Improvement of Student Critical Thinking Skills with the Natural Product Mini Project Laboratory Learning

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ABSTRACT

This research aims to investigate effect of learning using natural product mini project laboratory on students' critical thinking skills. The research was conducted on sixth semester of 59 students of chemistry and chemistry education program from one of the state universities in West Nusa Tenggara, Indonesia in 2012/2013. This research revealed class where the student learn using natural product mini project laboratory had more critical thinking skills than those using verification laboratory. The average n-gain of critical thinking skills for experiment class was 0.58 while for the control class was 0.37. The highest n-gain in the experiment class was 0.70 for "deciding on an action (selecting criteria to judge possible solutions) indicators", while the smallest n-gain was 0.47 for "the making and judging value of judgments (balancing, weighing, and deciding) indicators. We concluded that the natural product mini project laboratory was better than verification laboratory in improving the students' critical thinking skills.

Keywords: *Natural Product Mini Project Laboratory; critical thinking skills; N-gain*

ABSTRAK

Penelitian ini bertujuan untuk menginvestigasi pengaruh praktikum mini proyek kimia bahan alam terhadap keterampilan berpikir kritis mahasiswa. Penelitian ini menggunakan sampel 59 mahasiswa semester enam program studi pendidikan kimia dan kimia salah satu universitas negeri di Nusa Tenggara Barat, Indonesia tahun ajaran 2012/2013. Hasil penelitian ini menunjukkan mahasiswa kelas eksperimen yang menggunakan praktikum mini proyek kimia bahan alam lebih baik keterampilan berpikir kritisnya dibandingkan dengan mahasiswa yang menggunakan praktikum verifikasi. Rata-rata n-gain keterampilan berpikir kritis kelas eksperimen 0,58 sedangkan kelas kontrol 0,37. N-gain tertinggi kelas eksperimen yaitu 0,70 terjadi pada indikator menentukan suatu tindakan (memilih kriteria untuk mempertimbangkan solusi yang mungkin), sedangkan yang terendah yaitu 0,47 terjadi pada indikator membuat dan menentukan nilai pertimbangan (menimbang dan membuat keputusan). Penelitian ini menyimpulkan praktikum mini proyek kimia bahan alam lebih baik dalam meningkatkan keterampilan berpikir kritis mahasiswa dibandingkan dengan praktikum verifikasi.

Kata Kunci: *praktikum mini proyek kimia bahan alam; keterampilan berpikir kritis; N-gain*

INTRODUCTION

Critical thinking skills play an important role to help students understand subject matter [1]. A study of over 1100 college students shows that scores on a college level critical thinking skills test significantly correlated with college GPA [2]. Explanation for research results can be considered from the constructivist view of knowledge that students create knowledge internally. Students are required to think critically in connecting new concepts with previous learning. Students are capable of building incorrect connection to previous learning that are invalid or the foundations of which are faulty.

The researches showed that critical thinking skills can be learned [3-5]. Laboratory instruction can be improved critical thinking skills [4,6]. Laboratory activities can be designed such that students had to create their own procedures to solve a problem and submit a written report describing the procedure. The activity required students to think critically to produce a good laboratory activity. Laboratory activity is an

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important component of undergraduate science education [7-8]. Nevertheless, in Indonesia natural product chemistry course is not supported by laboratory activities although Indonesia has a very high diversity of plants that can be used in natural product chemistry laboratory [8]. By considering the point, this paper discusses laboratory activities in natural product chemistry course that can improve critical thinking skills of the students.

Critical thinking is defined as the "reflective and reasonable thinking that is focused on deciding what to believe or do" [9]. The literature on critical thinking has roots in two primary academic disciplines: philosophy and psychology [10]. Definitions of critical thinking emerging from the philosophical tradition "judging in a reflective way what to do or what to believe" [2], while definitions of critical thinking emerged from the cognitive psychological approach "seeing both sides of an issue, being open to new evidence that disconfirms your ideas, reasoning dispassionately, demanding that claims be backed by evidence, deducing and inferring conclusions from available facts, solving problems, and so forth" [11]. Critical thinking consists of three parts: the first, critical thinking involves the questioning, secondly, critical thinking trying to answer the question with a reason, and third, critical thinking to believe the reason [12]. Indicators of critical thinking skills by Ennis [9] consists of 12 components: 1) focus on question, 2) analyzing arguments, 3) asking and answering questions of clarification and challenge, 4) Judging the credibility of a source, 5) observing and judging observation report, 6) deducing and judging deductions, 7) inducing and judging inductions, 8) making and judging definitions, 9) defining term and judging definitions, 10) identifying assumptions, 11) deciding on an action, and 12) interacting with others.

Natural product chemistry (NPC) is an advanced course on students majoring in chemistry and chemistry education programs. In Indonesia this course is usually presented in the 3rd year students. NPC course examines the type, distribution, and function of secondary metabolites. NPC has contributed in discovery of secondary metabolites for industrial drug, and NPC has contributed to the cultivation plants through the study of secondary metabolites contained in plants that play a role in the regulation of plants life and relationship with the ecosystem [13]. Strategies to assess the secondary metabolites from plants through the process of isolation that has resulted in many compounds from plants native to Indonesia [14-17]. From hundreds of secondary metabolites that can be isolated from Indonesian plants, many of them show interesting biological activities such as antibacterial [14, 15], antimicrobial [16], antioxidant [17], and others. This can be used to guide the isolation to the active pure compound. Various bioactivities show potential lead compound useful for industrial drug or pesticide industries. Students can use plants located in the surrounding environment for laboratory activities of isolation secondary metabolites. These activities provide an opportunity for students to prove the concept that polar compounds are soluble in polar solvents as well as nonpolar compounds are dissolvable in nonpolar solvents, invented the concept such as the distribution of secondary metabolites in each species of plant, or to connect new concepts with the knowledge that has been previously owned learners through scientific measures to rationalize various phenomena such as the various properties of plants that can be used by humans for treatment. The purpose of the research is to investigate effect of learning using natural product mini project laboratory on students' critical thinking skills.

EXPERIMENTAL SECTION

Method

This study uses a quasi-experimental research with nonequivalent control group design [18]. Respondents consisted of 31 students 3rd years from the department of chemistry education (experiment class) and 28 students 3rd years from the department of chemistry (control class) from one of state universities in the West Nusa Tenggara, Indonesia. The research implementation took place during second semester of the 2012/2013 academic years. This research spent time 180 min per week for an entire semester (16 weeks). Experiment class using the natural product mini project laboratory [8] while the control class using verification laboratory.

The Natural Product Mini Project Laboratory

The natural product mini project laboratory (NP-MPL) started by giving a problem and ended with concluding complex concepts. Various series of isolation activities such as extraction, fractionation, purification and characterization of secondary metabolites into basic laboratory activities. Learning begins with a problem that was given "how to isolate the secondary metabolites from a variety of plant species?" Plant species that would have been determined previously isolated by researchers on the degree of difficulty in obtaining secondary metabolites. Furthermore, students in group (3-4 students) were given the opportunity to conduct a study of literature from various sources. From any literature, the students designed their own practicum.

Table 1. Example of The Question and Critical Thinking Skill Indicators

Questions	Answer	Critical thinking skill indicators
A compound can be classified into the categories of primary metabolites if they meet the following criteria EXCEPT .... a. Formed through the main metabolic pathways b. The main constituent in every organism c. Found the same in every organism d. Necessary for the existence of an organism e. Used organism to defend itself Reason: a. Primary metabolites are not formed through primary metabolic process b. Primary metabolites are not directly used for growth c. Primary metabolites are not used as a basis for the development d. Primary metabolites are not involved in the process of reproduction of organisms e. Primary metabolites do not play a role in the process control environment	E Reason: e	Strategy and tactics: deciding on an action (selecting criteria to judge possible solutions)

In the process of designing practicum the students determined its own procedures to be used. The procedure can be referenced either from text books, research reports, as well as internet access. In this process the students will be challenged to think critically in selecting appropriate procedures and information in order to produce a good design laboratory activity. Lecturers informed signs to be written in the student laboratory project proposals, reports, and presentation of proposals and reports. Subsequently presented a project proposal by students that have been drawn in a group. Lecturers and other groups given respond and ask questions about the proposal submitted by the group who presented the proposal. After the proposal was presented, the students began to implement a practical plan that has been drawn up through the stage of determining a suitable solvent and eluent with a small-scale experiment. Furthermore after successfully getting the appropriate solvent for extraction and eluent for fractionation students did laboratory work on a large scale. This activity introduces of the concept of polar-nonpolar to the students

Students in groups implemented their project proposal and should evaluate and develop procedures for the laboratory experiments. At this stage students can develop a range of critical thinking skills. After the implementation was completed, the students made a report and presented the results respectively. Learners will obtain a variety of information on the experiences of the group itself or other group's experience. After the groups presented result, learners can infer the concepts complex as the difference of primary and secondary metabolites, characteristic, function, structure, nomenclature, and process of isolation secondary metabolites in various plant species.

The Verification Laboratory

The verification laboratory was used for control class following the steps that was described by Domain [19]. The topic in this verification laboratory is "isolate curcumin from *Curcuma longa*. The students read the directions from a manual which has been prepared by instructor. Furthermore the students followed the specific procedure to isolate curcumin from *Curcuma longa.* The obtained curcumin are typically used only for comparison against the expected result (curcumin standard).

Instruments and Data Processing

The instrument used in this research was NPC concept test integrated with critical thinking skills tests containing 35 questions. The validity of the instrument was determined by using content validity of experts. The instrument also has been tested for validity and reliability by 34 students who have programmed natural product chemistry course in the previous year. Reliability of the test was very high at a price of 0.99 [20]. Examples of questions used in this study presented in Table 1.

Data processing was done by calculating the percentage of normalized gain scores (% g) using the formula in equation 1 [21]. Statistical calculations such as normality test, homogeneity, and mean difference test of normalized gain scores from experiment class and control class used SPSS 12 for Windows.

$$\% g = \frac{S_{post} - S_{pre}}{S_{max} - S_{pre}} x100\%$$

Equation 1. Normalized gain formula

Table 2. Recapitulation Score of Critical Thinking Skills

Critical thinking skill indicators	Experiment class %			Control class %		
	Pretest	Posttest	N-gain	Pretest	Posttest	N-gain
Identifying or formulating criteria for judging possible answers	32	72	60.97	31	52.33	36.36
Balancing, weighing, and deciding	28	63	47.42	22	40.32	26.51
Prima facie application of acceptable principles	33	75	63.27	33	60.22	46.84
Generalizing	24	61	51.04	24	53.76	42.94
Selecting criteria to judge possible solutions	28	78	69.71	28	49.37	32.58
Average	29	70	58.48	28	51.20	37.05

Criteria of equation 1 was followed the category high = % g > 70, medium = 30 ≤ % g ≤ 70, poor = % g < 30.

Plant samples used in this study consisted of leaf of *Artocarpus altilis*, heartwood of *Hopea odorata*, rhizomeof *Curcuma xanthorrhiza*, rhizome of *Kaemferia pandurata*, rhizome of *Curcuma aeruginosa*, rind, pulp, and seed of *Cassia grandis.*

RESULT AND DISCUSSION

Experimental Result

The implemented of NP-MPL succeeded in isolated eight compounds. Only two isolated compounds were identified structure consist of pinostrobin (**1**) from rhizomes of *Kaemferia pandurata* and curcumin (**2**) from rhizome of *Curcuma xanthorrhiza.* Other groups cannot be identified structure of isolated compounds because of less pure of isolated compound.

Effect of Learning with NP-MPL on the Students' Critical Thinking Skill

The critical thinking skills of students were assessed from the pretest and posttest. Indicators of critical thinking skills in this study consist of: elementary clarification: focus on a question (identifying or formulating criteria for judging possible answers), inference: making and judging value of judgments (balancing, weighing, and deciding), inference: making and judging value of judgments (prima facie application of acceptable principles), inference: inducing and judging inductions (generalizing), strategy and tactics: deciding on an action (selecting criteria to judge possible solutions). Each indicator was analyzed based on the pretest, posttest, and N-gain. Recapitulation score of critical thinking skills was presented in Table 2.

The average pretest score of the experimental class was 29.10% of the ideal score, while the average pretest score of control class was 27.76% of the ideal score. Furthermore, based on the data acquisition posttest average score of the two classes were known that the average posttest score of the experimental class was 69.72% of the ideal score, while the average posttest score for control class was 51.20% of the ideal score. Acquisition average N- gain was 0.58 for the experiment class and the control class was 0.37. The result shows an increased in N-gain critical thinking skills of the student from experiment class higher than the control class.

Inference: making and judging value of judgments (prima facie application of acceptable principles) was an indicator of the highest increase in control class (46.83%) and the lowest increase occurred in inference: making and judging value of judgments (balancing, weighing, and deciding) indicators of 26.51%, while the highest increase in the experiment class occurred on strategy and tactics: deciding on an action (selecting criteria to judge possible solutions) indicator of 69.71% and the lowest increase occurred in inference: making and judging value of judgments (balancing, weighing, and deciding) indicators of 47.42%. Statistical calculations such as normality test, homogeneity, and mean difference test of improved critical thinking skills of students from experiment class and control class were presented in Table 3.

Non-parametric statistical test was performed using Mann-Whitney test α = 0.05 with 2 Independent Samples Test. The results were a significant difference of critical thinking skills between control class and experiment class for elementary clarification: focus on a question (identifying or formulating criteria for judging possible answers) indicators and strategy and tactics: deciding on an action (selecting criteria to judge possible solutions) indicators, while inference: making and judging value of judgments (balancing, weighing, and deciding), inference: making and judging value of judgments (prima facie application of acceptable principles), inference: inducing and judging inductions (generalizing) indicators did not a significant difference between the experiment class and the control class.

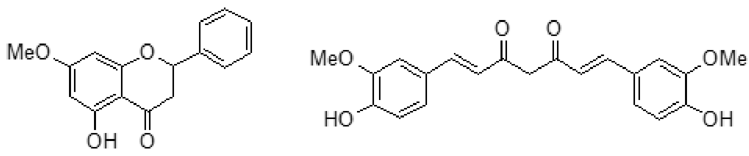
Discussion

All groups have implemented their own design laboratory activities, but only two groups succeeded in

Table 3. Statistical Calculations of Critical Thinking Skills

Critical thinking skills indicator	Normality test (α = 0.05)				Hom (p)	Mann-Whitney test (α = 0.05)		
	p		Criterion			U	p	Significantly
	Exp	Cont	Exp	Cont				
Identifying or formulating criteria for judging possible answers	0.047	0.590	Not normal	Normal	0.060	262.50	0.009	Significant
Balancing, weighing, and deciding	0.002	0.000	Not normal	Not normal	0.099	405.00	0.656	Not significant
Prima facie application of acceptable principles	0.047	0.014	Not normal	Not normal	0.025	333.00	0.125	Not significant
Generalizing	0.149	0.036	Normal	Not normal	0.702	397.50	0.578	Not significant
Selecting criteria to judge possible solutions	0.445	0.021	Normal	Not normal	0.025	171.50	0.000	Significant

Normality test (Shapiro-Wilk)
Homogeneity test (Levene Statistic)



(A) (B)

Fig 1. Isolated compounds from *K. pandurata* and *C. xanthorrhiza*

structural elucidation of their isolated secondary metabolites. Pinostrobin (Fig. 1 A) was successfully isolated by the group investigating *K. pandurata,* and curcumin (Fig. 1 B) was isolated by the group investigating *C. xanthorrhiza*. Although the majority of the student groups failed to isolate a secondary metabolite that could be characterized, they have gained experience in designing laboratory activities and conducting isolation of secondary metabolites.

The students tend to use the internet for literature review. The group of *K. pandurata* use Chairul and Harapini [22] as the main reference and group of *C. xanthorrhiza* use Cahyono et al. [23] as the main reference. It is quite interesting on implementation phase. Both groups did not follow the same procedure exactly with the main reference of the proposal that had been developed earlier. Development of a chemical component separation procedure was performed by students follow the trend of the easiest components apart from one another. Thus, the eluent and isolation steps of secondary metabolites that were used by both groups becoming original. Detailed procedures developed by both groups can be seen below.

The dried rhizome of *K. pandurata* (110 g) was extracted with acetone. The acetone extracts were evaporated to yield 6.15 g crude extract. GCC of the 800 mg crude extract over Si gel, using a *n*-hexane and chloroform (9:1) as eluent, afforded 4 fractions. Fraction II was recrystallized with *n*-hexane to yield 171 mg pinostrobin. Purity confirmed by testing 3 eluent systems.

The dried rhizome of *C. xanthorrhiza* (147 g) was extracted with ethanol. The ethanol extracts were evaporated to yield 40.10 g crude extract. GCC of the 800 mg crude extract over Si gel, using *n*-hexane and chloroform (1:9) as eluent, afforded 7 fractions. Fraction 5 was GCC on Si gel (chloroform 100%) to yield 51 mg curcumin. Purity confirmed by testing 3 eluent systems.

Pinostrobin: obtained as a colorless solid; UV (MeOH) λ_{max} (log ε) 239 (0.3023), 290 (0.9889) nm; IR (KBr) v_{max} 3429 (OH), 3061-2845 (CH sp^2, CH sp^3); 1643 (C=O), 1443; 1302; 1342; 1381 (C=C aromatic) cm^{-1}; ^{1}H NMR ($CDCl_3$, 500.1 MHz) *σ* 7.365 (5H, *m*, H-2',3',4',5',6'); 6.050 (2H, *d, J*= 6 Hz, H-6 & H-8); 5.356 (1H, *dd, J*= 13,5; 3 Hz, H-2), 3.77 (3H,s, OMe), 3.072 (1 H, *dd, J*= 13; 4 Hz, H-3) and 2.799 (H, *dd, J*= 17;2 Hz, H-3) ppm. ^{13}C NMR ($CDCl_3$, 125.8 MHz) *σ* 195.7 (C-4); 77.3 (C-2) ; 43.3 (C-3); 103.1 (C-4a); 162.7 (C-5); 94.2 (C-6); 164.1 (C-7); 95.1 (C-8); 167.9 (C-8a); 138.4 (C-1'); 126.1 (C-2'); 128.8 (C-3',4',5'); 126.1 (C- 6').

Curcumin: obtained as a yellow powder; UV (MeOH) λ_{max} (log ε) 261 (0.567) and 419 (1.887) nm; IR (KBr) v_{max} 3500 (OH), 2939-2850 (CH sp^2, CH sp^3); 1627 (C=O), 1588; 1508; 1427; (C=C aromatic) cm^{-1}; ^{1}H NMR (Aceton-d_6, 500.1 MHz) *σ* 3.949 (6H,*s*, OMe); 5.600 (2H,*s*, H-4); 6.463 (2H, *d*, *J*= 15.5 Hz, H-2, H-6); 7.575 (d, *J*= 15.5 Hz, H-1, H-7); 6.926 (2H, *d*, *J*= 8 Hz, H-6',H-6''); 7.116 (2H, *d*, *J*= 8 Hz, H-5',H-5") and 7.054 (2H, *s*, H-2', H-2") ppm. ^{13}C NMR (Aceton-d_6, 125.8 MHz) *σ* 147.9 (C-3); 146.8 (C-5); 101.2 (C-4);

Table 4. Descriptors of the Laboratory Instruction Styles

Style	Characteristics		
	Outcome	Approach	Procedure
Expository	Predetermined	Deductive	Given
Inquiry	Undetermined	Inductive	Student Generated
Discovery	Predetermined	Inductive	Given
Problem-based	Predetermined	Deductive	Student Generated

56.0 (2-OMe); 114.9 (C-6', C6"); 122.9 (C-1', C1"); 124.0 (C-5', C5"); 127.7 (C-2', C2"); 133.1 (C-3', C3"); 133.9 (C-4', C4"); 121.8 (C-2, C-6) and 140.6 (C-1, C-7) ppm.

Laboratory activities in NP-MPL created an active learning occurred in class. Active learning enhances student critical thinking skill [1]. Throughout the history of chemistry education four distinct styles of laboratory instruction have been prevalent: expository, inquiry, discovery, and problem-based. Domin [19] distinguishes four practical style based on the outcome approach, and procedure. Table 4 describes the differences of the practical style.

Most universities in Indonesia use expository laboratory [24]. The expository laboratory instruction emphasis on following specific procedures to collect data and no attention to plan the investigation or interprets results. Students spend more time in determining the correct results than planning and organizing the experiment. Therefore, students do not enough time to think about the science principles being applied in the laboratory. Thus, critical thinking did not occur in expository laboratory activities [19].

Instruction in NP-MPL provided opportunities for students actively construct their knowledge. This process was assisted by interactions with peers and the lecturer. Students obtained secondary metabolites from medicinal plants that encounter in everyday life. It was very interested experience for students. All these activies made NP-MPL more effectively improved students' critical thinking skill than expository laboratory.

CONCLUSION

The critical thinking skills of students using NP-MPL were significantly higher for elementary clarification: focus on a question (identifying or formulating criteria for judging possible answers), and strategy and tactics: deciding on an action (selecting criteria to judge possible solutions) indicator than the student using expository laboratory. Acquisition of the average N-gain of the experiment class was 0.58 and the control class was 0.37. This suggests that the students using NP-MPL were more effective for improving critical thinking skills rather than those using expository laboratory.

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