Indian Journal of Science and Technology, *Vol 9(24), DOI: 10.17485/ijst/2016/v9i24/96058, June 2016*
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

The Changes of Middle School Students' Perception and Achievement based on the Teaching Method in Physical Computing Education

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Abstract

Background/Objectives: This study aims to identify effective teaching method in physical computing education for middle school students. **Methods/Statistical Analysis**: This study conducted a comparative analysis of middle school students' perception and achievement between different teaching methods in physical computing education. Physical computing classes were provided for 30 hours, 49 students randomly participated in two classes. **Findings:** The results showed no statistically significant difference in perception and achievement between teaching methods. However, the results regarding the process of perception change suggest that there is a possibility that the problem-based inquiry method helps with gradual increase of class difficulty and improving class satisfaction. However, regarding learning basic concepts, the analysis results suggest that the direct teaching method is likely to be more helpful. **Application/Improvements:** In terms of future direction, ongoing efforts to find the teaching method that best fits the characteristics of physical computing education are needed.

Keywords: Case Study, Physical Computing Education, Teaching Method

1. Introduction

In the current informational society, people live in a world where driverless cars are driving, Artificial Intelligence (AI) computers and compete in games, and basketball players study coding[1-3]. Moreover, instead of Information Technology (IT) being influenced by people, people are influenced by IT, as in the cases of the human brain being changed by IT and presidential elections being influenced by search algorithms[4]. Such cases suggest that IT has permeated people's lives, and in the future, IT can be expected to change people's lives to an unimaginable extent[5]. Therefore, students in this era face a situation in which they must learn computing, the core of IT.

Educational policymakers are pushing toward providing computing education to all students through efforts such as adding content on computing to a curriculum or making such content compulsory through revision of national curricula[6,7]. Moreover, computing education researchers and educators are developing various teaching learning tools. The teaching learning method is used to teach principles of computer science without using computers in classrooms, and environments in which individuals or groups can learn programming using online applications have been introduced[8,9]. Various programing environments where young students can program and learning basic principles of computing are also being developed[10]. In addition, a wide range of

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hardware has been developed and used for computing education[11].

More recent efforts include the application of physical computing to computing education to stimulate interest and increase convergent thinking and creativity in students[12-14]. Physical computing can stimulate students' interest, such as in robot education, where they see a physical object operating and serving as a subject in convergent education for learning aspects of hardware, software, and design. Although physical computing initially began in colleges of design, it became accessible to young students due to the advent of hardware and programming environments that beginners can also easily manipulate. As these demonstrate, tools for computing education are being continually refined, and educational exploration regarding their effective utilization is just beginning. Since physical computing has aspects of both hardware in electronic engineering and software in computer science, a wide range of factors must be considered in providing physical computing education for young students[15].

Therefore, this study aims to identify effective teaching method in physical computing education for middle school students. Specific research questions are as follows.

Research Question 1) In physical computing education for middle school students, what are the changes in students' perception that occur across different stages of the course of each teaching model?

Research Question 2) In physical computing education for middle school students, is there a difference in students' perception and achievement between teaching models?

2. Background

2.1 Teaching Method in Computing Education

The most basic teaching method in computing education is the direct teaching method, which has a foundation in research on behavioral science. In this method, an instructor explains facts, laws, and behaviors, and learners acquires knowledge through observation, memorization, and repetitive practice[16]. In computing education, the direct teaching method is usually used for young students at the initial stage of learning programming language.

Regarding programming, one of the most important domains of computing education, student-centered teaching methods that allow students to develop programs and evaluate them effectively have been proposed. These methods include project-based learning, design-based learning, and the Use-Modify-Create strategy.

Project-based learning is the teaching method for students to acquire knowledge and skills by carrying out a project[17]. Learners proactively carry out a series of processes: analysis of project characteristics, establishing and executing a plan for solution, and evaluating and reflecting on the output. Students undergo the stages of project preparation, topic selection, activity plan, development and representation, and summary and presentation.

Design-based learning is a learning method proposed in D-School in Stanford University, which applies design thinking to the learning method[18]. Design-based learning focuses on implementing an idea and testing it, and involves empathizing, defining, imagining, building a prototype, and testing. Empathizing is the process of observing a phenomenon and getting involved in and experiencing it. Defining involves analyzing and defining the problems observed in the phenomenon. Imagining involves devising ways of problem solving using various creative strategies. The last step is building a prototype, testing it, and repeating the process.

Lee et al. (2011) proposed the Use-Modify-Create stages for improving young learners' computational thinking skills in the rich IT environment[19]. In the Use stage, a learner is unable to develop his or her own tool and uses a given tool. In the Modify stage, the learner is in the process of making the given tool his or her own by modifying it for his or her use. In the Create stage, the learner continues to make the tool his or her own and creates a new tool through the process of testing, analysis, and refinement.

In computing education, research on teaching methods involves the process of identifying effective teaching methods that fit various educational objectives and targets, and a wide range of teaching methods ranging from the direct teaching method to design-based learning method are used.

2.2 Physical Computing in Education

Physical computing is "the field of problem solving or representing a creative idea through designing and programing the interaction between the computing environment and the real world into input, processing, and output procedures, and promoting the expansion of knowledge by sharing the results"[15]. Physical computing is a domain of in which various disciplines converge, including design, embedded system, software, and electronic engineering[20,21]. Although physical computing used to be considered a field for experts only, lately it has become possible for even elementary students as well as college students and secondary students to be able to develop programs. This is because easy tools for beginners have become available, and the maker movement for direct development using innovative technology has become a worldwide phenomenon.

Physical computing education is the field in which students learn various domains of physical computing. In particular, physical computing in computing education is used by researchers and instructors for "stimulating interest through hands-on experience in the physical computing representation process, creativity of representing ideas, and composition and expansion of knowledge through knowledge-sharing with peers[15]. In secondary education, physical computing education is included in a regular curriculum (as in Korea), or provided by private sector in the form of various educational programs. Hardware boards used in physical computing education includes Arduino, Raspberry Pi, and the sensor board, and the program development environments include visual programming environments such as Modkit and Scratch, and text programming environments such as Arduino and Python[11].

It has not even been 20 years since the term "physical computing" first appeared, and the research on physical computing education with students is at its infant stage. Recent studies on the subject include studies on goals of physical computing education, and the relationship between physical computing education and computer science education, tool used in physical computing education, and development of educational programs[11,13]. However, the research on effective teaching method for physical computing education is rather sparse.

3. Research Method

The objective of this study is to investigate students' perception and achievement by teaching method.

3.1 Class Plan

Physical computing classes were provided for three months from September to December in 2015, over 30 hours in 15 class periods. The classes were offered in N middle school, located in Gyeonggi province, and 49 students randomly participated in the classes, with 24 in Class A and 25 in Class B.

Table 1 shows stages of the physical computing classes.

Since students had no previous experience in physical computing education, Stages 1–3 provided Class A and Class B with the identical basic education on physical computing to ensure students were at the same level when the teaching methods diverged. In these stages, students learned the basics of how to use hardware and the programming environment that were to be covered

Table 1. Content, Hours, And Teaching Method By Class Stage

Stage	Contents	Time	Teaching method
1	Introduction to physical computing - H/W: LED, electronic engineering basics - S/W: basic usage of programming environment	2h	Direct teaching
2	Making a LED stand - H/W: LED, Pushbutton, PhotoResistor - S/W: variable, sequence, condition, loop	4h	Direct teaching
3	Making a moving sheep - H/W: Servo Motor, Potentiometer - S/W: transform of variable	8h	Direct teaching
4	Various input and output devices - H/W: LED, Motor, buzzer, sensor(tilt, sound, ultrasonic, sound and so on) - S/W: function, debugging	6h	Class A: direct teaching Class B: problem-based inquiry teaching
5	Team project - Team production and presentation of physical computing project	8h	Project-based

in physical computing. In Stage 4, students manipulated various hardware and effective programming methods to build various input and output devices. In this stage, the direct teaching model was used in Class A, and the problem-based inquiry model was used in Class B. In Stage 5, all students produced and presented their project output in teams.

In Stage 4, the direct teaching method used in Class A involved a teacher explaining the sample work, and students learning the skills by imitating it and then carrying out exercises designed for integration of the skills with previously acquired skills[22]. Specifics of the method are as follows.

1. Review of previous class contents
2. Statement of the current class's goal
3. Presentation of learning materials – demonstration and explanation of sample work
4. Guidance on practice – providing code samples, circuit diagrams, and corrective feedback
5. Provision of individual exercises – providing additional codes, circuit diagrams, and corrective feedback

Table 2. Stages surveyed by factor

Factors	Stage 2	Stage 3	Stage 4	Stage 5	Post-Class
Class Difficulty	√	√	√	√	
Class Satisfaction	√	√	√	√	
Individual Output Satisfaction	√	√	√	√	
Paper examination					√
Project assessment					√

In Stage 4, the problem-based inquiry model used in Class B involved students solving problems using web resources based on the problem situations prepared by the teacher, comparing their solutions with the teacher's solution, and evaluating their own and other students' solutions[23,24]. Specifics of the method are as follows.

1. Presentation of a problem – prepared by teacher prior to class

Table 3. Survey instrument for student's perception

Factor	Items	Score
Class Difficulty	How difficult was today's class? Designing and producing output Coding the program Configuring electronic circuit Communicating with peers Teacher's explanation	5-point Likert scale
Class Satisfaction	How satisfied are you with today's class?	5-point Likert scale
Individual Output Satisfaction	How satisfied are you with the output you created today?	5-poitn Likert scale

Table 4. Evaluation measure for student's achievement

Factor	Items	Method	Score
Paper examination	Question that asks about the role of microcontroller in the physical computing structure chart Question that asks where to connect the circuit diagram to execute the given code Question that askes to complete the program code to execute the given circuit diagram	Paper	1 point per question, making the total score 3 points
Project assessment	How much did the student incorporate his or her ideas when building the project? Did the project output actually work? How actively did the student communicate with other team members?	Project Note & Presentation	3-point Likert scale completed by the teacher who taught the class

2. Analysis of the problem – redefining the problem and establishing a plan

3. Data collection – utilizing previous class materials and web resources

4. Devising a solution for the problem

5. Sharing and evaluation – of the solution with the teacher and other students

3.2 Suvey Design

This study surveyed students' perceptions at each stage, and measured their achievement after the course. The perception was measured by class difficulty, class satisfaction, and individual output satisfaction. Achievement was measured by conducting a paper examination and project assessment.

Individual factors were surveyed in the following Table 2.

Students' perceptions of difficulty and satisfaction were measured using 5-point Likert scales. Class difficulty was measured by students' ratings on the degree of difficulty in designing and producing the output, coding the program, configuring electronic circuit, communicating with peers, and understanding the teacher's explanation. Satisfaction was measured by satisfaction with the class in each stage, and the satisfaction with the output they created.

Table 4 shows paper examination and project assessment.

4. Results

4.1 Changes in Students' Perception across Class Stages by Teaching Method

Changes in students' perception across class stages by teaching method were assessed using class difficulty, class satisfaction, and individual output satisfaction.

Figure 1 shows the class difficulty scores of Class A and Class B by class stage.

According to the results on change in class difficulty for all students, the difficulty ranged between 1.99 and 2.2, suggesting an overall level of "easy." The difficulty decreased in Stage 3, increased in Stage 4, and then decreased again in Stage 5. The results showed that the difficulty of Stage 4, in which different teaching methods were applied, was higher than in other class stages.

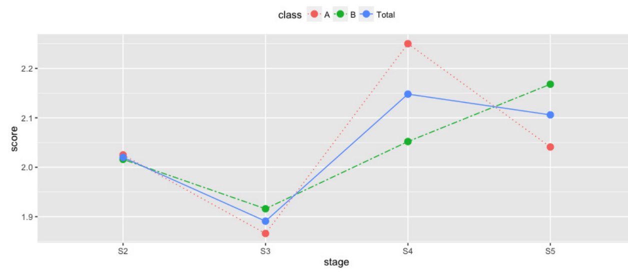

Figure 1. Change in class difficulty across class stages.

Considering that an appropriate level of difficulty is required for learning, Stage 4 is likely to be more helpful for student learning than example imitation stages (Stage 2 and Stage 3).

Class difficulty of Stage 4 for Class A, in which the direct teaching method was applied, was found to be higher than in other stages. On the other hand, the class difficulty of Stage 4 for Class B, in which the problem-based inquiry method was applied, was higher than those of the example imitation stages (Stage 2 and Stage 3), and lower than that of the project building stage (Stage 5). Considering that students' confidence in learning can be increased effectively when class difficulty increases gradually, the problem-based inquiry method is likely to better link the sample imitation and the project building stages than the direct teaching method. In turn, if the direct teaching method has lower class difficulty – for example, through easier explanation or ongoing feedback provided by the teacher –, it has the potential to be an effective teaching method.

Figure 2 shows the class satisfaction scores of Class A and Class B by class stage.

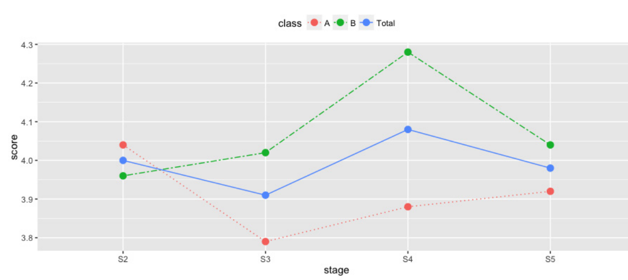

Figure 2. Change in class satisfaction across class stages.

According to the results on change in class satisfaction for all students, the satisfaction ranged between 3.9 and 4.1, suggesting an overall level of "satisfactory." The satisfaction decreased in Stage 3, increased in Stage 4, and decreased again in Stage 5. It appears that students perceived the process of making a paper sheep imitating the sheep-shaped doll in Stage 3 more difficult than they did other class activities. It was found that class satisfaction with Stage 4, in which the direct teaching method and the problem-based inquiry method were applied to the classes respectively, was higher than the example imitation stage (Stage 2 and Stage 3) and the project building stage (Stage 5).

Class satisfaction with Stage 4 for Class A (direct teaching method) was found to be higher than in Stage 2 (making an LED stand) and Stage 5 of building a project. Class satisfaction of Stage 4 for Class B (problem-based inquiry method) was highest among all stages. In both Class A and Class B, the satisfaction was higher in Stage 4 than in earlier stages. In other words, the direct teaching method and the problem-based inquiry method are likely to increase students' satisfaction with physical computing class. In particular, in Class B, the result of higher satisfaction in Stage 4 than other stages suggests that the problem-based inquiry method can be an effective teaching method in physical computing education.

Figure 3 shows the individual output satisfaction scores of Class A and Class B by class stage.

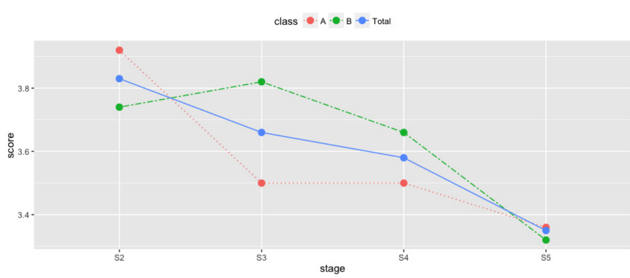

Figure 3. Change in individual output satisfaction across class stages.

According to the results on change in individual output satisfaction for all students, the scores ranged between 3.5 and 3.9, suggesting an overall level of "satisfactory." The individual output satisfaction tended to decrease as class stage progressed. It was found that, with the progression of the class, unlike class satisfaction, which showed variation across teaching methods and class topics, individual output satisfaction continually decreased. Moreover, students' satisfaction with learning output also decreased in Stage 4, in which different teaching methods were applied.

In physical computing education, the process with which students actually build a physical computing system is important. Moreover, students must show high satisfaction with the physical computing system they build to become committed to additional learning after the class. Therefore, instructor- or systemic-assistance with students' satisfaction with learning outputs is necessary.

4.2 Analysis of Students' Perception and Achievement by Teaching Method

Table 5 shows the results of analysis of difference in students' perception and achievement between Class A and Class B.

Table 5. Difference in students' perception and achievement by teaching method

Factors	Class	M	SD	df	t
Class Difficulty	A	2.25	0.912	47	0.696
	B	2.05	1.070		
Class Satisfaction	A	3.88	1.361	38.43	-1.241
	B	4.28	0.855		
Individual Output Satisfaction	A	3.50	1.319	47	-0.480
	B	3.66	0.997		
Paper examination	A	1.92	1.349	43.684	1.831
	B	1.28	1.061		
Project assessment	A	1.83	0.761	34.9	0.190
	B	1.80	0.408		

The results on class difficulty showed slightly higher rating in Class A (2.25) than in Class B (2.05). The results on class satisfaction showed slightly higher rating in Class B (4.28) than Class A (3.88). The results on individual output satisfaction was slightly higher rating in Class B (3.66) than Class A (3.50). However, in each item, the difference between Class A and Class B was not statistically significant.

The mean score of paper examination was higher for Class A (direct teaching method) than Class B (problem-based inquiry method). On the other hand, the mean score of project assessment was similar between Class A and Class B, around the score of 1.8. However, on both mean scores of paper examination and project evaluation, the two classes showed no statistically significant difference. Nevertheless, paper examination scores suggest that the direct teaching method can be more helpful for students' understanding of basic concepts of physical computing than the problem-based inquiry method.

5. Summary and Conclusions

The objective of this study was to examine the difference in students' perception and achievement by teaching method in physical computing education with middle school students.

The results of analysis on change in students' perception across class stages by teaching method are as follows: First, class difficulty was perceived by students as "easy" overall, but the difficulty of the stage in which the teaching methods varied (Stage 4 of 5) was perceived highest. In terms of the requirement of gradual increase in class difficulty, the problem-based inquiry method showed more natural progression of difficulty than the direct teaching method. Second, class satisfaction was perceived as "satisfactory" overall, and the satisfaction with the stage in which the teaching methods varied was highest. The problem-based inquiry method showed the possibility of being more helpful for increasing class satisfaction than the direct teaching method. Third, the individual output satisfaction was overall at the level of "satisfactory," but tended to gradually decline with the progression of the class regardless of teaching method. The difference in change pattern in class satisfaction and individual output satisfaction suggests the need for instructors' consideration of additional strategies to promote leaners' satisfaction with individual output in physical computing classes.

The results of the analysis on students' perception and achievement by teaching method are as follows: First, there was no significant difference in students' perception by teaching method. Second, there was also no significant difference in students' achievement by teaching method. However, the results suggest there is a possibility that the direct teaching method can be more helpful for students' understanding of basic concepts of physical computing than the problem-based inquiry method can.

In general, it is said that learning motivation is important for improving students' learning achievement in education. One strategy to stimulate learning motivation is to imbue students with positive perceptions, such as learning satisfaction and confidence. Increasing students' confidence in learning in physical computing education requires the strategy of gradually increasing difficulty at appropriate levels. In addition, in physical computing education, it is important for students to build their own outputs. Accordingly, satisfaction needs to be analyzed separately regarding class and individual output. Notably, as the results of this study showed, individual output satisfaction can be low while class satisfaction is high; therefore, considering the method to enhance satisfaction with individual output is necessary for effective physical computing education.

Effective physical computing education requires development and testing of various teaching methods. Continuing efforts must be made to identify the teaching methods that are appropriate for physical computing education, by examining the latest teaching methods such as web-based, gamification-based, and designing-based methods, as well as the teaching methods examined in the present study

6. Acknowledgment

This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government(MSIP)(No. 2015R1C1A1A02036950).

7. References

1. Google's Driverless Cars Run Into Problem: Cars With Drivers. The New York Times. Available from: http://www.nytimes.com/2015/09/02/technology/personaltech/google-says-its-not-the-driverless-cars-fault-its-other-drivers.html. Date accessed: 05/05/2016.
2. "Go" Matches Between Lee Sedol and AlphaGo Push AI Boundaries. NBC News. Available from: http://www.nbcnews.com/tech/tech-news/go-match-between-lee-sedol-alphago-push-ai-boundaries-n533821. Date accessed: 05/05/2016.
3. NBA Superstar Chris Bosh: Here's Why You Should Learn to Code. Chokshi S, editor. Wired. Available from: http://www.wired.com/2013/10/chris-bosh-why-everyone-should-learn-to-code/. Date accessed: 05/05/2016.
4. Carr N. The Shallows. W. W. Norton & Company: New Yorw, 2011.
5. Tomorrow's technology will lead to sweeping changes in society – it must, for all our sakes. The Conversation. Available from: http://theconversation.com/tomorrows-technology-will-lead-to-sweeping-changes-in-society-it-must-for-all-our-sakes-36023. Date accessed: 05/05/2016.

6. Ministry of Education. 2015 revised national curriculum: middle school curriculum. Ministry of Education: Sejong, 2015.
7. National curriculum in England: computing programmes of study. Available from: https://www.gov.uk/government/publications/national-curriculum-in-england-computing-programmes-of-study/national-curriculum-in-england-computing-programmes-of-study. Date accessed: 05/05/2016.
8. Bell T, Alexander J, Freeman I. Computer science unplugged: School students doing real computing without computers. The New Zealand Journal of Applied Computing and Information Technology. 2009 Sep; 13(1):20–9.
9. Code.org. Available from: https://code.org. Date accessed: 05/05/2016.
10. Jang Y, Lee W. A Study on Utilization of Programming Language for Physical Computing Education. The 2014 Summer Conference of Korean Association of Computer Education, South Korea, 2014; 27–32.
11. Jang Y, Lee W, Kim J. An Analysis of Educational Tools for Physical Computing Education. The 3rd International Conference on Small Medium Business, Vietnam, 2016.
12. Richard GT. Employing physical computing in education: how teachers and students utilized physical computing to develop embodied and tangible learning objects. The International Journal of Technology, Knowledge and Society. 2008; 4(3):93–102.
13. Przybylla M, Romeike R. Physical computing in computer science education. The 9th Workshop in Primary and Secondary Computing Education, Germany. 2014; 136–7.
14. Rubio MA, Romero-Zaliz R, Manoso C, de Madrid AP. Enhancing an introductory programming course with physical computing modules. Frontiers in Education Conference, Spain. 2014. p. 1–8.
15. Jang Y, Lee W, Kim J. Analysis of Pedagogical Usability about Tools in Physical Computing Education for Middle School Students. International Journal of Applied Engineering Research. 2015; 10(90):636–41.
16. Gunter MA, Estes TH, Mintz SL. Instruction. 5 ed. Allyn & Bacon: Boston. 2005.
17. Project-based learning. Available from: https://en.wikipedia.org/wiki/Project-based_learning. Date accessed: 05/05/2016.
18. Lee H-K, Breitenberg M. Education in the New Millennium: The Case for Design-Based Learning. International Journal of Art and Design Education. 2010 Feb; 29(1):54–60.
19. Lee I, Martin F, Denner J, Coulter B, Allan W, Erickson J, Malyn-Smith J, Werner L. Computational thinking for youth in practice. ACM Inroads. 2011 Feb; 2 (1):32–7.
20. Physical Computing. Available from: https://en.wikipedia.org/wiki/Physical_computing. Date accessed: 05/05/2016.
21. O'Sullivan D, Igoe T. Physical Computing: Sensing and Controlling the Physical World with Computers. Thomson: Boston. 2004.
22. Rosenshine B. Teaching functions in instructional programs. The Elementary School Journal. 1983 Mar; 83(4):335–51.
23. Suchman JR. The elementary school training program in scientific inquiry. University of Illinois Press: Urbana. 1962.
24. Some Thoughts about WebQuests. Available from: http://webquest.org/sdsu/about_webquests.html. Date accessed: 05/05/2016.