Mobile-Nature of Science Model of Learning for Supporting Student Performance on General Chemistry Classroom

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Abstract—Development of student understanding of nature of science, conceptual understanding, and scientific literacy on learning must be supported by proper learning process. An offline and online environment on mobile learning oriented with Nature of Science oriented learning can be considered to commit. Mobile-Nature of Science (Mobile-NOS) is suitable model of learning for this purpose. Evaluating the influence of Mobile-NOS model of learning application towards Students' understanding of nature of science, chemistry concept understanding, and scientific literacy on general chemistry learning are focus of this study. This study was carried out by posttest only control group design, in form of quasi experimental. There are 44 sample determined by saturated sampling technique of general chemistry students as population. Sample divided into two group equally, the experimental and control group. Data were collected by understanding nature of science questionnaire, scientific literacy test, and chemistry conceptual understanding test. Data was analyzed by independence sample t test. The result of the study showed that the application mobile-NOS model of learning make students better on understanding of nature of science, conceptual understanding, and scientific literacy.

Keywords—Mobile-NOS model of learning, understanding of nature of science, conceptual understanding, scientific literacy.

1 Introduction

In developed world, More than 95% of students in colleges are users of smart mobile devices and use this for academic purposes. Using the mobile devices can supporting students learning on the move at any place and any time as new task of learning [1][2][3]. The use of mobile technologies in education impacts student motivation.

Mobile learning environment provide collaboration, information sharing, mobility and interactivity for students, teachers, and the university [4]. Mobile technology has support the born of the concept of mobile learning as new teaching and learning techniques. [5] [6] defined mobile learning as the application of tablets, PCs, or smartphones technology in the learning process.

Designing mobile technology for learning in university should provide an appropriate, supportive, enriched environment for this method of learning [7][8]. Students convenience with the interactivity and accessibility of mobile learning [9]. This encourage students in fun learning activities and place students as the main subject in learning, foster motivation to learn, foster to develop student skills, so learning becomes meaningful [10][11][12]. However, mobile learning must be for education the main objective, not for entertainment [13]. Effective mobile learning should accommodate students to actively participating in the knowledge building process. Therefore, there is a need for mobile applications that create effective environments which are student centered [14][6].

Guiding students become problem solvers who have scientific characters must become main purpose of chemistry learning. Student is able to compare natural tendencies and distinguish of objects and events naturally. Effective learning environment must be completed with assignments to improve effectiveness in shaping and using concepts. Students must develop skills to complete assignments and science process consciously. Helping students to understanding knowledge, producing ideas, developing concept, transforming concept into skills, making formulations, testing hypotheses are requirements for effective learning environment [15]. The better science process on learning, the better learning achievement will be [16] [17] [18] [19].

The results of observation by researchers, the level of understanding in the nature of science in first-year students at Universitas Pendidikan Mandalika is 66,192 with medium category. In line with research [20], most students currently have a moderate level of understanding of NOS. Most of these research subjects are in the intermediate level in their studies at the university. Undergraduate students should have a high understanding of nature of science because this can change as it advances to higher levels of study. Researchers suggest that efforts to raise understanding in the nature of science are still needed at universities [21] [22].

According to [23], focus on the understanding of the nature of science (NOS) as a form of human knowledge and inquiry can force student performance achievement in science learning. The main objective of science curriculum today is integrating nature of science (NOS) and establish it as important learning goal [24][25]. Understanding NOS is a characteristic that is expected to exist in someone who has scientific literacy [26]. So that, developing mobile learning must be oriented to the nature of science.

According to [27], science teaching approach should be regarded as "education through science", rather than "science through education". Nature of science education is aim to give foundations based on activity theory rather than logical positivism. Understanding NOS links to establish the achievement of personal domain, stressing intellectual and communication skill development, promotion of character and positive attitudes, achievement in the social education domain, stressing cooperative learning, and socio-scientific decision-making. Although the nature of science is seen as an important component of science education, the over-riding target for science teaching is based on enhancing scientific and technological literacy.

NOS learning as inquiry approach providing constructivist learning experiences and develop student scientific literacy [28][29]. However, this requires quite long learning time, while learning time in the chemistry curriculum in Indonesia only 200-300 minutes per week. The inquiry learning experience cannot always cover all aspects of NOS. Moreover, Less than 30% of the NOS aspects explicitly present on Indonesian high school chemistry textbook [20]. Collaboration of mobile learning in inquiry-based Nature of Science (NOS) named Mobile-NOS model of learning established on this study.

Mobile-NOS model of learning should be supported by mobile applications on smartphone. These can be interactive module applications, teaching materials, social media, and learning websites that used both inside and outside the classroom by teachers and students. Mobile-NOS model of learning must be able to show the aspects of the nature of science explicitly through learning process. The stages of learning are reading context in electronic articles, in-depth question and answer, case observation, procedures demonstration, case study research, carrying out procedures, communicating science knowledge, and authentic assessment [30]. How mobile-NOS model of learning play role to student performance and achievement of understanding NOS, concept understanding, and scientific literacy are issues that still need to be evaluated on chemistry learning.

2 Methodology

This research conducted with quasi experimental method and carried out by post-test only control group design at the Faculty of Applied Science and Engineering, Universitas Pendidikan Mandalika. There are 44 students of General Chemistry course on academic years of 2018/2019 selected by purposive sampling technique divided into experimental and control group. Experimental group was learned by mobile-NOS model of learning, while control group by conventional learning method. The data of this study consist of understanding of NOS, conceptual understanding, and scientific literacy. The data were collected by understanding of NOS questionnaire, conceptual understanding test, and scientific literacy test. Understanding of NOS questionnaire was tested by conduct on 84 students of Universitas Pendidikan Mandalika. Instrument validity was analyzed by product moment correlation and reliability by three split technique of Alpha correlation test [31]. This questionnaire consists of 39 valid items predictor of 10 understanding of NOS aspect with very high reliability coefficient about 0.802. Conceptual understanding and scientific literacy test respectively consist of 15 and 22 valid items with 0,699 and 0,824 of reliability after tested on 40 subjects. Data of this research was analyzed by independence sample t test assisted with Ms. Office Excel 2010 and SPSS 16.0 for windows.

3 Result and Discussion

3.1 Effect of mobile-NOS model toward understanding of NOS

The nature of science aspects was observed on this study. Students understand that knowledge is tentative meaning students understand that the truth of science knowledge is temporary until the discovery of new scientific evidence. In chemistry, we are familiar with theories about the atomic model. The Thomson atomic model in his day was considered to be true knowledge in accordance with the available evidence through the cathode ray experiment. But after an experiment of alpha rays into thin plates of gold carried out by Rutherford, the truth of the Thomson atomic model was refuted. Scientific knowledge that is believed at this time might be denied by the new scientific evidence in the future. Students who understand that science knowledge is tentative can also accept that an investigation of the same science object may have different results or change. For example, knowledge about molecular masses that were once predicted by Raoult law has now changed after the discovery of the spectroscopic method.

Students who understand that scientific knowledge is based on empirical data are aware of the urgency of experimentation as a method of collecting data. They believe in scientific knowledge as a truth that must be supported by data in a real context. For example knowledge of the law of the rate of a particular chemical reaction must be supported by appropriate rate data. Sometimes science knowledge comes only from human thought and there is no data that can prove its truth. But the results of such thought are very logical and can be used to explain scientific phenomena. This aspect of the nature of science can be understood by students who understand that some scientific knowledge is a product of human inference. For example, the octet rule, a thought put forward by W. Kossel and G.N. Lewis, can be used to predict and explain atomic bonding form a compound.

The fourth aspect of the nature of science is the human creativity needed to develop knowledge, to differentiate / create data images. For examples, the scientific knowledge about atomic models that only depended on spectrum data. Thomson, Rutherford, and Bohr creativity have provided us with information about how to understand, describe, and elaborate the model of atom based on each experimental data. Student who understanding this aspect, can accept facts about every scientific methods can be change or develop by human creativity / ideas. On chemistry, various methods of measuring or analysis of solutions, such as titrimetric, potentiometric, spectrophotometry, are examples of scientific methods developed with human creativity. Cathode ray experiment, alpha light scattering, the spectrum of hydrogen atoms, are various methods of human creativity for describing the atomic model.

Students who understand the scientific method, understand how the scientific method is carried out which consists of formulating the problem, compiling an experimental plan, collecting data, analyzing data, and making conclusions. However, they agreed to open up those who could use the existing trial steps and modify procedures sometimes needed. Students who understand that knowledge cannot be separated from the theory / understanding of scientists (driven by theories), can position scientific theories as they should. They can accept the existence of different theories for explain a phenomenon. This aspect appears very much in the material of chemical science. For example the bonds in compound, can be understood with the octet / Lewis theory or molecular orbital theory. The form/structure of molecule can be elaborated by hybridization theory or VSEPR theory sometimes.

Students who understand the nature of science can position scientific law and scientific theory well. Students believe laws of science cannot be refuted, while the truth of scientific theory is not absolute. Science theory can be disputed, refined, or accepted by the presence of new theories. In many chemical science subjects containing this aspect, for example in bonds forming, the octet rule is no longer considered an adequate theory to explain the phenomenon of bonding in relations after the appearing of valence bond theory, VSEPR and molecular orbital theory. They can also accept that they can choose a theory to explain an exact phenomenon and not use another theory.

Students know that some of the laws, theories, concepts, and procedures of science are named according to their inventors. For example Raoult law, Bohr's theory, Avogadro's number, and the Karl-Fischer method are named after the inventor. These students understand aspects of the nature of science, namely the social dimension of science. They can also accept that science is built with scientific agreements that inherited continuously by scientist, researchers, and inventors. For example, an agreement about 1 mole which is equivalent to the Avogadro number (6.02 x 1023) particles or similar charges repel and different types of attraction will attract each other is the foundation concept that builds the knowledge of chemical science to date.

Students realize that science is built on the basis of traditional culture and vice versa, the development of science can affect human lifestyles and culture. Students who realize this understand the nature of science in the social and cultural fields. The culture of scientists in Germany in the early 20th century who examined the phenomenon of photons has provided a new perspective to explain various scientific objects such as the electronic state of atoms, chemical bonds and molecular shapes, as well as spectroscopy and spectrophotometry. The discovery of radioactivity and core reactions has changed the way humans obtain energy, detect and treat disease, and breed superior agricultural crops.

Students' understanding on every aspect of the nature of science for experiments and control class as presented in Figure 1.

(1.scientific knowledge is tentative; 2. scientific knowledge comes from empirical data; 3. Scientific knowledge is a product of human inference; 4. human creativity is needed to develop knowledge; 5. scientific method; 6. Knowledge is inseparable from the theory / understanding of scientists (Theory driven); 7. Scientific law; 8. Scientific theory; 9. social dimension of science; 10. Planting science in the social and cultural fields).

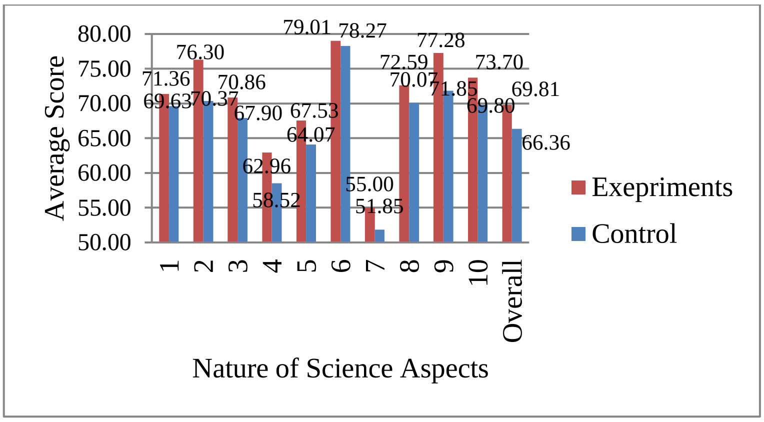

Fig. 1. Students understanding of NOS aspects after learning

Based on the study, the highest score of students understanding of NOS lies in the knowledge cannot be separated from the understanding of scientists with a high category and the lowest score lies in scientific law with sufficient category, while the rest are in the good category. The results are in line with the results of the study [20] [32] [33]. The average understanding of students about the nature of science experiment class (69,801) is higher than control class (66,192). T test results show that t statistic is greater than t critical. There for, it must be concluded that students' understanding of NOS is better with Mobile-NOS model application.

Table 1. t test results in Understanding of Nature of Science

Group	N	Mean	t_{stat}	df	$t_{Critical\ (two\text{-}tail)}$	Sig.
Experiment	22	69,801	5,353	42	2,021	0,000
Control	22	66,192				

The results showed that most students believed that scientific knowledge should only be in the form of facts that can be felt by the human senses neither abstract. According to [34], science must only be in the form of observation and experiment. Students believe that science phenomena should be explained as they are without human imaginations involved. Most students disagree that theory is the result of human creativity. Most students agree all experiments must be completed with hypotheses. Most students disagree the subjective and irrational of humans though also work scientific knowledge building. Most students assume that scientific law is solely derived from logical thinking, and theory will never be scientific law.

This understanding of the nature of science needs to be improved so that students have a greater chance of success in learning science. According to [33], the stronger belief that science knowledge is changing and tentative (in the epistemological aspects of science), the higher understanding and curiosity in science. Student epistemic beliefs about the development of scientific knowledge have a direct effect on the knowledge domain. Beliefs about justification of scientific knowledge have direct and indirect effects on the goals of the attainment and acquisition of knowledge. Understanding of NOS will support student achievement in learning science [21].

Stages of learning activities in the core part of mobile-NOS learning are reading context in electronic articles, in-depth questioning, case observation and observation, demonstration of procedures, searching literature, implementing procedures, and communicating science knowledge [23].

At the stage of reading context in electronic articles, students read articles in a mobile application or website that has been provided or recommended by the teacher. At this stage students can understand the characteristics of NOS namely the development of scientific knowledge can influence and be influenced by social, cultural, or community values. In the deep question and answer stage, the lecturer asks in-depth questions related to articles. Lecturers conduct question and answer with students so students know the background knowledge they need. Activities are carried out outside the classroom through groups that the teacher has created on social media or learning websites. At this stage students can understand the characteristics of NOS ie scientific knowledge can be derived from the results of the inference of scientists. Inference is a reasonable explanation about scientific phenomena or facts that can be seen in daily life or through experimentation.

At the stage of case observation and intervention, students are tasked with solving contextual cases through an investigation process. This activity is carried out in class. The lecturer guides students to propose a problem statement and formulate a hypothesis. This activity is carried out through groups that have been made by lecturers on social media or learning websites. At this stage students can understand the characteristics of NOS, scientific knowledge can be derived from the scientist's inference.

At the procedure demonstration stage, the lecturer presents a live demonstration of the investigation method related to the case which will be solved through video / picture that has been available through a mobile learning facility. For this purpose, the lecturer can provide the video / image through the learning website, share files or links through social media groups, or ask students themselves to search for videos or related images via the internet. At this stage students can understand the characteristics of NOS such as based on empirical data and scientific methods.

In the literature search stage, the lecturer guides students to conduct library studies related to learning topics. At this stage the lecturer can explain explicitly the characteristics of NOS, namely knowledge cannot be separated from the Driven Theory of previous scientific understanding of a phenomenon or scientific knowledge. Driven theory can be a reference for students in explaining the phenomena they will observe in experimental activities. On this occasion, students who understand about scientific theory and law can explain the characteristics of theory and scientific law and their position in science. Students can also understand that scientific knowledge is tentative, (temporary) which is indicated by the existence of various theories or explanations of a particular scientific phenomenon. Lecturers can also provide understanding that the results of the experiments they will obtain may be different. By understanding that scientific knowledge is tentative, students will be more confident in explaining the results of their observations.

At the stage of carrying out the procedure, the lecturer asks students to prepare an investigative procedure. At this stage the lecturer can convey explosively the characteristics of NOS namely scientific knowledge can develop thanks to the creativity of humans / scientists, scientific creativity is needed to develop knowledge. The method compiled by scientists is one of scientific knowledge. The lecturer then asks students to carry out the investigative procedures that they have compiled. Students are also allowed to make modifications of procedure during the practicum process. In condition, the procedures they have prepared previously have weaknesses or obstacles in implementation. At this time students can understand the experimental procedures carried out in order to obtain empirical data to build knowledge.

At the stage of communicating science knowledge, lecturers ask students to prepare reports as the results of activities or to fill in the report formats in form of worksheets. After preparing a report or worksheet, the lecturer can ask students to present the results of their experiments in a group discussion. At this stage students can gain an understanding of the social dimensions of science that require a form of appreciation for the work, experiments, or critical ideas to scientists. The form of appreciation can be in the form of providing opportunities for scientists to present their findings. Then more than that, actual scientific knowledge can be disseminated in this way. Knowledge of science can be a reference or basis for the development of scientific knowledge next. At this stage students are also welcome to include solutions that are considered appropriate for the problem. Lecturer can explain the cultivation of science in the social and cultural fields explicitly. Science develops to solve human and environmental problems, improve the quality of life, or balance out lifestyles. The application of science products must consider the socio-cultural aspects of society.

Nature of science-oriented learning can encourage students to become: 1) utilitarian, understand science and manage technological objects and processes in everyday life, 2) democratic, make decisions on socio-scientific issues, 3) cultural, appreciate the value of science as part of contemporary culture, 4) morals, developing understanding of the norms of the scientific community that embody moral commitments about general values to society, 5) science learning: fulfilling the tasks of learning. Learning based on Nature of Science can make students' abilities in applying concepts and understanding of the nature of science better [35] [36] [37].

However, this study shows that the increase that occurred in understanding of the nature of science is still relatively low at 69,801. In contrast to studies conducted by [35], understanding of the nature of junior high school students reached an average of 79.17. This could have happened due to differences in the measurement instruments for understanding of the nature of science used. In addition, the implementation of learning that is very short in this study, only one learning activity, causing the increase that occurred is still relatively low. Learning that explicitly includes NOS, whether integrated with the material or not, can be used to improve students' understanding of NOS. However, it needs to be considered the use of learning time must be realistic [38][39]. Therefore it is very necessary to consider providing a more learning experience so that the achievement of understanding the nature of students can be higher. Understanding of the science nature can have an impact on student performance in science learning process. Other studies have shown that NoS-oriented learning can positively influence the understanding and belief in the nature of science, the ability to apply concepts and learning outcomes [36] [40].

3.2 Effect of mobile-NOS model toward conceptual understanding

Data on students' understanding of concepts was obtained from the results of reasonable, multiple-choice questions given after all learning activities were carried out. The distribution of students' understanding of the concept provide on fig. 2.

Based on this research result, it appears that the average understanding of students 'concepts understanding in the experimental class is higher than the control class. The average score of concept understanding of experimental class is 72.12, while control class is 62.72. Students on experimental class who excellent on concept understanding are 2 students, 18 students are on good category, and 2 students are on poor category. 13 students of control class are on good category and the rest, 9 students on poor category. The significance value is smaller than the significance level ($\alpha = 0.05$), so the null hypothesis (Ho) is rejected. It can be concluded that there is a significant influence of mobile-NOS model of learning on student concept understanding. When conducting learning activities on control class, students are only fixated with the teacher's explanation without any reciprocity. The exchange of information only occurs within the group environment and when working on test questions. Information obtained during the practicum and discussions with group members are limited. Better things happen on experimental class. Students reach their conceptual understanding through learning activities on classroom and undergo self-study with mobile-NOS application media assisting.

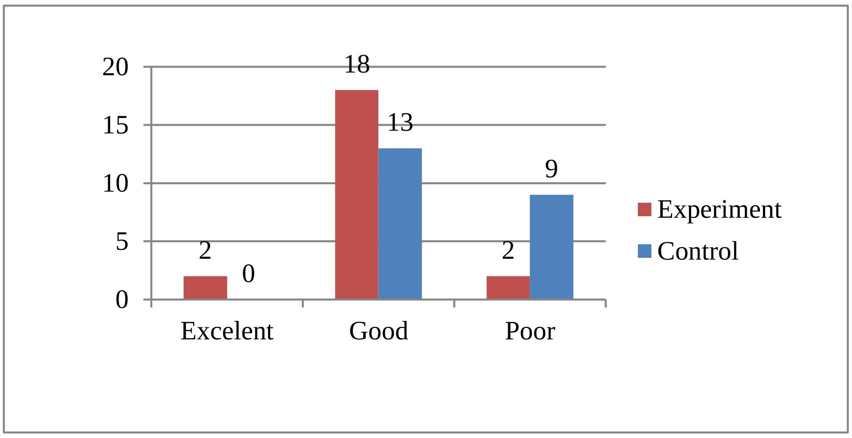

Fig. 2. Number of Student on Conceptual Understanding Categories

Table 2. t Test Result of Conceptual Understanding Data

Group	**N**	**Mean**	**t_{stat}**	**df**	**$t_{critical\ (two\text{-}tail)}$**	**Sig.**
Experiment	22	72.12	4.315	42	2,021	0,000
Control	22	62.72				

3.3 Effect of mobile-NOS model toward scientific literacy

Data on scientific literacy of students was obtained from the results of reasonable multiple-choice test results given after all learning activities were carried out. The results of the distribution of scientific literacy scores of the experimental class and control class of students can be seen in Fig. 3.

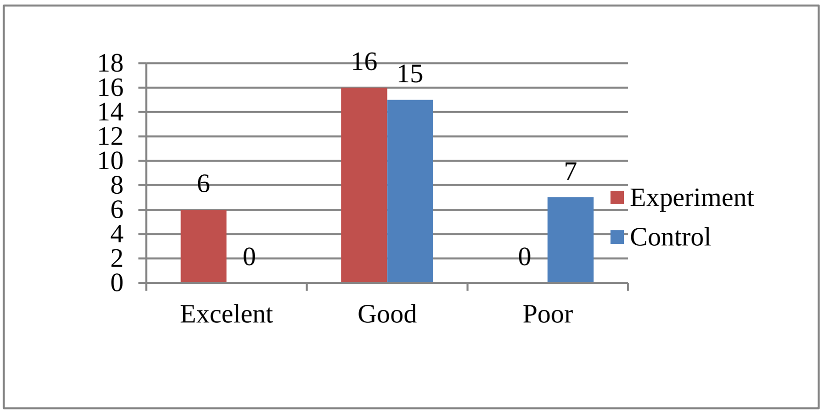

Fig. 3. Number of students on scientific literacy categories.

Table 3. T Test Result of Scientific Literacy Data

Group	N	Mean	t Stat	df	t Critical two-tail	Sig.
Experiment	22	76.10	6.336	42	2,021	0,000
Control	22	64.05				

Based on research result, the average score of student scientific literacy in the experimental class is higher than the control class. The average score of scientific literacy of students in experimental class is 76.10 and control class is 64.05. Independent sample t-test for students scientific literacy data obtained t arithmetic is 0,000 <0.05. It can be concluded that there is an effect of the mobile-NOS model of learning on students' scientific literacy.

The result of this study showed that mobile-NOS model application supporting student to achieve better scientific literacy on chemistry learning. The scientific literacy aspects observed in this study are content, context, process, and attitude. Through the steps of mobile-NOS model of learning can greatly support the achievement of students' scientific literacy. The stages of mobile-NOS model of learning are reading context in electronic articles, in-depth questions and answers, case observation, demonstration of procedures, library research, carrying out procedures, communicating science knowledge, and authentic assessment [23]. This learning model is facilitated also with mobile learning devices that already developed with considering what is suggested by [5], there are contextual features, learning content, learner behavior, and adaptation methods.

Mobile-NOS model of learning, supports learning characteristics that refer to [27] are gave foundations based on activity theory rather than logical positivism, encompasses an understanding of NOS, links with the achievement of goals in personal domain, intellectual stressing and communication skills development, promotion of character and positive attitudes, plus achievement of goals in the social education domain, stressing cooperative learning and socio-scientific decision-making.

At the stage of reading context in electronic articles, students understand the context of knowledge they will learn, students having foundations based on activity rather than logical positivism in the process of gaining knowledge. The context presented can be in the form of socio-scientific issues. Articles are provided on mobile learning application media. Every student obtained this application on first time learning carried out. The context on the article should be closed to student daily life. According to [41] mobile learning integration is more successful when aligned with local cultural context. Mobile learning tools that might be culturally appropriate in one context may not always be accepted in another.

In the in-depth question and answer stage, there will be stressing intellectual and communication skills development, as well as the promotion of character and positive attitudes in students. This stage not only classroom activity but also discussion through text message or social media application on group that initiate by teacher. According to [42][43] in discussion via text message, learning transfer occurred and being influenced most by learner’s characteristics especially in term of their motivation as well as their perceive utility/value of the learning to their academic performances. Through the stages of case observation and demonstration of procedures students understand the mastery of knowledge about the content, context, and scientific processes that are foundations based on activity theory rather than logical positivism. At the library research stage, aspects of the content of the material are deepened by students according to their needs based on the context that is the focus of learning. On this stage, students must realize knowledge they need.

At the stage of carrying out procedures students work in groups, promotion of character and positive attitudes occur here. The mastery aspect of science process skills occurs at this stage. At the communicating science knowledge stage, through the group presentation process, students can again experience stressing intellectual and communication skill development. Aspects of mastery of content and knowledge context are needed here. If students discuss socio-scientific issues then they will be forced onto socio-scientific decision-making. The attitude of those who can understand differences of opinion on an issue will make them experience promotion of character and positive attitudes. Students' experiences in mobile learning make them more aware of the goals of learning. Study of [44] showed mobile learning can help developing students self-efficacy. According to [45], there is a positive effect of mobile learning on the knowledge acquisition, learners’ achievements, attitudes and motivation despite the high cognitive load. On that way, students who are taught with the mobile-NOS model of learning can succeed in achieving scientific literacy.

4 Conclusion

Based on the study results, the value of t statistic for understanding of the NOS, conceptual understanding, and scientific literacy data respectively are 5.353, 4.315, 6.336 that greater than t critical (2.021) in the one-tail hypothesis test using independence sample t test. Student understanding of the nature of science, conceptual understanding, and scientific literacy in experiment class who is learned by mobile-NOS model of learning significantly higher than control class. Therefore, it can be concluded that the application of the mobile-NOS model of learning can support students' performance on general chemistry learning.

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