Virtual Microscopic Simulation (VMS) to promote students' conceptual change: A case study of heat transfer

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Abstract

Most students cannot understand the concepts of science concepts. The abstract concepts that require visualization help students to promote to the understanding about the concept. The aim of this study was to develop Virtual Microscopic Simulation (VMS) in terms of encouraging conceptual change and to promote its effectiveness connected to students' understanding of the microscopic material of heat transfer. The sample consisted of 80 students' whose age ranging from 19 to 21 years old. The VMS related to heat transfer was evaluated through a pre-, post-, and retention tests. The tests scores were analyzed using both qualitative and quantitative methods. The findings suggested that the VMS allows students' to achieve the better understanding of their students' understanding and their significance for the effectiveness of students' understandings.

Keywords: Virtual Microscopic Simulation (VMS), Conceptual Change, Heat Transfer.

Introduction

Physics concepts, in nature, consist of both microscopic and macroscopic properties (Gould & Tobochnik, 2010). Macroscopic properties could be observed and measured easily. Hence, macroscopic properties generally well understood. In reverse, microscopic properties could not be understood very well (i.e. misunderstanding or misconceptions. Physics studies many concepts both macroscopic and microscopic. Objects of macroscopic size are composed of elements of microscopic size that bind each other to form the structure of the object. The macroscopic properties of objects will be determined by the properties of the constituent microscopic elements. For example, metal objects have properties corresponding to the constituent nature of the elements of the metal elements. If a microscopic phenomenon can be understood then the macroscopic phenomenon will also be easy to understand. Unfortunately because of its invisible nature it is very difficult to understand this microscopic phenomenon. This limitation will lead to the comprehension of a non-comprehensive physical phenomenon (Wibowo, et al, 2017).

Physics is part of the Natural Science specifically studying the phenomenon of the inanimate nature or matter in the sphere of space and time. Natural phenomena are formed when there is an interaction between matters with energy. So physics actually studies the matter, energy, and interaction between the two. For example in everyday life there is an observed phenomenon that increases the temperature of a substance when heated. This event is actually an interaction between substances with heat energy that affect the increase in temperature of the substance. The results of empirical investigations indicate that there are several factors that affect the high low temperature rise of the substance when heated, among others, the mass of substances, heat of the substance type, and the amount of heat given. Macroscopically this condition can be understood because it is based on measurable quantities of observations. When there is a question as to why the mass of the substance, the heat of the substance type, and the amount of heat given influence the temperature rise of the object when heated, the observed data cannot provide sufficient explanation because what is studied is the object in the macroscopic level. To be able to answer the above questions required a more fundamental study to the microscopic level of the object. "The microscopic system is able to ease the help of macroscopic systems" (Gould and Tobochnik, 2010).

Physics learning is conducted at various levels of formal education as a means to study the concepts, principles, laws and principles and inter-conceptual interrelationships that occur in an observed physical phenomenon that leads to constructed conceptions in the minds of students. The quality of conception formed in the minds of students is very dependent on the learning process experienced (Suherman and Wibowo, 2017). Verbal learning will not produce a scientific conception in the minds of the students; instead it can lead to a misconception of conception called misconception. If the student has a certain conception and the conception is different from the scientific conception, then it is said the student has misconception (Kartal, 2011).

Learning that only through the process of listening lecture without doing anything else like taking notes, then contributed in the mastery of the material only by 5%. If followed by reading, then contributing to the mastery of the material by 10% and when learning with the help of audio-visual, it will contribute to the mastery of the material by 30% (The Higher Education Academy, 2008). The results of this study indicate that if students can visually see the physical material that is microscopic then the student will be easier to understand it and will avoid the construction of a misconception. Visualization of the movement of the water particles also enhances learners to more easily understand and to more meaningful conceptual development (Gould & Tobochnik, 2010).

The simulation media that can visualize the material or phenomenon of microscopic physics is required both for physics-oriented learning conception constructs as well as physics-oriented reconstruction of conceptions. Characteristics of physics learning construction of conception is the study of physics in which there is a process of constructing the conception of physics from the initial state that does not understand the concept of becoming a concept. Therefore, a concrete step in the process is needed that can construct knowledge and correct (reconstruct) the concept if it is not in accordance with the scientific context (Srisawasdi et al., 2014). Evidence has occurred construction of conception in a person can be seen from the level of understanding (level of understanding). Conception constructions carried out on physics learning using virtual simulations require conception constructs related to the level of understanding that the students know and how effective they are in reducing misconceptions (Saglam and Deveciogle, 2010). In the learning stages construction of lecturer, conception shows the phenomenon or event, the phenomenon that is written in the form of microscopic. The Microscopic of phenomenon using virtual simulation done in various stages of construction of conception construction. Therefore, the key word in the process of altering conception is the occurrence of cognitive conflict in the minds of students (Nieminen, et al. 2010).

In the literature, there have also been lots of studies (e.g. She 2003; 2004b) showing that the use of virtual simulation can remediate learners' misconceptions and can provide in depth and sound understanding. Other obvious examples in science concepts as follows; Finkelstein, et al. (2005) showed that the use of virtual media can help learners in building-related conception of velocity and acceleration in the motion of projectiles; Atasoy & Akdeniz (2007) showed that the use of computer simulations in learning Newton's laws of motion can help reduce misconceptions that occur in learners; Trundle & Bell (2010) showed that simulation to draw scientific moon shapes or in their conceptions of the causes of moon phases. Miklopoulos and Natsis (2011), the three treatments were equally effective in facilitating desired conceptual change the use of simulation media on climate change materials to facilitate construction of the transformation in the conception in the minds of learners; Olympiou, Zacharia, & de Jong (2013) showed that the use of media simulation of light and color dispersion is effective in helping students to construct its conception so that the ability to understand can be improved; Srisawasdi & Kroothkean (2014) showed that the use of virtual simulation media on the concept of light waves could improve understanding of the concept of waves and the process of conceptual change students towards scientific conception.

Based on the findings of the research, the researchers determined the change of conception through the development of virtual simulation media for physics learning, as follows: (1) In the event of conduction, the heat flows because it is carried by the molecule of the moving substance. (2) At the time of thermal equilibrium is still the heat transfer occurs so that the temperature of different objects. (3) In convection heat transfer events, the rate of convection gets faster when water boils. (4) Objects that more quickly absorb radiation heat, will be more slow emitting radiation heat.

Some virtual media related to the subject of physics have been developed at the University of Collorado in the form of PhET Simulation which can be accessed and downloaded for free by the general public. This developed virtual media has been widely used by physics lecturers including in Indonesia from educational institutions at the secondary school to college level. However, not all the virtual media required for physics learning related to abstract and microscopic phenomena is available, there are still many virtual media related to the microscopic material of undeveloped physics, such as the simulation of the change of substance, the simulation of the working mechanism of heat transfer.

However, an idea to innovate in the development of virtual simulation. The availability of virtual media related to abstract and microscopic phenomena is believed to be very helpful in the process of construction and reconstruction of conception in the learning of physics, especially for microscopic teaching meters, therefore researchers are interested in developing virtual media that other researchers have not yet developed in the hope of contributing real in improving the quality of physics learning at various levels of secondary school and college level through the provision of one of the supporting tools of physics learning in the form of virtual media.

One of the application software that can be used to create a virtual simulation is Macromedia Flash 8 Some of the advantages possessed by this simulation can combine text, animation, sound and colour. This advantage can clearly visualize a microscopic phenomenon. In addition, Macromedia Flash 8.0 has facilities that can be optimized by students, teachers or lecturers.

Based on the problems and thought-thinking solutions described above, the researcher conducted the research Virtual Microscopic Simulation (VMS) to promote students' conceptual change a case study of heat transfer concept.

Virtual simulations

Computer simulation is a computer program that contains a specific system model (either factual or theoretical) and that can be executed, after execution of the output can be analyzed (Brey, 2008). Computer simulations typically model abstract concepts and involve mathematical models. Computer simulations have become an important part of mathematical modeling and natural systems, social systems, and technological systems. Simulation modeling is usually done with the aim of visual modeling that becomes more realistic and realistic. Benefits of simulation are to make the abstract system into a concrete system, or a graphical representation of the abstract system. The microscopic phenomenon is the event of an unobserved state (abstract) and occurs in the very small matter (micro) (Mainwood, 2006). Microscopic examples in physics are the size of microstructural particles in water and the movement of water particles that cannot be observed by the sense of sight.

Simulation-based learning is computer-based learning; where students gradually understand the original concepts they have then demonstrated, leading to changes in their original concepts (de Jong and van Joolingen, 1998). Physics simulation experiments overcome the drawbacks of traditional physics teaching and promote reforming the methods of physics classroom teaching under the new curriculum ideas (Li, 2009).

Simulation aims to increase the potential of teachers in learning and to facilitate learners actively involved. Computer simulations have wide a range of opportunities for concept modeling and process. Simulation also provides a bridge between the knowledge of students before and after learning of physics and to help learners develop the scientific understanding through active reformulation and to decrease misconceptions or to provide conceptual change (Samsudin, et al, 2016).

Macroscopic and microscopic of physics

As described superficially earlier, a characteristic of physics consists of microscopic and macroscopic properties (detailed in the Table1). Mainwood (2006) stated that the Physics that may describe the very small, so for the moment I shall verbalize of "micro-physics" and "macro-physical" leaving it open Whether Reviews. These terms refer to the current standard model of particle. Macroscopic properties in physics are defined as a concept that can be observed with the eye and can be measured. For instance, a car is moving at a certain speed. In this task; the speed of the car can be observed by the senses and speed of the car can be measured. Microscopic properties are defined as properties of unobservable by eye (i.e abstract) and are only observed in micro level or in particulate nature of matter. Examples of microscopic physics are the size of the constituent particles of water in micro scale and movement of water particles cannot be observed by the senses of sight (Wibowo et al, 2016).

From the microscopic properties in Physics, one of them is duality of particles and waves. Particles can behave as waves and waves behave as particles. The concept of wave particle duality is observed by two experiments namely the photoelectric effect by Albert Einstein and electron diffraction experiments by G.P. Thomson (Crowell, 2006). The concept of electric and electron diffraction photograph is difficult to observe, it was created a media as a tool for the "visualization" hard particles directly observed by eye.

Table 1. Microscopic and Macroscopic of Physic

Fields	**The Main Theory**	**Concept**	**Category Physics**

Classical mechanics	Newton's laws of motion, Mechanics Lagrangian, Hamiltonian Mechanics, Fluid Dynamics, Continuum Mechanics	Dimensions, Space, Time, Motion Length, Velocity, Mass, Momentum, Force, Energy, Angular momentum, Torque, Conservation law, Harmonic oscillator, waves, and Power	Macroscopic
Electromagnetic	Electrostatic, Electricity, Magnetism, Maxwell's equations	Electric charge, electric field, magnetic field, electromagnetic radiation, Magnetic monopole	Microscopic
Atomic physics, molecular and optical	Atomic physics, molecular physics, Optics, Quantum Optics	Diffraction, Electromagnetic radiation, Laser, Polarization,	Microscopic
Particle physics	The standard model atomic, physics accelerators, nuclear physics	Electromagnetic, particle elements,	Microscopic
Condensed matter physics	Solid matter physics, material physics, polymer physics, material, Fermi	Phases (gas, liquid, solid, Bose-Einstein Condensate, a super conductor, super fluid), electrical conduction, Magnetic	Microscopic

In summary, the obtained picture that physics departing from microscopic observation of a system, the system is very small (very small size - i.e. Angstrom level), cannot be measured directly as an example of a single particle system. Explanation of this single particle system can be done through the laws of classical and quantum mechanics and for considerable amounts can be helped by using a numerical (computer).

Conceptual change

In recent decades, research have publicized that students move toward to science lessons by instructional conceptions and ideas concerning the phenomena and concepts to be academic that are not in harmony amid knowledge views. Besides, conceptions and ideas are firmly held and are resistant to change (Duit, 2006; Duit &Treagust, 2003). The first was Ausubel's (1968) dictum that the most important single factor influencing learning is what the learner already knows and hence to teach the learner accordingly. His clinical interview method deeply influenced research on investigating students' conceptions (White & Gunstone, 1992).

Most conceptual change strategies were designed based on students' alternative conceptions (e.g. Coştu et al, 2007). Conceptual change texts that can be used to overcome some common misconceptions regarding "sound intensity" and "how fast sound travels (Özkan, G & Sezgin Selçuk, 2013). The individual level revealed that the engagement in dialectical argumentation predicted conceptual learning gains, whereas consensual explanation development did not (Asterhan & Schwarz, 2009). It is suggested that combining different conceptual change methods such conceptual change text/refutation text, argumentation with the intervention may be more effective in reducing student alternative conceptions (Çalik at al. 2010). Development of conceptual change in the teaching of aspects important the nature of science (Çepni & Çil, 2012). The intersection of conceptual change and reading comprehension was studied in science education (Sinatra & Broughton, 2011). The implications of these findings for future research and developing students' conceptual change in physics are discussed by Taasoobshirazi & Sinatra (2011).

However, teaching with analogies is an effective teaching method for higher learning achievement and in preventing misconceptions (Pekmez, 2010). Conceptual change strategy was designed based on students' alternative conceptions (Samsudin, 2016). Consistency conception of the students in this study includes the pattern of student answers using the same concept models in answering a series of questions asking the same concept. This data was obtained through the conception consistency test instruments tested one by asking questions with the same concept more than once.

Methods

Research Design

The method used in this research is the method of mixed methods (Creswell, 2014), which emphasizes on data collection by involving the processing of quantitative and qualitative data that is done simultaneously during the development process. In this regard, same test was implemented as pre-, post-, and retention with in one group experimental design, as exposed in Figure 1.

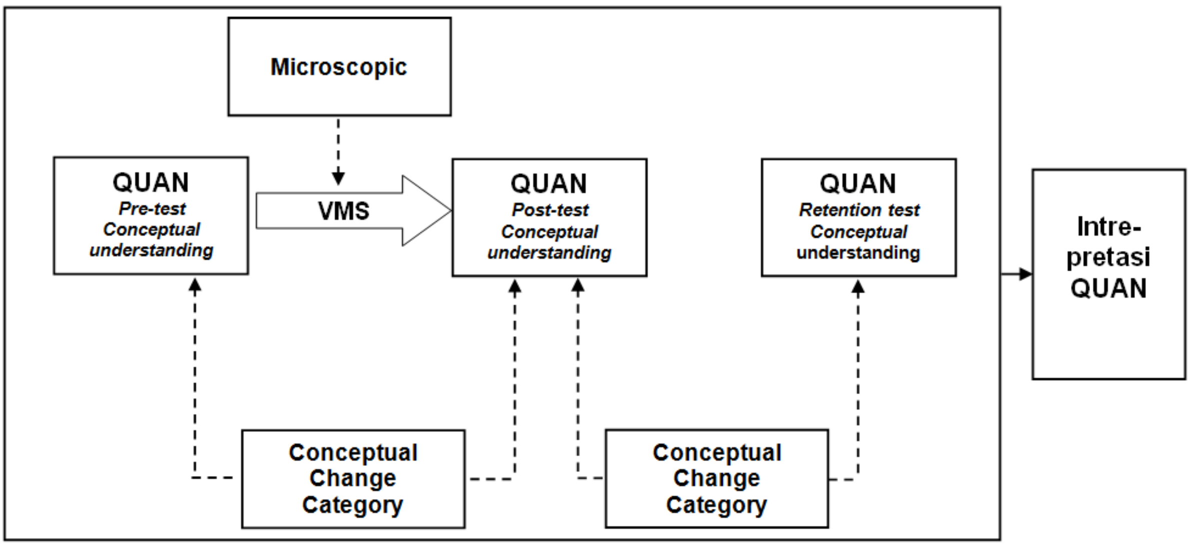

Figure 1. Sequential Explanatory Research Design

Based on figure 1 The information method used in this research is the method of mixed methods, the quantitative study stage in this study, quantitative and qualitative data were collected simultaneously to answer different research questions (different data types). The steps in this research are: 1) collect quantitative and qualitative data and analyze it (planning stage); 2) use the analysis to develop VMS (development stage, qualitative data); and 3) applying VMS has been developed on population samples (Stages of media applications to obtain quantitative data and analyze them).

Sample

The Research was conducted on 80 students, whose age ranging from 19 to 21. Before the treatment, the pre-test was applied to determine students' prior understanding about heat transfer (conduction, convection, and radiation). The treatment was utilized using Virtual Microscopic Simulation (VMS) in the experimental group. After the treatment; the same test was administered as post-test to all students. Finally, the same test was administered as retention test for retention of students' understandings.

Table 2. Sample Test Implementation

Gruop	Learning strategis	Sample / Years	Variabel
Experimental	Conceptual Change with Interactive Lecture Demonstration (ILD)	80 Students / 2016	Conceptual Understanding

Based on Table 2. Sample of sample implementation test with 80 students for conceptual change oriented physics learning. Sample of implementation test taken by purposive sampling that is sample determination technique with certain consideration. The consideration of research sample selection is because based on information from preliminary study result is found that the students of understanding the concept of physics have not fully comprehended physics concept so that this research can build scientific conception.

Instrument

Virtual Microscopic Simulation (VMS) to Promote Students' Conceptual Change: Case Study in Heat Transfer for conceptual change oriented physics learning using a written test instrument in the form of a description to measure students' level of understanding.

Table 3. Instrument Test Implementation

Data Type	Data Type	Data Type	Data Type
Type Conceptual	The written test	Students	Essay of the concept

Understanding			

Based on Table 3. Instrument test implementation of research the change of students' type conceptual understanding as elicited in students' written responses. The number of conceptual change was described by Progress, Maintain-Correct, Maintain-Partial Correct, Maintain-Incorrect, Retrogression from pretest to posttest and from posttest to retention test.

Learning materials

The treatment (i.e. VMS) consists of three parts concept, namely conduction, convection and radiation. Simulation is used to build understanding of heat transfer concept. This media is created using Macromedia Flash 8 main software and design drawings using the Corel Draw.

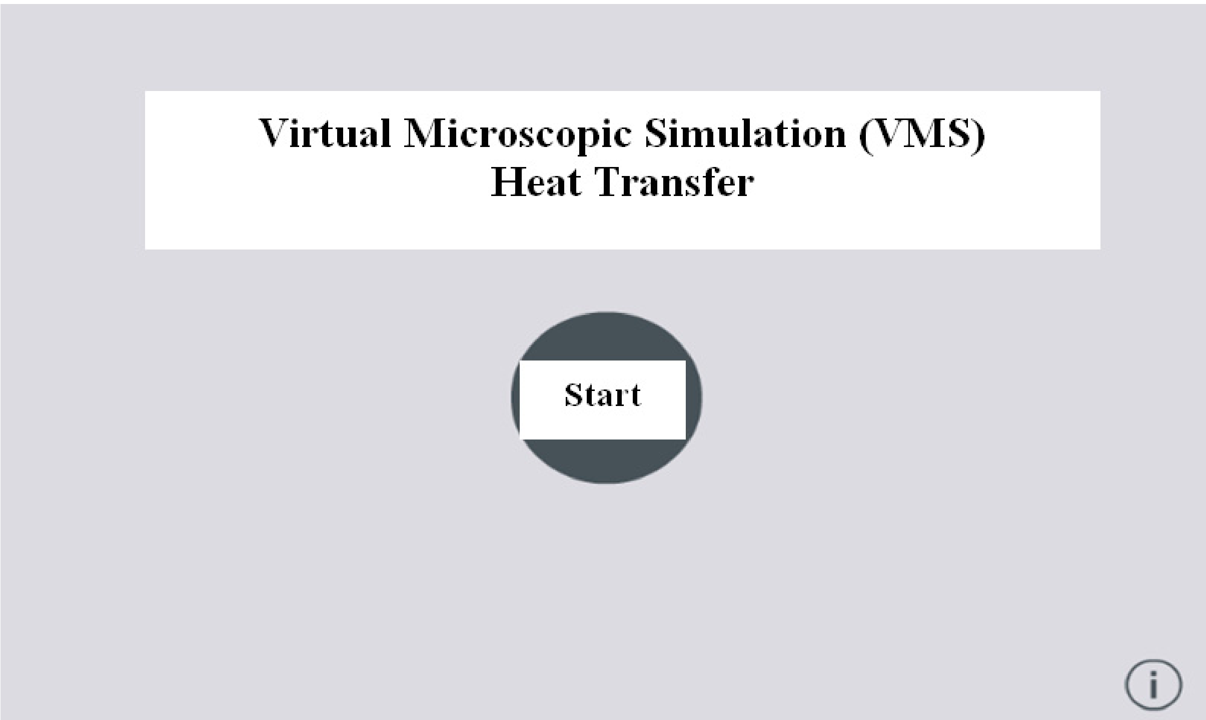

Figure 2. Main Menu Display of VMS (Used with macromedia flash 8)

The result of development in the form of computer program, which can present visual effect of process of microscopic heat transfer on computer screen. The process of heat transfer that is presented include conduction, convection, and radiation.

The design of the developed media display contains two views, namely the initial display and simulation display. The initial view of the media is the main view when the simulation application is opened. When the user opens the simulation application, then the initial view that appears is like the following picture.

Figure 3 is a picture of conduction of the metal when heated. When the metal is heated to other end of the metal will feel the heat, but we know what kind of heat propagation. This simulation seeks to explain how explanation there is. Besides, the most important part of the simulation is to explain microscopic constituent particles of metal when heated. VMS conduction section there is two parts is material conductivity A and conductivity material B.

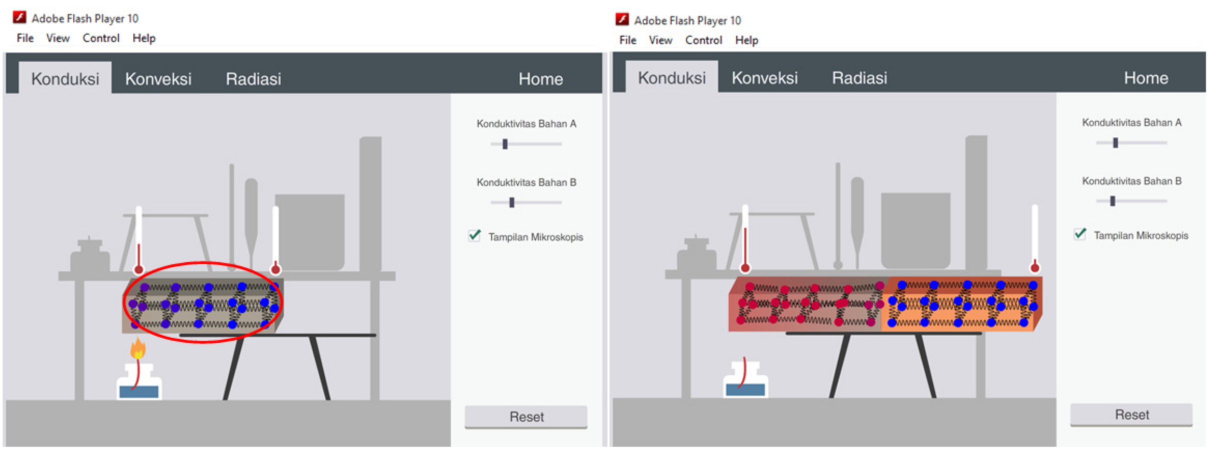

Figure 3. VMS Conduction: Microscopic of the Material is Heated

In the conduction simulation display, there is one rod placed on the support table, where at each end of the rod is placed a thermometer to see the changes macroscopically when the heat transfer occurs. At the bottom of one end of the rod is placed Bunsen as a heat source.

The simulated form that can be performed on this screen is a conduction heat conduction simulation on one end of the heated rod using Bunsen. This simulation serves to show the process of conductive heat transfer and counter the students' misconception on the concept of conduction, where the student assumes that, ”In conduction event, heat flows because it is carried by the molecule of the transporting agent”. In this simulation, microscopic process of heat transfer in conduction. The heat transfer can be observed by the occurrence of temperature rise at the tip of the stem that is not in direct contact with the heat source using a thermometer. In addition microscopically (through the representation of bonds between elements in solids with springs) the heat transfer can be observed with particles composing the ends of solids that are in direct contact with the vibrating heat source is stronger than the particles that do not experience direct contact with the heat source. The greater the vibration, the kinetic energy is also greater. The large kinetic energy causes the nearby particles to vibrate to become stronger than before, and so on down to the other end composing particles. This can be seen also by changes in the particle color gradation from blue (indicating still low temperature) to reddish color (indicating high temperature).

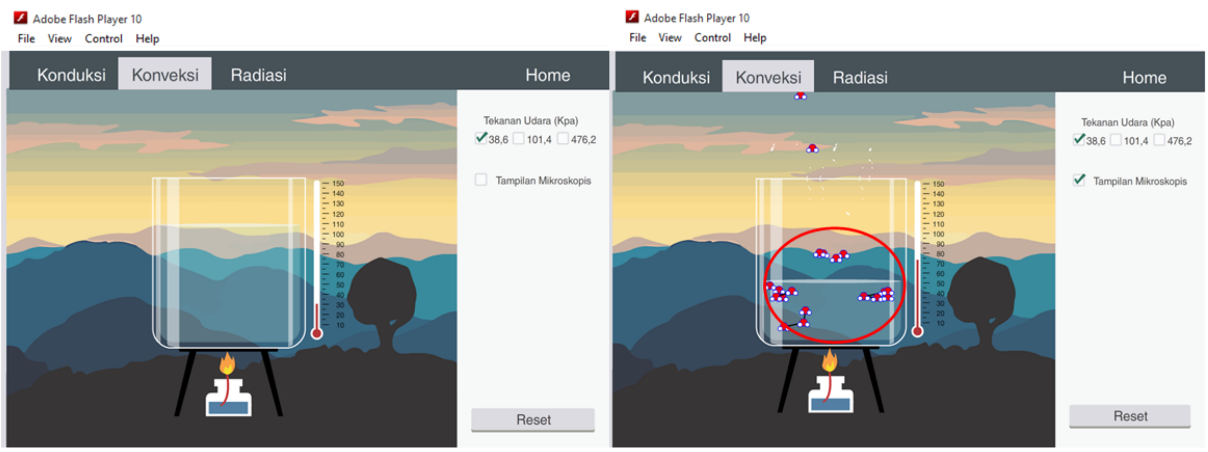

Figure 4. VMS Convection: Microscopic of Heat the Water in the Mountains (38,6 Kpa)

The simulation form that can be done on this screen is the convection of convection while cooking water. In addition, the simulation of this convection can also be shown variations of the boiling point of water due to the influence of external air pressure. This screen simulation serves to demonstrate conventional heat transfer processes during the cooking process of water and counter the students' misconception on the concept of convection, where students assume that, “On convection heat transfer events, the rate of convection gets faster when water is boiling".

Figure 4 and 5 are pictures of VMS media convection; these simulations explain how the movement of water particles is heated. Water heating is carried out in three different places, namely in the mountains with a pressure of 38.6 kPa, around the beach with a pressure of 101.4 kPa and at a pressure of 476.2 kPa. The movement of water particles in the simulation of this in detail and show the most important part of this simulation is to explain the movement of microscopic water particles when heated.

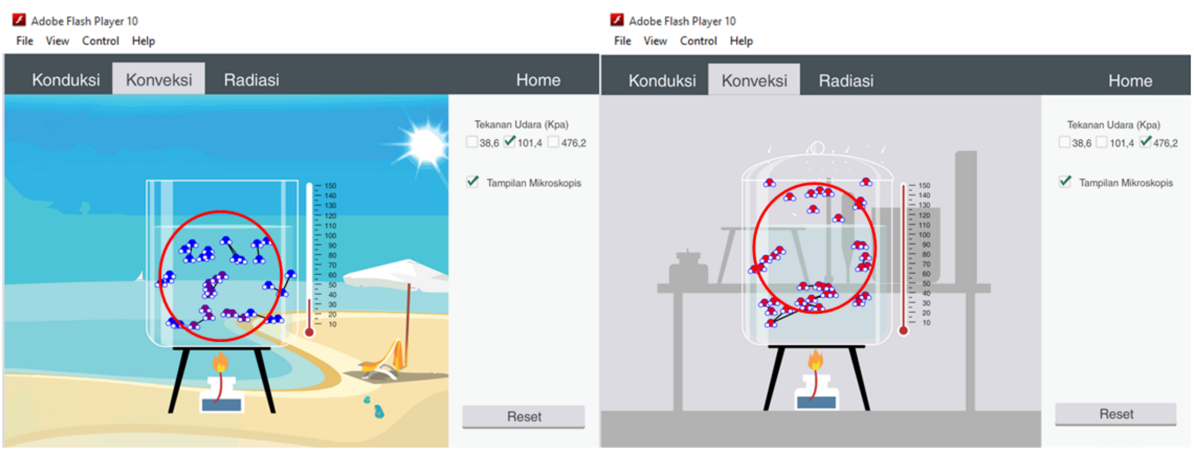

Figure 5. VMS Convection: Microscopic of Heat the Water at the Beach and (101,4 Kpa) and (476,2 Kpa)

In this simulation, we can show microscopic process of convection heat transfer. The heat transfer can be observed by the occurrence of temperature rise in water after heating. In addition, microscopically water particles that are in direct contact with the heat source have greater kinetic energy (can be seen with changes in particle color gradation) than before and move faster. In this section the water molecules move away from each other as a result of this part expansion so that the density of the species becomes smaller than the mass of the type of water that is still cold on it, consequently this water molecule moves up. While the exposed water part moves upward, the water molecules on the left and right sides try to fill the position of the rising water section. The position of a moving water molecule that fills the water position (direct contact with the heating source) rises is replaced by a water molecule above it that moves downward to fill an empty position, and so on

Figure 6 is a radiation image VMS media, these simulations explain how radiation with electromagnetic waves do. This simulation shows wave source toward premises exposed to intense radiation difference of temperature, 2500 K, 3000 K and 4000 K. The constituent particles move in this simulation the show with detail as well as the most important part of this is to explain the microscopic simulations.

When the user clicks the radiation button on the menu bar, the user will be directed to enter the radiation simulation screen. At the beginning of the screen simulation of radiation there are two identical but different colored bars, namely black and white. At the center of the screen is placed a radiation source that can emit thermal radiation on both objects. At each end of the rod is placed a thermometer that serves to see the macroscopic changes as a result of radiation heat transfer process.

The simulation form that can be performed on this simulation screen is the simulation of radiation through thermal radiation transmitters on two different colors in a vacuum. This simulation serves to show the difference of absorption and transmit power between two different color objects. This simulation contributes to counter the students' conceptual understanding on the concept of radiation, where students assume that, "Objects that more quickly absorb radiation heat, slower to emit radiation heat"

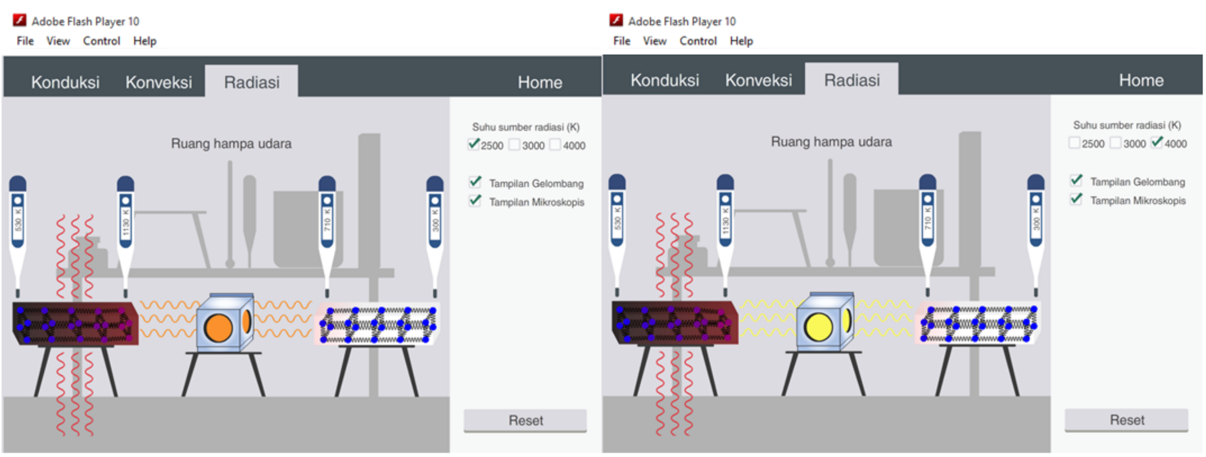

Figure 6. VMS radiation: microscopic of the material is heated to a temperature of 2500 K and 4000 K

In this simulation, microscopic process of radiation heat transfer can be shown. The heat transfer can be observed by the occurrence of temperature changes in black and white objects after absorbing or emitting radiation. In addition, microscopically the particles making up black and white objects that are in direct contact with the heat sources have a greater kinetic energy (can be seen with changes in particle color gradation) than before and move faster, but the kinetic energy of black body particles is greater than that of objects white. Meanwhile, when black and white objects emit radiation, the kinetic energy of black matter particles decreases faster (microscopic) than white matter. This shows that the absorption and power of black body transmit greater than white matter.

Learning strategy use VMS for learning the physics-oriented conception of the material conversion of heat transfer with the following characteristics: (1) display the physical processes of heat transfer in microscopic and macroscopic and as closely as possible with the actual process; (2) accommodate the student conceptual understanding in the material of heat transfer; (3) includes a simulation of the phenomenon of conduction, convection, and radiation; (4) using a constructivism understands that covers the process of assimilation and accommodation; and (5) give the expansion of the learning experience (extension), in order to strengthen the construction of conceptions on students.

Media validation

Products that have been made are then consulted to be validated by physics and media experts. Validation is done on three aspects: the compatibility of virtual simulation media with material curriculum of heat transfer, virtual simulation media display and interactivity of virtual simulation media. The result of validation of virtual simulation media of heat transfer is shown in Table 2.

Table 2. Results Validation of Virtual Media Simulation of Heat Transfer

No	Rated aspect	Validation Score		
		I	II	III
Conformity of Virtual Simulation Media with Curriculum:				
1	Conformity of simulation with basic competence	4	3	4

2	Systematic presentation of material to achieve competence	4	3	4
3	Consideration of material difficulty level	4	3	4
4	Compatibility between virtual simulations displayed with the concept of heat transfer	3	3	4
5	Relevance of the material with visualization and simulation provided	4	3	4
6	Compatibility of the simulation in emphasizing the microscopic aspect	4	3	4
Total		23	18	24
Average (%)		21,7 (90,3%)		
Category		Good		
Virtual Simulation Media View :				
1	Size and layout of menu display	3	3	3
2	Size and layout of the navigation key	4	3	4
3	Selection of the type and size of letters used	4	3	3
4	Size, and layout of simulation display	3	3	4
5	Quality animation	3	3	3
6	Display of virtual simulation media background	4	3	4
7	Color display composition used in virtual simulation	3	4	3
Total		24	22	24
Average (%)		23,3 (83,3%)		
Category		Good		
Interactivity of Virtual Simulation Media :				
1	Ease of selecting menu	4	3	4
2	Ease of use of the navigation key	4	3	4
3	Clarity linking buttons to other pages	3	3	4
4	Accuracy of response on user command	4	2	4
Total		15	11	16
Average (%)		14 (87,5%)		
Category		Good		

Repair Suggestions and Conclusions
Validator 1: The background color and animated image are adjusted. Can be used after repair.
Validator 2: The logic aspect of the picture is noticed again. Can be used after repair
Validator 3: The juxtaposition of images in conduction simulation and background selection of the laboratory for conduction and radiation simulation. Can be used after repair.

Media validation is done by three experts in the field of physics concepts, physics and physics learning experts. Table 2 shows that the virtual simulations that have been developed are in accordance with the curriculum of matter heat transfer, as well as with the appearance and interactivity of the media are also quite good. The media can already be used in research after repair. Expert advice is used to improve the media that has been created, so the media really worthy of use in research. Improved media views on expert suggestions and judgments will be presented in the discussion.

Data Analysis

The classification of categories set five by She and Liao (2010) in Table 2 were used to analyses the data obtained from the heat transfer concept. The scoring of the text was achieved by the evaluation of the data in the first tiers, second tiers and three tiers.

The students' written responses to open-ended question items were analyzed quantitatively. The analyses showed students' understanding (pre-, post-, and retention-test) and changing their understandings from pre-, post- and retention test. As analysis procedure, we used three-stages in early outlined, firstly, the researchers began with repeatedly read the students' written responses (pre-, post-, and retention-test). After that step was the advance of a common conceptual understanding rubric that useful to all items and then item specific rubrics consistent with key concepts of heat transfer. The qualitative data collected from students' responses to the items were quantitative into a numerical score based on the item-specific rubrics. This numerical score represented the students' level of conceptual understanding about heat transfer. In order to use statistical analysis for students' conceptual understanding scores, the normal distributions of data were not met for their scores. As a result, nonparametric statistics of Wilcoxon Signed Rank Test used to check significantly difference for their conceptual understanding scores on the pre-, post-, and retention tests. Next, the quantitative content analysis including five categories (given in the Table 2) based modification from She and Liao (2010).

Table 3. Quantitative Analysis Categories

Category	Representation
Progress (PG)	coverage the student's conceptions improved
Maintain-Correct (MC)	degree to which the student's conceptions be maintained correctly
Maintain-Partial Correct (MPC)	degree to which the student's conceptions be maintained as partially correct
Maintain-Incorrect (MIC)	degree to which the student's conceptions be maintained as partially incorrect
Retrogression (RG)	degree to which the student's conceptions retrogressed

However, analysis representation of the change of students' conceptual understanding as elicited in students' written responses. The number of conceptual change was described by respective percentages for PG, MC, MPC, MIC, and RG from pretest to posttest and from posttest to retention test.

Findings

Analysis of Effectiveness of the Virtual Microscopic Simulation (VMS)

To explore the effectiveness of the VMS on the students' conceptual understanding of heat transfer, statistical analysis was performed and given in the Table 3. The results indicated that there was a statistically significant difference with overall pre-, post-, and retention-test scores of conceptual understanding of heat transfer. The results of Post hoc analysis with Wilcoxon signed rank test indicated that the students through a great progression of their conceptual understanding of heat transfer considering from pretest to posttest and the posttest score was significantly better than the pretest, show Z: -4.33, P(post>pre) < 0.012. Besides, a great progression of their conceptual understanding was established on a discrepancy between pretest and retention-test scores, and the retention-test score was significantly better than the pretest, show Z : -4.33, P(post>pre) < 0.012. Though, they too ended a slight reduce of conceptual understanding scores from posttest to retention test and its difference was also significantly, show Z : -2.27, P(post>pre) < 0.023.

Table 4. Statistical Results of Wilcoxon Sign Rank Test of Conceptual Understanding

Types of Tests	SD	Mean (max. = 20)	Mean Rank	Post hoc comparison
Pretest (a)	2.02	9.15	1.48	(b) > (a)*
Posttest (b)	2.64	16.35	2.48	(b) > (c)*
Retention test (c)	2.85	12.55	2.28	(c) > (a)*

In summary, Table 4 indicated that there was a statistically significant difference among overall pre-, post-, and retention-test scores of conceptual understanding of heat transfer. The result indicated that the students' conceptual understanding showed significant improvement after simulating by the VMS (as of 8.15 to 17.25), other than they ended a slight reduce as of posttest to retention test (as of 17.25 to 11.65). Post hoc analysis with Wilcoxon signed rank test conducted with adjustment applied and the results indicated that the students blot a great progression of their conceptual understanding of heat transfer from pretest to posttest and the post test score was significant. VMS significant for the effectiveness students' understandings

Analysis of Conceptual Change Category

The effectiveness of VMS on the students' conceptual development of heat transfer was also investigated in this study. Five categories (PG, MC, MPC, MIC, and RG) were used to interpret a transitional change of students' conceptual understanding from pretest to posttest and posttest to retention test. The percentages of the quantity of conceptual change on the transitions were presented in Figure 7 and 8.

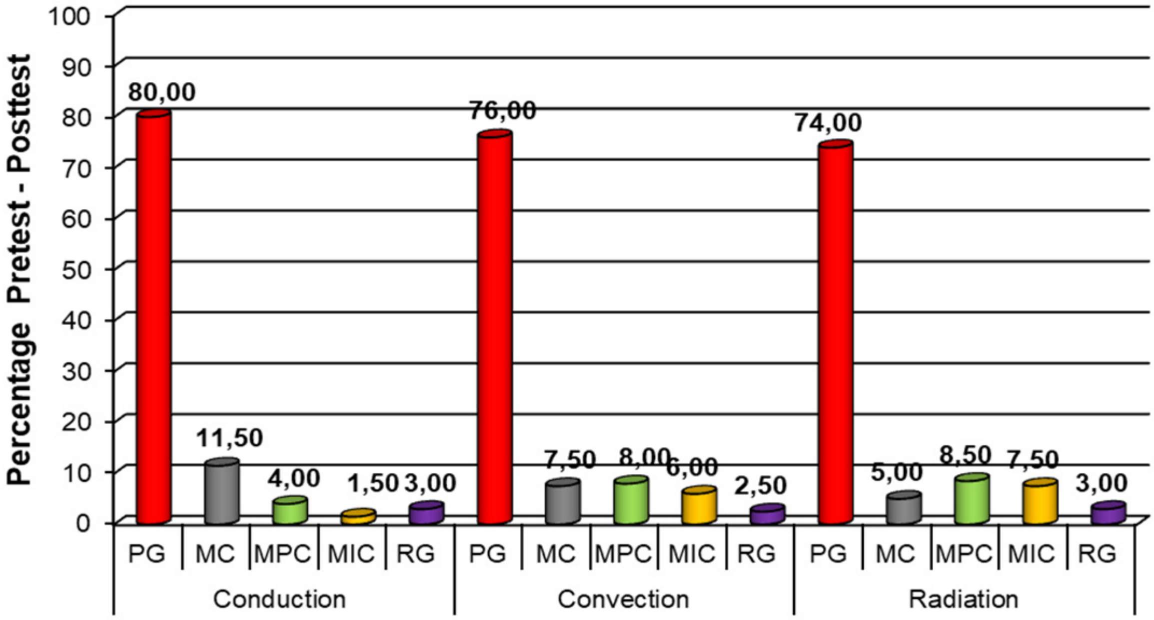

Figure 7. Pretest-Posttest of Conceptual Change of Heat Transfer

Figure 7 to pretest posttest of conceptual change of heat transfer, the percentage of the Progress (PG) category was higher than any other category. The conceptual change on conduction concept percentages was for Progress (PG) 80.00, for Maintain-Correct (MC) 11.50, for Maintain-Partial Correct (MPC) 4.00, for Maintain-Incorrect (MIC) 1.50, for Retrogression (RG) 3.00 respectively. The conceptual change on convection concept percentages was for PG 76.00, for MC 7.50, for MPC 8.00, for MIC 6.00, for RG 2.50 respectively. The conceptual change on radiation concept percentages was for PG 74.00, for MC 5.00, for MPC 8.50, for MIC 7.50, for RG 3.00 respectively. This result indicated that there was an understanding development of the students after learning to use the VMS.

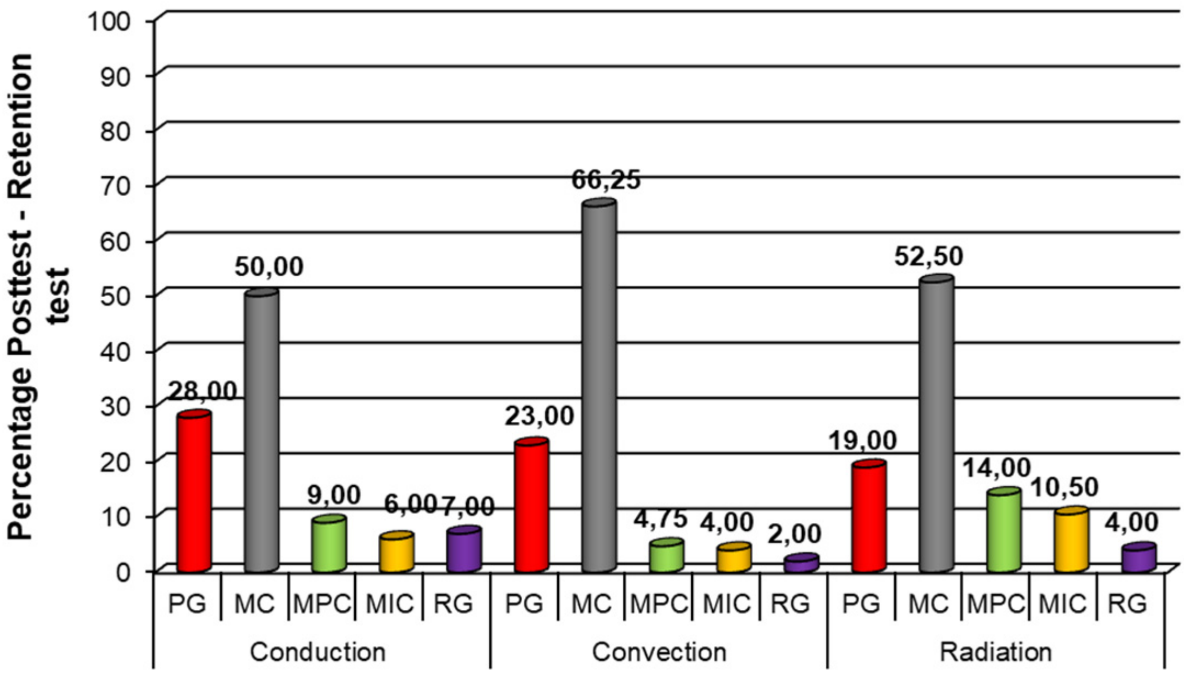

Figure 8. Posttest-Retention Test of Conceptual Change of Heat Transfer

Figure 8 displayed the percentages of the quantity of posttest retention test of conceptual change of heat transfer. The conceptual change on conduction concept percentages was for PG 28.00, for MC 50.00, for MPC 9.00, for MIC 6.00, for RG 7.00 respectively. The conceptual change on convection concept percentages was for PG 23.00, for MC 66.25, for MPC 4.75, for MIC 4.00, for RG 2.00 respectively. The conceptual change on radiation concept percentages was for PG 19.00, for MC 52.50, for MPC 14.00, for MIC 10.50, for RG 4.00 respectively. This result indicated that there was consistency of student understanding after learning to use the VMS.

Students' Quantity Conceptual changes

The results showed that overall students who experienced conceptual change after learning decreased quantity. All conceptual change labels can be well-reheated. At the time before learning, the number of students who conceptual change on each label conceptual change is low, the majority of students are in the category Progress (PG) 80.00, for Maintain-Correct (MC) 11.50, for Maintain-Partial

Correct (MPC) 4.00, for Maintain-Incorrect (MIC) 1.50, for Retrogression (RG) 3.00 respectively of students is scientific knowledge.

The application of virtual heat transfer simulation media on the conceptual alteration learning model has been able to help improve the students' understanding of the matter of heat transfer through the reduction of the quantity of students who have not understood the concept of (Maintain-Incorrect and Retrogression) and the reduction of the quantity of students experiencing conceptual change. Similarly, the quantity of students experiencing conceptual change decreased until there was no single student identified conceptual change on each label conceptual change. This result is similar to the findings of Dega et al. (2013), the study findings that interactive simulations are more effective for constructing cognitive conflicts in facilitating conceptual change to remediate the conceptual changes of students.

The reduction of the quantity of students experiencing lake of knowledge and error in the learning process occurs during the concept explanation phase at the confrontation stage of conception up to the stage of concept extension, where in that phase there are activities that enable students to construct their conception through assimilation and accommodation of new concepts. The concept construction process is supported by the use of real props media and virtual simulation of heat transfer during the learning process. Through the implementation of such a process, students who initially experienced a lake of knowledge and error changed to understand the concept (scientific knowledge).

Meanwhile, the reduction of the quantity of students experiencing conceptual changes in the learning process begins since the confrontation stage of conception is then reinforced to the extent of concept expansion. In the confrontation stage of conception, students are presented facts or actual phenomena that occur contrary to the student's early conception. This fact or phenomenon is performed with real demonstrations and virtual simulations that cause conflicts in student thinking. The occurrence of these cognitive conflicts diminishes students' beliefs over their early conceptions, so they attempt to review the initial conception. This stage becomes the beginning of the process of change of conception. This stage will facilitate the process of reconstruction of conceptions in students' cognitive structure. Reconstruction of conception occurs since students experience cognitive conflict to arrive at the stage of concept expansion. The decline in the quantity of students experiencing conceptual changes from the posttest resulted in a change in student conception, from conceptual changes to true conceptions in accordance with the conceptions of experts or scientists. Changes in this conception cannot be separated from the effective role of both media demonstration media real phenomena and virtual simulation media used in cognitive conflict strategy with Interactive lecture Demonstration (ILD).

Changes in students' responses in each category were presented in Table 4. Students' responses were further analyzed in term of unveiling their misconceptions based on test items of pre- post- and retention tests. These are presented in Table 5.

Table 5. Changes in students' responses in each category based on each test items.

No. Test	Progress (PG)			Maintain-Correct (MC)			Maintain-Partial Correct (MPC)		
	Retrogression (RG)	Posttest	Retention test	Retrogression (RG)	Posttest	Retention test	Retrogression (RG)	Posttest	Retention test
1	S2 S4 S6 S24 S35	S5, S7, S13	S6	S4, S20, S22, S29, S31 S33,	S35, S41, S44, S45	S20, S29, S31	S30, S32, S38	S20, S22, S29,	S38
2	S1, S10, S19, S22, S34	S6, S15, S24, S27, S30,	S10	S38, S58, S11, S22, S27	S10, S18	S27	S2, S4, S10, S14, S15, S17, S18, S19, S20, S22, S29, S31 S33, S34, S35, S41, S50,	S13, S34, S35, S41, S44, S45, S49, S50, S51, S37,	S29, S47
3	-	S24, S27, S30, S38, S47	S7, S15, S18	S38, S58	S10,	S4, S10, S14	S2, S13, S15, S17, S18, S19, S20, S22, S29, S31 S33, S34, S35, S51, S52, S57	S41, S44, S45, S49, S50, S51, S57, S58	S13, S34, S35
4	S22, S34, S50, S41, S42	S52, S57	S42, S57	S28, S25, S12	S14, S17, S24, S34,	S25, S34	S1, S6, S11, S17	S26, S33	-
5	S38, S15, S32	S24, S27, S34, S44, S45, S58	S3, S7, S18	S17, S20	S27, S45,	S33, S38	S3, S10, S19, S22, S34, S50, S41, S42	S49, S50, S52, S57	S14, S35, S38, S30, S31, S32,
6	-	S17, S18, S22, S33, S38, S45, S47, S51, S52	S17, S18,	-	-	S2, S3, S19, S24,	S10, S15, S17, S19, S20, S24, S29, S30, S31, S32, S34, S41, S44, S49, S52, S50, S58	S27, S34, S35, S44, S57	S31, S50
7	-	S7, S13, S15, S19,		S58	-		S4, S10, S14, S17, S18, S24, S29, S30, S32,	S2, S3, S10, S24,	

		S27, S34, S41, S58					S33, S35, S44, S47, S49, S52, S57	S44, S47, S50, S57	
8	S1, S2, S3, S4, S5, S6, S7, S8, S9, S10, S13, S14, S17, S19, S23, S25, S26, S29, S30, S32, S34, S36, S38, S39, S42, S44, S45	S1, S3, S5, S6, S7, S9, S10, S14, S17, 19, S22, S28	S3, S4, S5	S24, S44, S47, S50,	S45,	-	S10, S14, S17, S19,	S19	-
9	S11, S12, S16, S21, S24, S33, S40, S43	S11, S21		S15, S17, S18, S19, S20, S22,	S34, S35, S41, S44, S45, S49		S30, S32, S38, S44	S14, S19, S20, S22, S29, S31,	
10	-	S24, S27, S30,	S28	S38, S58	S10, S18	S38	S2, S3, S4, S10, S14, S15, S17, S18, S19, S20, S22, S29, S31 S33, S34, S35, S41, S50, S51, S52, S57	S13, S34, S35, S41, S44, S45, S49, S50, S51, S57, S58	S33, S50

No. Test	Maintain-Incorrect (MIC)			Retrogression (RG)		
	Retrogression (RG)	Posttest	Retention test	Retrogression (RG)	Posttest	Retention test
1	S5, S14, S19, S20,	S44, S45, S47	S47	-	-	-
2	S24, S27, S30, S32, S38, S44, S45, S47	S2, S4, S5, S14, S19, S20, S22, S29, S31, S32, S33, S52	-	S5, S7, S13,	S7	S5
3	S14, S19, S24, S27, S30, S32, S38, S44,	S2, S3, S4, S5, S20, S22, S29, S31	S14, S19	S5, S7, S13, S49	S5	-

	S45, S47					
4	S19, S15, S42	S27, S9 S45	S9, S19	-	-	-
5	S4, S5, S13, S14, S18, S24, S44, S47, S49	S2, S4, S5, S10, S13, S19, S20, S22, S29, S30, S31,	S29, S35, S41	S2, S7, S15, S57	S17	-
6	S13, S14, S18, S22, S27, S33, S35, S38, S45, S47, S50, S21	S4, S5, S10, S15, S20, S29, S30, S31, S32, S41, S49, S50, S48	S13, S14	S7	-	-
7	S2, S3, S5, S7, S13, S15, S19, S20, S22, S27, S31, S34, S38, S41, S45, S50	S4, S5, S14, S18, S20, S22, S29, S30, S31, S32, S33, S38, S45, S49, S51, S52		S51	S17 S35	
8	-	S86, S13, S23	S49	S22, S27	-	-
9	-	-	S15	S24, S27, S30,	S24	-
10	S24, S27, S30, S32, S38, S44, S45, S47	S2, S3, S4, S5, S14, S19, S20, S22, S29, S31, S32, S33, S42	S32, S42	S5, S7, S13,	-	-

Frequency and proportion of students' misconceptions of heat transfer

Misconceptions of Students (M)	Pretest		Posttest		Retention test		Conceptual Change
	SC* (f)	%	SC* (f)	%	SC* (f)	%	
M_1: At the time of thermal equilibrium continues to occur so that the temperature of the heat transfer of different objects.	S12, S29,&S27, S34 (4)	33	S22 & S30 (2)	17	S1 (1)	8	Positive (+)
M_2: Objects more quickly absorb the heat radiation, will be slower emit heat radiation.	S7, S23,& S33 (3)	25	S25 & S32 (2)	16	-	-	Positive (+)
M_3:-	S12& S22 (2)	16	S15 (2)	16	S15 (1)	8	No Change(0)
M_4: In the event conduction, heat flow because the dye molecules carried by intermediaries who move	-	-	-	-			No Misconceptions
M_5: In the event conduction, heat flow because the dye molecules carried by intermediaries who move	S9, S12, S17, S39, S37, S38, S44, S45, S39, S42, S46, & S49 (12)	90	S15, S28, S20, & S32 (4)	33	S29 (1)	8	Positive (+)

* refers to students' misconceptions

As seen from the Table 5, Conceptual change about heat transfer through each test changed over time (pretest, posttest, and retention test), which are generally positive. Their frequency varied significantly, and this data was also presented in the Table 4. From the Table 4, positive conceptual changes occurred in students' minds. The table showed that students' alternative conceptions and difficulties decreased after the intervention. For illustration regarding the Table 5, the percentage decreased from 33% to 17% with retention test 8 % for pretest, posttest and retention test.

Conclusions

This research informed the impact of innovative teaching method called Virtual Microscopic Simulation (VMS) for the development of students 'conceptual understanding' of heat transfer by showing the cognitive process of conceptual change. The result showed the increasing of students' conceptual understanding scores from pretest, posttest, and retention test to statistically significant effect across three concepts of heat transfer. This indicated that the teaching method effectively helped student construct a more scientific view of heat transfer. The result is consistent with the research findings that students performed better achievements with learning from computer simulation (e. g. Savinainen and Scotr, 2002; Atasoy and Akdeniz, 2007; Spyrtou et al., 2009; Macabebe et al., 2010; Saglam-Arslan & Devecioglu, 2010; Kaewkhong et al., 2010; She, 2003; She, 2004b; Trundle & Bell, 2010; Miklopoulos & Natsis, 2011; Dega et al., 2013; Djanett et al., 2013). The results showed that the percentage of the progress (PG) category was higher than another category.

In addition, students' conceptual change in this research was a deep process of reconstructing students' alternative conceptions into scientific conception, called radical conceptual change, and the process of conceptual change could be encouraged by the promoting with VMS.

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