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THE PRACTICALITY AND EFFECTIVENESS OF CASE STUDY-BASED MODULE ON CHEMICAL THERMODYNAMICS COURSE (IDEAL AND REAL GASES) AS LEARNING TOOL DURING THE COVID-19 PANDEMIC

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Abstract

The case study-based module on chemical thermodynamics course (ideal and real gases) was developed to fulfill the needs of undergraduate students in online learning during the COVID-19 pandemic. The purpose of this study was to test feasibility of case study-based module. The case study-based module refers to the 4D model (define, design, develop, and disseminate) by integrating the one group pretest-posttest design at the develop stage. The feasibility of the module was measured through validity, practicality and effectiveness using validation sheet, evaluation test sheet and questionnaire sheet. Data were analyzed descriptively, quantitatively (Wilcoxon Signed Rank Test) and qualitatively. The case study-based module was suitable for one of learning tools, which was proven by the findings that 1) meets valid and reliable criteria, 2) meets practical criteria with support for general achievements students' very positive response to the aspects of module (construction, material, motivation and case study), and 3) meets the effective criteria by increasing the average score pretest-posttest in medium category which contains the cognitive level of analyze-C4, evaluate-C5, and create-C6. The implication of development case study-based module can facilitate students in online learning during the COVID-19 pandemic so that they will successfully reach the course learning outcomes of Chemical Thermodynamics, which includes mastery of knowledge about main principles of thermodynamics, ability to solve science and technology problems, ability to use information and communication technology based learning resources, make decisions based on the relationship of concepts with laboratory activities, and practice responsibility.

Keywords – Module, Case study, Chemical thermodynamic, COVID-19 pandemic.

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1. Introduction

The Chemical Thermodynamics or Physical Chemistry II is compulsory course which is programmed by undergraduate chemistry students at Universitas Negeri Surabaya. Chemistry is branch of science that deals matter and changes, while physical chemistry is branch of chemistry that deals subject principles based on physics concept and mathematical language, the basis for developing spectroscopic and its interpretation (molecular structure and electron distribution associated with material properties), and understand the chemical reactions take place (Atkins & de Paula, 2010). Physical chemistry is divided into four areas, namely thermodynamics, quantum chemistry, statistical mechanics, and kinetics (Levine, 2009). Thermodynamics deals the changes in heat and work involved chemical reaction and associated with the laws of thermodynamics. The chemical thermodynamics course is full of calculations and its derivation, so the material not only contains conceptual knowledge but also procedural knowledge. The characteristics of procedural knowledge are appropriate to be taught using teacher centered learning (TCL) (Arends, 2012), because the chemical thermodynamics equation will be easily followed by students when given oral presentation by the lecturer.

TCL was implemented as traditional methods (presenting material and doing exercise) which affected the achievement of students' conceptual knowledge. It can not be developed independently by students. The findings of the test results of higher cognitive level were done poorly by students. There were 80 undergraduate program of chemistry education students of 2019 class (UPCE-19) as one of research population who had conducted TCL on chemical thermodynamics on even semester of the academic year 2020/2021, 33% of students were able to complete properly cognitive level of Evaluate-C5, while 85% of students were able to complete Apply-C3 question. The revised version of Bloom's taxonomy (Krathwohl, 2002) namely Analyze-C4, Evaluate-C5, and Create-C6 as the higher cognitive levels which came up more complex and abstract. This proves that students were less able to use their knowledge of thermodynamics to evaluate phenomena as one of the course learning outcomes (CLO) of the Chemical Thermodynamics course.

Implementation TCL in this course was unable to accommodate the entire CLO, so that several learning method should be combined, especially in online learning as the impact of the COVID-19 pandemic. Kurniasari, Pribowo and Putra (2020) concluded that 48% of students stated that the evaluation of learning from home with more assignments was not effective because it burdened them and the lack of two-way interaction between students and teacher and dominated by teacher activity in oral presenting. The lecturer team of chemical thermodynamics course combined traditional and a case study as learning methods for the undergraduate program of chemistry students of class 2020 (UPC-20) in odd semester of the academic year 2021/2022. It can help students to actively participate solving real-life problems implementation learning approach namely student centered learning (SCL). The findings of students' test result that there was increasing the percentage number (69% of 61 UPC-20 students) who can complete properly question of analyze-C5 level. Meanwhile, only 13% of them are able to solve question of create-C6 level, namely came up ideas for solving cases as real-life problems. This proves that the majority of students still have difficulty in constructing ideas even though the learning method transition had been conducted from TCL to SCL.

Keiler (2018) concluded that the success of the learning transition from TCL to SCL is influenced by teachers' commitment and the role of students as peer tutors. Teachers/lecturers must have a strong commitment to prepare learning tools and ensure implementing the lesson plan. Meanwhile, students who have better academic (mastery of concepts) can be used as peer tutors for their friends who still have difficulty understanding the material. Vygotsky stated that students can reach the objective area of the zone of proximal development (ZPD) through interaction with their environment which can bring up scientific reasoning abilities (debate and analysis), then switch to reach the subjective area of ZPD through imitating actions as a result of reasoning (Chaiklin, 2003). However, the limitation of online learning was not being able to interact actively between students mainly through presenting material. The inline finding by Basar (2021) that distance learning during the COVID-19 pandemic was influenced by internet quotas and signals, which caused students could not follow properly material be presented by teacher. The ministry of education and culture provided a policy in the form of expanding learning resources. School and institution have competed to encourage teacher/lecturer to develop learning tools to facilitate students in online learning during the COVID-19 pandemic.

Module is one of learning tools which can be used by students in online learning during the COVID-19 pandemic. The effectiveness of the module in supporting students' learning activity was proven by previous research. Module in higher education can be used preparing students to hone thinking skills, communication skills, practical skills, and the value of technology applications which were required in the world of work (Willmot & Perkin, 2011). Matanluk, Mohammad, Kiflee and Imbuga (2013) concluded that the constructivist-teaching based module can improve thinking skills and active participation of students in constructing knowledge. Linda, Herdini, Sulistya and Putra (2018) found that 100% of students stated that the existence of learning resources was important and 85.54% of students had difficulty learning chemistry due to lack of learning resources.

Based on those description, it is necessary to develop a module as learning tool to support students in online learning during the COVID-19 pandemic. CLO of Chemical Thermodynamics course which demands the achievement of mastery of knowledge, the ability to solve science and technology problems, the ability to use technology resources, make decisions in everyday life through laboratory activities, and practice responsibility. The case-study as learning method must be integrated in the module of Chemical Thermodynamics course to accommodate the entire CLO. Bonney (2015) described that case study as a learning method based on real situation which required students' participation, through the presentation of narrative content with questions that can encourage students to solve complex problems so that they can reach higher levels of Bloom's taxonomy (Roell, 2019). The finding from previous studies deals the effectiveness of implementation case study in learning. Escartin, Saldaña, Peña, Rey, Jiménez, Vidal et al. (2015) concluded that case study makes students to be able applying knowledge in real life, encourage students' active roles in the learning process, and significantly improve learning outcomes. Case studies can prepare students to face the real world and real work through the case reports from news source are discussed interactively in the problem-solving process (Lerner & Richey, 2005).

The case study based module on chemical thermodynamics course (ideal and real gases) was also equipped with chemistry project using surrounding materials as practicum tools, virtual lab (PhET simulation), and video demonstrations. It would provide students' experience with macroscopic aspect of properties and behavior of gases. In addition, the module would be made explicit the microscopic aspects (particulate level) of gases along with symbolic aspects to differentiate the characteristics of ideal and real gases. Gabel (1999) described that students find difficulty when they directly interpret macroscopic aspect (through laboratory activity) into microscopic aspect, because the lack of modeling and analogies to imagine particulate level. Herunata, Rosyida, Sulistina and Wijaya (2021) concluded that the implementation of chemical representation in learning could improve the representational competence of students so that they achieved sound understanding of the concept. Students learned chemistry by interconnecting three representations (macroscopic, microscopic, and symbolic) can potentially improve their conceptual understanding. Students' mature concepts can be used to solve the cases. Nath (2005) concluded that students learned to create a safe environment through implementation of case study. When students actively contribute to solving cases in real life, so that an attitude of responsibility would be embedded in protecting environment.

2. Research Method

2.1. Population and Sample

The population of this research was considered for define stage and develop stage of the case study based module which were undergraduate program in chemistry (UPCE) students and undergraduate program in chemistry education (UPCE) students, faculty of mathematics and natural sciences, Universitas Negeri Surabaya. The population for define stage consist of 94 UPCE students of 2018 class, 66 UPC students of 2018 class, 80 UPCE students of 2019 class, 65 UPC students of 2019 class, and 61 UPC students of 2020 class. Their achievement were evaluated after experiencing learning transition on chemical thermodynamics course during COVID-19 pandemic. The population for develop stage were 80 UPCE students of 2019 class because they had conducted chemistry thermodynamics course on even semester 2020/2021. The technique used to get research sample for develop stage was cluster random sampling. The sample of this research was 52 UPCE students which would perform readability test (pretest-posttest and questionnaire) of the case study based module.

2.2. Instrument

Instrument was used in this research consist of module, evaluation sheet (pretest-posttest) and questionnaire sheet. It was validated by three experts in physical chemistry field and chemistry education field by using validation sheet. Questionnare sheet was used to measure the practicality of module, while evaluation sheet (pretet-posttest) was used to measure the effectiveness of module.

2.3. Research Design

The research procedure in developing the module refers to the 4D model (Thiagarajan, Semmel & Semmel, 1974) consist of Define, Design, Develop, and Disseminate. The define stage involved analyzing the material and students' characteristic. Chemical thermodynamics course contains full of mathematical calculation which should be applied to solve problem everyday life. The analysis of the midterm test, the majority of students were unable to solve the higher cognitive level questions (analyze-C4, evaluate-C5, and create-C6), but tend to be easier to solve apply-C3 level contains calculation problem. The design stage was begun with analyzing the material matrix of chemical thermodynamics (ideal and real gases) and exploring relevant cases that occur in the society. In this research, the development of module was limited to the initial material of chemical thermodynamics, namely gas systems (ideal and real) and its behaviour. The module consists of material, cases and guiding questions to create solution, and calculation exercise of thermodynamics at the end. The develop stage was conducted with validation process and readability test. The validation process was carried out by three experts in the field of physical chemistry and chemistry education, they validated module, questionnaire, and evaluation tests (pretest-posttest). The readability test was carried out with students who had programmed Chemical Thermodynamics course by referring to the one group pretest-postet design (Fraenkel & Wallen, 2009). The aim was to measure the practicality and effectiveness of the case study-based module on chemical thermodynamics (ideal and real gases). While the disseminate stage has not been carried out because it will be disseminated on the chemical thermodynamics course in the even semester academic year 2021/2022.

2.4. Data Analysis

The instrument validation score used Likert scale ranging from 1 (less good) into 4 (very good) (Creswel, 2012). The validation results from 3 experts in the field of physical chemistry and chemistry education were analyzed the validity and reliability of the research instruments. The interpretation of validity is based on the mode/median of validation score from three experts, with details of instrument can be considered valid if the minimum value 2.5 as midpoint of the Likert scale (Chyung, Roberts, Swanson & Hankinson, 2017). Meanwhile, the interpretation of reliability based on interrater reliability used the percent agreement among experts (McHug, 2012) with the details of instrument can be considered reliable if the minimum percent agreement 75% (Bhattacherjee, 2012).

Analysis of the practicality of module was obtained from students' questionnaire results. Questionnaire was in the form of positive question and negative question with score referring to Guttman scale, the response was "Yes" (score 1) or "No" (score 0) (Abdi, 2010). Then the percentage of the number of students who answered "Yes" to each question was calculated. The interpretations of percentage number of students' response were 81 (very positive), 80≥response≥61 (positive), 60≥response≥41 (quite positive), 40≥response≥21 (less positive) and 20≥response (not positive) (Riduwan, 2015).

Analysis of the effectiveness of module was obtained from the result of evaluation tests (pretest and posttest). The module can be interpreted as effective if there is significantly difference in the mean scores of pretest and posttest using inferential statistic and N-gain. The pretest-posttest difference scores was tested for prerequisites (normality) using Shapiro-Wilk to determine the type of inferential statistical test (Paired Sample t-Test or Wilcoxon Signed Rank Test) (Abbot, 2011). If pretest-posttest difference scores has a significance value < 0.05, then the data is not normally distributed. Significance value of normality test determines the distribution of data is nomal or not normal as prerequisite for statistical test. The distribution of research data is not normal, so using nonparametric inferential statistical test namely the Wilcoxon Signed Rank Test with interpretation (Creswel, 2012) if the asymptotic significance (2-tailed) < 0.05, then there is a significant difference in the mean score of pretest and posttest. Asymptotic significance (2-tailed) is probability value to ensure that the distribution does not deviate significantly from 2 tailed distribution. It used for decision rule to reject null hypothesis which means there is a significant difference in pretest and posttest.

Effect Size is used to determine the findings strength of the research (Durlak, 2009) with an interpretation of its value around 0.2 including "small", its value around 0.5 including "medium", and its value around 0.8 including "large". While the N-Gain is used to determine the category of the mean scores improvement of pretest-posttest with category interpretation (Hanke, 1998), namely N-gain value $(g) \geq 0.7$ including "high", $0.7 > (g) \geq 0.3$ including "medium", and $(g) < 0.3$ including "low".

3. Results and Discussion

3.1. The Course Matrix of Chemical Thermodynamics and Students' Characteristic (Define Stage)

The chemical thermodynamics is a compulsory course which is programmed by UPCE students in fourth semester, while UPC students in third semester. The material scope and course learning outcome described in the Table 1.

In addition to students studying the mathematical aspects of thermodynamics, it is necessary to be explicit involving students to solve real-world problems that occur in the society and it is necessary to keep laboratory activities even though formal learning is carried out in online during the COVID-19 pandemic. The learning transition were occurred during the COVID-19 pandemic on this course described in the Table 2.

Material Scope	Course Learning Outcome(CLO)
The properties and behavior of gases; gas kinetics, energy, heat and work; internal energy and enthalpy; the direction of the process and the concept of entropy; free energy and its relationship to system stability, chemical equilibrium, electrochemical cell thermodynamics, solution thermodynamics, phase equilibrium and appropriate laboratory activities.	1. Understand the basic principles of thermodynamics and their application
	2. Able to solve science and technology problems in the field of chemistry in general and in a simple scope such as through the application of knowledge and the application of relevant technology
	3. Have the ability to use learning resources and ICT-based learning media for understanding the concept of energetics
	4. Make decisions based on the relationship between the basic concepts of chemistry and laboratory activities, research results, and the existence of chemistry in everyday life.
	5. Practice responsibility towards work in their field of expertise independently

Table 1. The matrix of chemical thermodynamics course

Academic year	Student class	Learning Method
Odd semester 2019/2020	Undergraduate Program of Chemistry 2018 (UPC-18)	Offline (traditional learning and laboratory activity)
Even semester 2019/2020	Undergraduate Program of Chemistry Education 2018 (UPCE-18)	Method transition from offline to online per 13 March 2019 (synchronous and asynchronous). Laboratory activity is replaced by observing video demonstration of practicum.
Odd semester 2020/2021	Undergraduate Program of Chemistry 2019 (UPC-19)	Online (synchronous and asynchronous). Traditional learning and observing video demonstration of practicum.
Even semester 2020/2021	Undergraduate Program of Chemistry Education 2019 (UPCE-19)	Online (synchronous and asynchronous). Traditional learning and observing video demonstration of practicum.
Odd semester 2021/2022	Undergraduate Program of Chemistry 2020 (UPC-20)	Online (synchronous and asynchronous). Traditional learning, Case study based learning, limited offline practicum in the chemistry laboratory, and observing video demonstration of practicum.

Table 2. Method transition on chemical thermodynamics course during the COVID-19 pandemic

The learning method transition (offline-online) influenced students' final score after programed chemical thermodynamics course described in the Figure 1.

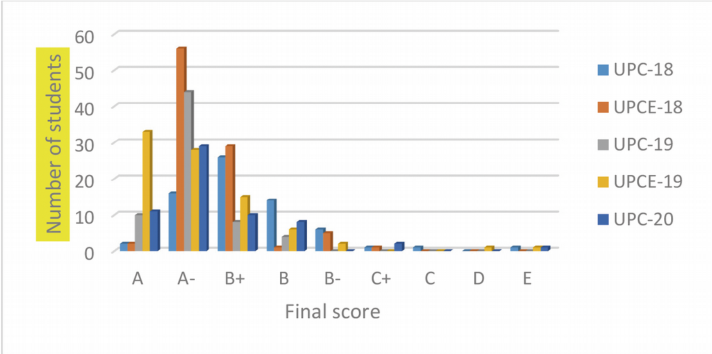


Figure 1. The Recapitulation of final score on chemical thermodynamics course

Figure 1 described students' final score on chemical thermodynamics after programed in different semesters. The final score is obtained from score conversion at 0-100 scale becomes 0-4 scale and alphabet A-E based on academic guideline of Universitas Negeri Surabaya, with details of A (scale value 4 for interval score $85 \leq x < 100$), A- (scale value 3,75 for interval score $80 \leq x < 85$), B+ (scale value 3,5 for interval score $75 \leq x < 80$), B (scale value 3 for interval score $70 \leq x < 75$), B- (scale value 2,75 for interval score $65 \leq x < 70$), C+ (scale value 2,5 for interval score $60 \leq x < 65$), C (scale value 2 for interval score $55 \leq x < 60$), D (scale value 1 for interval score $40 \leq x < 55$), and E (scale value 0 for interval score $0 \leq x < 40$). The finding after implemented online learning of this course in several students classes showed that there was increasing in the final score of A, A–, and B+. This proved that the online learning with the existence facilities consist of Unesa vi-learning platform, google classroom, google meet, whatsapp, and internet access which made students to be adaptable the learning transition during the COVID-19 pandemic. However, the majority of students stated that demonstration videos could be used as alternative to replaced offline laboratory activity (practicum) but it could not provide direct experience (science process skills). That skills were very important to be practiced by UPC students as prospective industrial analyst and UPCE students as prospective teacher.

The another finding that the majority of UPCE-19 students had difficulty solved question of evaluate-C5 level. This was presumably occurred because traditional method did not involve students in solving problems situated in real life contexts. So that the lecturer team tried to mix the tradtional learning methods (oral presenting material/giving exercise) and case study (giving the opportunity for students to solve cases in groups). It was implemented in UPC-20 students. Based on the results of midterm test, the majority of UPC-20 students were able to complete properly question of evaluate-C5 level, but theyl had difficulty solved question of create-C6 level. It was presumably occurred because students had not maximally able applied concepts to solve the case in everyday life as one of the exam questions. Students should be trained how to solve problems in real life by using their knowledge systematically which required problem solving stages and science process skills.

Based on those finding, it was necessary to develop a case study-based module that can provide a complete learning experience by explicit chemical representation in materials (macroscopic, microscopic and symbolic) and by solving the cases. Macroscopic aspect gave students' experience to carry out chemistry project using surrounding materials which easily practiced, virtual lab (PhET Simulation), and demonstration videos. It made students easy understand gases' behaviour. The module also presented microscopic images of the properties and behavior of gases (ideal and real) along with their symbols. When chemistry is learned by students in entirety of triple representations, they have complete knowledge to solve the cases. Contextual learning encouraged students' active contribution to apply their knowledge in real life (Dewi & Primayana, 2019). Module was a solution for students who meet learning difficulties (Rahmawati, Lestari & Umam, 2019). The module can help students not only to achieve the expected learning outcomes, but also to practice problem solving skills and generate products supporting the learning process. This research tried to develop a case study-based module on the chemical thermodynamics course (ideal and real gases), because many problems that exist in society can be solved by applying students' knowledge.

3.2. Design of the Case Study-Based Modul (Design Stage)

The module is one of the learing tools which can help students to carry out online learning during the covid-19 pandemic. Donnelly and Fitzmaurice (2005) described that the integration of learning strategies (one of which was case study) into the module aims to make students learning in depth, encourage students' continuous interaction with the material, and the presented knowledge explicitly so that students were easy to learn independently. Butcher, Davies and Highton (2006) stated that the module must contain factors that can trigger students to learn which consist of apperception, material guidance, processing activities (discussion/exercise), knowledge application, and feedback (assignment). The case study-based module was developed in this research which was limited to the initial material of chemical thermodynamics, namely the properties and behavior of ideal and real gases. The overview of the content of case study-based module described in the Table 3.

Module	Description
Chemical representations	
A. Macroscopic aspect Give direct experience (senseable)	Two-dimensional image • Classification of matter (The states of water as solid, liquid, and gas) • The process of achieving mechanical equilibrium (two gas systems are connected by a movable wall) • The process of achieving thermal equilibrium (two gas systems are connected by a diathermic wall) • Illustration of the applicability of the zeroth Law of Thermodynamics (two objects separately with third object are achieving thermal equilibrium with each other)
	Virtual lab (PhET Simulation) • Observation of expansion and compression processes as ideal gas behavior • Observation of gas behavior when temperature (T) is drastically increased which affects pressure (P) of gas system at constant volume (V) for analyzing the case (explosion of gas aerosol products due to incorrect storage at high temperature)
	Demonstration • The effect of temperature difference of two objects on its volume expansion because it is connected with each other (there is heat/energy flow). (source: https://www.youtube.com/watch?v=fJCaUKZWtwo)
	Chemistry project • The effect of increasing temperature on gas behavior (rapid motion of gas particles occupy container)
B. Microscopic aspect Give modelling at the particulate level by static animation (images) and dynamic animations (PhET simulation)	Classification of matter • The difference particulate image of H_2O molecules in solid, liquid, and gas states (the irregular distribution of molecules and the capable of forming hydrogen bond)
	Gas Variables (using ideal gas approach is more observeable in volume and pressure than real gas approach) • The difference of the particles interaction between ideal gas and a real gas, then its contribution on volume of gas system • The difference of the particles interaction between ideal gas and a real gas, then its contribution on pressure of gas system
	Temperature as one of gas variables • Illustration of the effect of temperature on the distance between H_2O molecules
	The collision type of ideal gas • Illustration of elastic collision occurs between ideal gas particles

Module	Description
	Boyle's Law • Illustration of the behavior of gas particles occupy in different volumes of container (possibility to collide the walls), then exert different pressure
	The collision type of real gas • Illustration of inelastic collision occurs between real gas particles
	Real gas • Molecules interaction (intermolecular force) of real gas
C. Symbolic aspect The expression of thermodynamic equations, chemical symbols, reaction equations and the curve (relationship between two variables of gas)	Reaction equation • The physical change of water (melting and evaporation)
	Equation of state • Gas variables consist of pressure (P), volume (V), number of particles (n), and temperature (T)
	Mathematical Equations • Relationship of pressure (P), force (F) and area (A) • Boyle's Law, inverse relationship between pressure (P) and volume (V) at constant temperature (T) • Charles' Law, relation volume (V) and temperature (T) at constant pressure (P); relationship between pressure (P) and temperature (T) at constant volume (V) • Avogadro's principle (Relationship volume (V) and number of particles (n) at constant pressure and constant volume (P, V) • Ideal gas equation, relationship between pressure (P), volume (V), number of particles (n), temperature (T), and gas constant (R) • Kinetic gas equation • Relationship of compressibility factor (Z), pressure (P), molar volume (Vm), gas constant (R) and temperature (T) • Van Der Waals equation (real gas)
	Curve • Boyle's Law of the P-V Curve and the P-(1/V) Curve of gas system • Charles' Law V-T Curve at constant P • Charles' law of the P-T curve at constant V • Lennard-Jones Curve • Z-P Curve describe Real Gases tend to behave like an Ideal Gas
Case study	
A. Residential home fires due to negligence when boiling water (source: tribunjateng.com)	Applied knowledge: Properties and behavior of gases (water vapor)
B. The ministry of health restricted the use of mercury fever thermometer in the health sector because highly toxic for living beings and the environment if it leaks out (source: health.detik.com)	Applied knowledge: How thermometer works, the applicability of zeroth law of Thermodynamics, the toxic and hazardous Materials/Impact of mercury on human health
C. Climbing Mount Everest which claimed many dead bodies when entering the Death Zone track about 8000 meters (source: science.kompas.com)	Applied knowledge: Boyle's law and the density of oxygen gas
D. Dry shampoo (one of gas aerosol products) explodes in hot car. The explosion due to improper storage (source: dream.co.id)	Applied knowledge: The Applicability of Charles' law

Module	Description
E. Accident on the Jagorawi Toll Road due to car's tire blowout during the summer (source: tribunnews.com)	Applied knowledge: The Effect of temperature variable on the behavior of gas
Exercise/Assignment	

Table 3. The overview of case study-based module

3.3. The Feasibility of the Case Study-Based Module (Develop Stage)

The feasibility of teaching material in terms of validity, practicality, and effectiveness (Nieveen, 1999). The feasibility of the module required other instruments such as evaluation test (pretest-posttest) and questionnaire, so that effectiveness and practicality could be measured. The validation was carried out not only on the module, but also on pretest-posttest and questionnaire. The feasibility of module and other instruments as follows:

3.3.1. The Validity of Research Instruments

The validity of the research instruments (module, pretest-posttest, and questionnaire) were obtained from an assessment by three expert lecturers in the field of chemistry education and physical chemistry. The interpretation of validity is based on the mode/median of validation score from three experts, with details of instrument can be considered valid if it has minimum value 2,5 as midpoint of the Likert scale (Chyung et al., 2017), ranging from 1 (less good) into 4 (very good) (Creswel, 2012). Meanwhile, the interpretation of reliability based on interrater reliability used the percent agreement among experts (McHug, 2012) with the details of instrument can be considered reliable if it has minimum percent agreement 75% (Bhattacherjee, 2012). The validity of the study case-based module contains valid and reliable criteria described in the Table 4.

Aspects	Module	
	Validity	**Reliability**
Construction	4.0 (valid)	75.0% (reliable)
Material	4.0 (valid)	77.8% (reliable)
Language	4.0 (valid)	77.8% (reliable)
Problem Based Learning Stages	3.0 (valid)	83.4% (reliable)
Science Process Skills	3.0 (valid)	75.0% (reliable)

Table 4. The validity of the case study-based module

The construction of the module (PDF file) was easily accessible via embedding a link. While the material of the module includes the completeness of components, concepts, and relevant with CLO. The case study-based module was developed based on the Chemical Thermodynamics' CLO which demands an active contribution of students to generate problem solving ideas of the cases by using science and technology. Language aspects includes language, terms, and the quality of identity and sources of information. The suggestions from the one of experts were check more carefully the use of foreign terms to be written in italics.

The use of case study-based module as learning tool required students' problem solving skills and science process skills. Khoiriyah and Husamah (2018) concluded that problem solving skills could be improved through problem based learning. The goals of problem based learning are: developing flexible knowledge, problem solving skills, active collaboration, and motivation (Hmelo-Silver, 2004). Problem based learning stages include authentic problem orientation and organizing student in learning, guiding group investigation, developing and presenting work, and analyzing and evaluating the problem solving processes (De-Grave, Boshuizen & Schmidt, 1996).

Science process skills indirectly integrated with manipulation skill which was explicitly assessed (Chabalengula, Mumba, Hunter & Wilson, 2009), because it gave students the chances to determine variables, practicum tool, practicum procedures creatively through laboratory activities for constructing the concepts (Fadzil & Saat, 2017). Laboratory activities with discovery learning require students' science process skills. The previous research had proven that science process skills can be trained through saveral laboratory methods. The achievement of science process skills in general were good category through Self-Project Based Learning (Rusmini, Suyono & Agustini, 2021), posttest scores of science process skills could be significantly improved through virtual reality laboratory (Artun, Durukan & Temur, 2020), and science process skills had increased in moderate category through simple simulation via computer (Siahaan, Suryani, Kaniawati, Suhendi & Samsudin, 2017). In this research, the module is equipped with chemistry project and PhET simulation. Students could provide direct experience on macroscopic level and make explicit science process skills, so that they generated practicum report as a product. The integrated science process skills in the module includes formulating problem, hypothese, identifying variables, designing and conducting experiment, tabulating data, analyzing, and concluding. The integrated science process skills were expected to be applied in everyday life, especially to support students in solving the cases.

The validity of the questionnaire and pretest-psottest were obtained by three expert lecturers in the field of education and the field of physical chemistry described in the Table 5.

The questionnaire consists of fourteen questions with "yes" or "no" answers. This questionnaire was used to measure the practicality of case study-based module. While the pretest-posttest questions consists of six items which were used to measure the effectiveness of case study-based module.

Instruments	Validity	Reliability
Questionnaire	4.0 (valid)	77.8% (reliable)
Pretest-posttest	3.5 (valid)	75.0% (reliable)

Table 5. The Validity of Questionnaire and Pretest-Psottest

3.3.2. The Practicality of Case Study-Based Module

The practicality of case study-based module was obtained from the questionnaire results. In addition, the readability test of module was conducted via the zoom platform about 100 minutes, so that students directly gave suggestions for improvement.

Table 6 described that students' response regarding construction aspect of module were very positive (VP), because it contains systematic material and to be developed attractively. The module was equipped with microscopic images and overview of the case phenomena. The student response related to the material of module were very posiive (VP) including the use of chemical representation and illustration in module make them easier to follow material. The macroscopic, microscopic, and symbolic aspects should be taught at the same time or in close proximity (Johnstone, 2009), so that students can easy to reach sound understanding (Gabel, 1999). The case study-based module also facilitated the chemical representations in studying the properties and behavior of gases. During the COVID-19 pandemic, it was not possible to provide laboratory activity in the campus. The case study-based module gave alternative of laboratory activity through chemistry project and virtual lab (PhET simulation) which provided direct experience for students in macroscopic aspects. Schank and Kozma (2002) concluded that the use of representational model can improve students' understanding of chemical representations and materials. The case study-based module also provided two-dimensional static animations to represent the existence of difference hydrogen bond in ice and liquid water which made students analyze the difference value for enthalpy of evaporation and melting process of water as a symbolic aspect.

Students' response related to motivational aspect of module were very positive (VP) which includes meaningful learning, explore knowledge actively, and lead proactive interaction of lecturer-student. While students' response related to case study in the module were very positive (VP) which includes the characteristic of cases were occured in real life, unique, relevant to the material, or expressing phenomena/problems, able to analyze the cases based on their knowledge, able to formulate problem solving for the cases, able to analyze cases based on supported data or evidence, able to integrate their knowledge to solve the cases, and do chemistry project using surrounding materials and virtual lab (PhET simulation) help students obtained insight into the cases.

Aspects	Response (%)	Category
Construction		
Is the module developed in interesting?	94.23	VP
Is the construction of material in the modules arranged in an unsystematic manner?	5.77	NP
Material		
Does the illustration in the Module meet clear and understandable characteristic?	100.00	VP
Does the Module make explicit the macroscopic, microscopic, and symbolic aspects to be easier learning Chemical Thermodynamics course (ideal gas and real gas)?	100.00	VP
Motivation		
Does the cases in the Module make you meet meaningful learning?	100.00	VP
Can the case study-based module improve your active participation in exploring the knowledge of Chemical Thermodynamics (ideal gas and real gas)?	98.08	VP
Can the module not encourage proactive interaction between lecturer and students?	5.77	NP
Case Study		
Does the cases (contemporary problems) in the module occur in real life?	100.00	VP
Does the cases meet unique characteristic, relevant to the material, to be observed in real life, or expressing the phenomenon/problem?	100.00	VP
Do you have ablility to analyze the causes of cases based on your knowledge of Chemical Thermodynamics?	100.00	VP
Do you have ablility to formulate ideas as problem solving for the cases?	98.08	VP
Does the module make you have ability to analyze the cases based on supported data and evidence?	100.00	VP
Can the module make you integrate the knowledge of chemical thermodynamics in solving the cases?	100.00	VP
Can the module help you to obtain insight into the cases by the existence of laboratory activity such as chemistry project and PhET simulation?	100.00	VP

Table 6. The Questionnaire Results of Students' Response in Very Positive (VP) up to Not Positive (NP) Categories

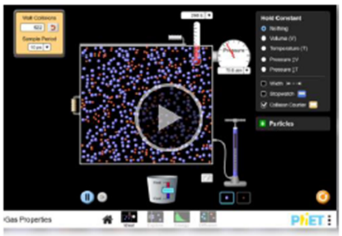
Based on the readability test using the zoom platform, there was one suggestion for improvement which was given by students. They had problem when practiced PhET simulation procedures in the Module. They suggested the procedure for PhET simulation, that it was necessary to add two initial steps so that easy to find laboratory theme about the properties and behavior of gases. The change of the procedure for PhET simulation in the module described in the Table 7.

The questionnaire results of construction, material, case study, and motivation of module aspects were very positive (VP) and the PhET simulation procedure had been revised based on students' suggestion, it could be concluded that the case study-based module meets practical requirement as learning tool. The case study-based module considered the characteristics of the material (ideal gases and real gases) and the characteristics of students. The module as learning tools must be easily accessible, contain clear material so that it was easily followed by students, and contain factors that trigger students to learn (the existence of apperception, material guidance, processing activities in the form of discussion/exercise, activities to apply knowledge, and feedback/assignment) (Butcher et al., 2006).

<table>
<tr><th>Students' Constraint</th><th>The change of the procedure for PhET simulation</th></tr>
<tr><td>Students difficult to find laboratory theme about the properties and behavior of gases</td><td>

Before

Lakukan praktikum secara virtual agar Saudara mendapatkan gambaran makroskopik dan mikroskopik (proses ekpansi atau kompresi) berdasarkan hubungan variabel $V \propto T$ pada sistem gas dengan **P konstan.**



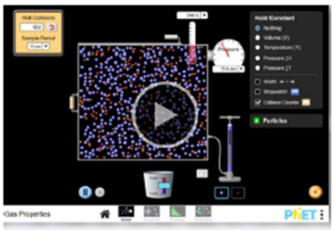
Prosedur:

1) Tambahkan 150 partikel (*heavy*)
2) Pilih *Pressure*↕ *V* pada menu (*hold constant*)
3) Naikan temperatur sistem gas hingga 400 K dengan tekan tombol heat
4) Amati perubahan yang terjadi (gerak partikel dan volume wadah)
5) Ulangi keempat langkah tersebut untuk penurunan temperatur sistem gas hingga 200 K

Link pHET Simulation: https://phet.colorado.edu/in/simulations/gas-properties

After

Lakukan praktikum secara virtual agar Saudara mendapatkan gambaran makroskopik dan mikroskopik (proses ekpansi atau kompresi) berdasarkan hubungan variabel $V \propto T$ pada sistem gas dengan **P konstan.**



Prosedur:

1) Klik tombol segitiga (*start*)
2) Pilih Gas properties-Ideal
3) Tambahkan 150 partikel (*heavy*)
4) Pilih *Pressure*↕ *V* pada menu (*hold constant*)
5) Naikan temperatur sistem gas hingga 400 K dengan tekan tombol heat
6) Amati perubahan yang terjadi (gerak partikel dan volume wadah)
7) Ulangi keempat langkah tersebut untuk penurunan temperatur sistem gas hingga 200 K

Link pHET Simulation: https://phet.colorado.edu/in/simulations/gas-properties

</td></tr>
</table>

Table 7. The readability result

3.3.3. The Effectiveness of Case Study-Based Module

The effectiveness of the module was obtained from the results of the pretest-posttest through inferential statistic and N-gain. The prerequisite test (normality) of the difference between pretest and posttest data was carried out using Shapiro-Wilk analysis with a significance level of 0.05 using the SPSS 21.0 for windows program described in the Table 8.

Data	Prob. Sig. Value of Shapiro Wilk	df	Significance Level	Interpretation
Difference (Pretest- Posttest)	0.003	52	0.05	Not normal distribution

Table 8. The result of prerequisite test (normality)

Based on the prerequisite test, would get probability/significance value of Shapiro-Wilk namely p value and degree of freedom namely df. In normality test, degree of freedom is same with the size of research sample (52 UPCE students). Probability/significance value (p value=0.003) was less than significance level (α value=0.05), so the difference between pretest-posttest data had not normal distribution. It was concluded that to test significant difference between pretest and posttest mean scores using nonparametric inferential statistic namely Wilcoxon Signed Rank Test described in the Table 9.

Based on the result of Wilcoxon Signed Rank Test, would get asymptoc Significance (2-tailed) namely probability value (p value = 0.00) was less than significance level (α value = 0.05), so there is a significant difference in pretest and posttest mean scores. The Z value and N were used to calculate effect size. Z value in Wilcoxon Signed Rank Test is rank mean of group to be compared to overall rank mean, which gets rid its negative sign for calculation effect size. While N is the total number of pretest data (52 students) and posttest data (52 students). The calculation from Z (6.281) and N (104), so it would be obtained Effect Size = 0.62. It could be interpreted that there is significant difference in the mean scores of pretest and posttest with the strength of the findings in medium category. While N-gain = 0.42, it could be interpreted that the increasing of mean scores pretest-posttest in the "medium" category. It can be concluded that the case study-based module meets effective requirement as learning tool.

Posttest-Pretest		Significance Level	Interpretation
Z Value	**Asymp. Sig. (2-tailed)**		
-6.281	0.000	0.05	The difference between pretest and posttest mean scores is statistically significant

Table 9. The result of Wilcoxon Signed Rank Test

The module facilitated students to solve the cases which there was significant difference in the mean scores of pretest-posttest consists of Analyze-C4, Evaluate-C5, and Create-C6 questions. It was due to the characteristics of the cases and the learning methods which were integrated in the module. Scholz and Tielje (2013) described the cases had several characteristics, namely contemporary problems that occur in real life, unique, relevant to the material, expressing phenomena, and it could be analyzed with the supported data or evidence generated through laboratory activities (demonstration or project). The learning methods or strategies were integrated into the module which could encourage students' active participation in discussions (Butcher et al., 2006), provide a formally structured learning experience and encourage continuous interaction with the material (Donnelly & Fitzmaurice, 2005). The case study was one of the learning approaches that able to train communication skills, critical thinking, and teamwork through solving several cases from news/mass media (Genereux, 2015). The case study-based module has medium category of its effectiveness, as learning tool during the COVID-19 pandemic. Similar findings are supported by previous research, Tanoira (2017) concluded that solved the cases in real-life context was significantly effective in helping students learn, improve learning experience, adapt faster, and more success in career. Minniti, Melo, Oliveira and Salles (2017) found that case study was feasible to be used as learning strategy that can encourage critical thinking, increase debate, teacher-student interaction, and cognitive development.

4. Conclusion

The case study-based module on ideal gases and real gases was feasible to be used as learning tool on chemical thermodynamics course. The case study-based module contains material that made explicit chemical representations (macroscopic, microscopic, and symbolic), case study (news/mass media and guiding questions for solving the cases), and exercise/assignment. The chemistry project, demonstration, and virtual lab (PhET simulation) as alternative for replacing laboratory activity generally to be constrained on campus during the COVID-19 pandemic. This was proved by the findings of the feasibility of the case study-based module as learning tool, namely: 1) meets valid and reliable criteria, 2) meets practical criteria with support for general achievements students' very positive response to the aspects of module (presentation, content, motivation and case studies), and 3) meets the effective criteria by increasing the average score pretest-posttest in medium category which contains the cognitive level of analyze-C4, evaluate-C5, and create-C6. The implication of development case study-based module can facilitate students in online learning during the COVID-19 pandemic so that they will successfully reach the course learning outcomes of Chemical Thermodynamics, which includes mastery of knowledge about main principles of thermodynamics, ability to solve science and technology problems, ability to use information and communication technology (ICT) based learning resources, make decisions based on the relationship of concepts with laboratory activities, and practice responsibility. For further research, it is expected that case study-based module can be developed on other chemical thermodynamic topics (the zeroth law of thermodynamic, the first law of thermodynamic, the second law of thermodynamic, the third law of thermodynamic, chemical equilibrium, electrochemical cell thermodynamics, solution thermodynamics, phase equilibrium) and other areas of physical chemistry (quantum chemistry, kinetics, and surface chemistry).

In addition, the confirmed COVID-19 cases decreased throughout the world (World Health Organization, 2022) and the phenomenon of learning loss experienced by students due to online learning during pandemic COVID-19 which was influenced by several factors such as students' economic background, parents' ability to guide learning from home, and students' cognitive ability (Engzell, Frey & Verhagen, 2021; Hammerstein, König, Dreisörner & Frey, 2021; Hanushek & dan Woessmann, 2020). It has made several countries to take policies establish offline learning namely learning from school, especially in Indonesia. Indonesian students were identified experiencing learning loss in literacy and numeracy aspects, so that they need learning recovery through inquiry, problem solving, and project methods (Kemendikbudristek, 2022). The possibility of using case study based module as complementary learning will very important, because it can support the learning recovery through the presentation of chemistry materials in the module contains triple representations (macroscopic, microscopic, and symbolic), students take more active in project and virtual laboratory which can train science process skills, and active involvement of students in applying most concept relevant for real-life situation (cases) which can train problem solving skills. However, in the adaptation process of learning recovery, it is possible for lecturers/teachers tend to implement traditional method and for anticipating teacher/lecturer plays dominant role in learning through oral presenting material, the possibility of using case study based module can be a complementary learning to increase student involvement in understanding independently the module material and in solving relevant cases that occur in the society. The case study based module must be developed independently by teacher//lecturer by considering the characteristics of material and characteristics of students, so that it will expected for students to be easy achieving domains of competence namely knowledge, skills, and attitudes.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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