could be adjusted according to the size of the wrist and fingers. Figure 3 presents the second version haptic glove that was modified in line with the feedback received through the first evaluation.

Figure 3. Second version haptic glove

After the second version haptic glove was developed, the glove was presented to the second participant group. They use the glove and explained their opinions for evaluation regarding the development. Table 2 shows the glove use times in the second participant group.

Table 2. Glove use times of the participants who participated in evaluations regarding the second version development

Sequence of practice	Department	Gender	Duration
Participant 5	Music Education	Male	30'
Participant 11	Music Education	Female	15'
Participant 12	Computer and Instructional Technologies Education	Female	30'
Participant 4	Music Education	Male	15'
Participant 1	Music Education	Female	23'
Participant 2	Music Education	Female	22'
Participant 13	Music Education	Female	20'
Participant 14	Psychological Counselling and Guidance	Male	17'

Participant 15	Psychological Counselling and Guidance	Male	50’
Participant 16	Psychological Counselling and Guidance	Female	46’
Participant 17	Industrial Engineering	Female	30’
Participant 3	Computer and Instructional Technologies Education	Male	60’

Table 2 demonstrates that the duration of the haptic glove use varied between 15’ and 60’. The majority of the students were from the Department of Music Education. Besides, students from Computer and Instructional Technologies Education, Psychological Counselling and Guidance, and Industrial Engineering participated in the research. As in the first evaluation, the participants used the glove for a while during which a piece of music was implemented to the participants by means of vibrations.

Meanwhile, the participants were asked to perform daily activities and express their opinions regarding the development. Furthermore, five students who took part in the first evaluation were included in the second evaluation to clarify whether deficiencies were remedied or not. Within the scope of the second evaluation, the following opinions were obtained from the participants.

Participant 5
I kept the melody better in mind since the vibrations were a bit at a faster frequency. Middle and ring fingers mixed a little.

Participant 11
I felt as if I were playing piano.

Participant 12
The vibrations are strong. I could use my hand freely during practice.

Participant 4
This one is easier to use. That the vibration motors were transferred to the fingertips was well in terms of feeling the vibration. However, the fingers might touch each other as it was thick.

Participant 1
The vibrations are clearer and faster. As they are faster, the melody sticks in my mind.

Participant 2
I feel the vibrations more clearly. It is beneficial that they are in the fingertips. The vibrations did not mix at all. Thus, I could solve the melody more easily.

Participant 13
I feel which keys I press. I could solve the melody. I can feel which key I pressed and how many strokes I passed. It could be beneficial for students to understand better.

Participant 14
My fingers got a little numb. I sometimes felt that the vibrations mixed.

Participant 15
When I had the glove on my hand, I did my work. It was not a problem. It was a nice feeling. After a while, I started not to take notice of the vibrations.

Participant 17
I was wearing the glove during the class and I listened to the teacher; there were some topics that attracted my attention. However, my focus was generally on my hand which the glove was on.

Participant 3
In comparison to the previous version, I perceived the vibrations more clearly. They did not mix this time.

When the participants’ views on development were investigated, it could be seen that the participants who took part in the first evaluation indicated that strengthening the vibrations, speeding

them up and transferring them to the first knuckles enabled to learn more permanently. In addition, the participants remarked that this experience was similar to playing piano and they could solve the melody while they were doing their daily work. Besides, some of the students expressed they used the glove comfortably, whereas some still had mixing problems on their middle and ring fingers. A participant thought that as pieces attached to the fingers were thick, the fingers touched each other. In line with these opinions, it can be seen that the glove still needs a number of remedies and development process should continue.

4. Results and discussion

In this study, a haptic glove was developed in order both to meet the needs of the students who studied at the Department of Music Education and to allow those to practice it who would like to learn how to play the piano. During this process, it was identified that there were not enough number of pianos for students to learn compositions included in the course content and improve themselves at their departments. For this reason, it was thought that the haptic glove might help students as additional material and might enable them to exercise while they were busy doing their daily work.

In the development of the haptic glove, two different evaluation processes were carried out in order to identify remedies and amendments were made in accordance with the views. Data obtained through the first evaluation demonstrated that the vibrations on the middle finger mixed; therefore, the vibrations needed to be accelerated and strengthened. Besides, some participants thought that the transfer of the vibrations to the first knuckles of the fingers would be more effective in sensing the vibrations without mixing them. In line with the opinions received from the first evaluation, amendments were made to the glove. To illustrate, the vibrations were put on the first knuckles of the fingers. After these amendments, the students expressed positive opinions. Hence, it can be said that the vibrations on the first knuckles are more effective in solving the melody and learning the composition.

Following these amendments, the students tried the glove for a while for the second evaluation and they expressed their opinions. Accordingly, the second version haptic glove increased the participants' recall level of the song and the students adopted positive attitudes toward the glove. In addition to that, the participants indicated that the haptic glove was a good practice and warm-up tool. Similarly, in their studies, Huang et al. (2008) referred to positive effects of the haptic gloves on students. Similarly, the participants remarked they could use the glove while learning the piano.

Moreover, the students expressed that they were feeling as if they had been playing piano with the haptic glove and the compositions were more permanent in their minds by means of the repetitive vibration combination. In his study, Grindlay (2007) conducted haptic experiments on percussion instruments and it was found that supporting sound-based education with haptic had a positive impact on students' performances.

5. Recommendations

The opinions offered by the participants were such amendments as putting led to the haptic glove. However, this could not be done in the present research. These amendments can be made in different studies and their effects can be investigated.

In this study, the haptic glove was developed for the right hand only. In future studies, haptic gloves can be developed where the right hand and left hand work together.

References

Anand, D. (2013). How haptic can help your project?. *Embedded Haptics May,* 68–71.

Barfield, W. (2010). The use of haptic display technology in education. *Themes in Science and Technology Education*, *2*(1–2), 11–30.

Civelek, T., Ucar, E., Ustunel, H. & Aydin, M. K. (2014). Effects of a haptic augmented simulation on K-12 students' achievement and their attitudes towards physics. *Eurasia Journal of Mathematics, Science & Technology Education, 10*(6), 565–574.

El Saddik, A., Orozco, M., Eid, M. & Cha, J. (2011). *Haptics technologies: bringing touch to multimedia*. Springer Science & Business Media.

Eid, M., Orozco, M. & El Saddik, A. (2007). A guided tour in haptic audio visual environments and applications. *International Journal of Advanced Media and Communication, 1*(3), 265–297.

Grindlay, G. C. (2007). *The impact of haptic guidance on musical motor learning* (Doctoral dissertation). Cambridge, MA: Massachusetts Institute of Technology.

Hamza-Lup, F. G. & Stanescu, I. A. (2010). The haptic paradigm in education: challenges and case studies. *The Internet and Higher Education*, *13*(1–2), 78–81.

Huang, K., Do, E. Y. L. & Starner, T. (2008). Pianotouch: a wearable haptic piano instruction system for passive learning of piano skills. In *Wearable Computers, 2008. ISWC 2008. 12th IEEE International Symposium on* (pp. 41–44). IEEE.

Huang, K., Starner, T., Do, E., Weinberg, G., Kohlsdorf, D. Ahlrichs, C. & et al. (2010). Mobile music touch: mobile tactile stimulation for passive learning. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 791–800, CHI '10). New York, NY: ACM. https://doi.org/10.1145/1753326.1753443

Miles, M. B. & Huberman, A. M. (1994). *Qualitative data analysis: an expanded sourcebook*. Thousand Oaks, CA: Sage Publications.

Newton, P. & Burgess, D. (2008). Exploring types of educational action research: implications for research validity. *International Journal of Qualitative Methods, 7*(4), 18–30.

Pawluk, D. T., Adams, R. J. & Kitada, R. (2015). Designing haptic assistive technology for individuals who are blind or visually impaired. *IEEE Transactions on Haptics, 8*(3), 258–278.

Seim, C., Chandler, J., DesPortes, K., Dhingra, S., Park, M. & Starner, T. (2014). Passive haptic learning of Braille typing. In *Proceedings of the 2014 ACM International Symposium on Wearable Computers* (pp. 111–118, ISWC '14). New York, NY: ACM. https://doi.org/10.1145/2634317.2634330

Yadav, S. & Krishnaiah, R. V. (2013). *Haptic science and technology* (arXiv preprint arXiv:1309.0185).

Yildirim, A. & Simsek, H. (2006). *Nitel arastirma yontemleri.* Ankara, Turkey: Seckin Publishing.