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Article

Designing Easy DNA Extraction: Teaching Creativity Through Laboratory Practice

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Abstract

Subject material concerning Deoxyribose Nucleic Acid (DNA) structure in the format of creativity-driven laboratory practice offers meaningful learning experience to the students. Therefore, a laboratory practice in which utilizes simple procedures and easy-safe-affordable household materials should be promoted to students to develop their creativity. This study aimed to examine whether designing and conducting DNA extraction with household materials could foster students' creative thinking. We also described how this laboratory practice affected students' knowledge and views. A total of 47 students participated in this study. These students were grouped and asked to utilize available household materials and modify procedures using hands-on worksheet. Result showed that this approach encouraged creative thinking as well as improved subject-related knowledge. Students also demonstrated positive views about content knowledge, social skills, and creative thinking skills. This study implies that extracting DNA with household materials is able to develop content knowledge, social skills, and creative thinking of the students. © 2016 by The International Union of Biochemistry and Molecular Biology, 45(3):216–225, 2017.

Keywords: *Teaching creativity; DNA extraction; laboratory practice; creative thinking skills*

Introduction

Ministry of Education and Culture (MOEC) of Indonesia has emphasized the importance of generating creative individuals through the curriculum shift and education policy reforms [1, 2]. As teaching creativity is defined as forms of teaching that are intended to develop learners' own creative thinking or behavior [3, 4], several researches has been attempted to develop creativity in Indonesian students [5–8], but none of them includes laboratory practice of DNA extraction in schools. Furthermore, although knowledge of DNA structure is essential in Indonesia biology curriculum, most of Indonesian secondary schools rarely apply DNA extraction because the materials and instruments in school laboratory are limited and inadequate to run standard protocol.

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Teacher can encourage their students to achieve learning outcomes in teaching and learning process through well-developed learning activity. Appropriate learning activity cultivates good academic performance including content knowledge, social skills, and creative thinking skills. One of activities that cover those aspects is laboratory practice. Laboratory practice guides the students to develop maximum scientific ability [9]. Jones and Eick [10] explained that laboratory practice can be described as situation in which learning occurs in action. Laboratory practice is an integrated formal knowledge and scientific knowledge with everyday experience and experimental knowledge. Laboratory practice develops creativity in science through discovery of reliable patterns and explanations of phenomena which lead to multiple solutions or novel products [11, 12]. Teaching students how methodically solve problems and how to systematically generate new ideas through laboratory experience are very direct methods to train creative thinking skills.

Creative thinking is defined as a process to feel the gap or disturbance because of losing some elements; making opinion or hypothesis; and communicating the result, which enable modification and retest of hypothesis which have been made [13]. Creative thinking has four key elements: (1) *fluency*, as ability to raise many ideas, (2) *flexibility*, as ability to look at a question or topic from different angle,

(3) *originality*, as ability to raise new ideas to previous way of thinking, and (4) *elaboration*, as ability to develop or add ideas in order to produce more detail ideas [14, 15]. Boden [16] has described three types of creativity: combinational (combining old ideas in new ways), exploratory (being creative within the rules of the domain), and transformational (permitting changes to the rules of the conceptual space). There is also two distinct views of creativity, called "high" or "big C creativity" (BCC) and "ordinary" or "little C creativity" (LCC). According to Craft [17], BCC refers to creativity displayed by geniuses with special gifts, while LCC can be seen when an individual demonstrates personal agency and self-direction in the form of considering possibilities. Students with LCC are able to consciously use prior knowledge to cope with daily challenges, resulting innovation that is novel to the students but not necessarily novel to wider world [17]. At this point, LCC means a willingness or intention to try options to solve problem in everyday challenges of life. Hence, we think that fostering creativity in the context of LCC can be implemented by providing opportunity to the students to conduct laboratory practice with range of alternatives, allowing students to develop hypotheses on their own, and then working collaboratively to design the procedure, analyse data, and present results to their peers.

Context of Study

Universitas Negeri Surabaya, one of teacher training institutes in Indonesia, prepares undergraduates students to become biology pre-service teachers who are ready to teach molecular biology in secondary schools, including promoting DNA technology. As an attempt to implement DNA technology in classroom, several education practitioners have described DNA extraction procedures which are much simpler and less inexpensive than standardized laboratory protocols [18–21]; however, some materials and instruments in those procedures, such as protease/proteinase K, sodium dodecyl sulphate (SDS), Tris HCl, TE buffer, and bench centrifuge are not always available in common secondary schools in Indonesia. Since the materials and instruments in Indonesia school laboratory are limited and inadequate to run those protocols, we suggested that our biology undergraduate students should be prepared to creatively teach an easy and affordable laboratory practice of DNA extraction. Hence, we specifically provides various household materials to encourage our students to think up how to modify standardized DNA extraction protocol, in terms of possibility-thinking and problem solving as proposed by LCC [17]. In this way, we expect that our biology undergraduate students would be able to teach DNA extraction (or other broader biology topics) in their future career as beginning teachers even though the school may not provide standard chemicals and laboratory instruments. Considering this purpose, the following questions were investigated: (1) Could easy DNA extraction with household materials become a laboratory practice which encourages creative thinking in students? (2) How did laboratory practice in DNA extraction affect student's understanding about DNA? (3) What were students' views about their knowledge, social skills, and creative thinking skills domain in response to their laboratory practice?

Method

Sample

This study involved 47 biology undergraduate students from three classes, which are similar in academic and socio-cultural backgrounds, in Universitas Negeri Surabaya, Surabaya, Indonesia, with age range 19–20 years old. They had learned basic genetics consisting Mendelian genetics, DNA and RNA structure, protein synthesis, gene, chromosomes, and cell biology. However, they had not conducted actual DNA extraction before. Therefore, though the household materials provided in this study were widely known used in previous works [18–21], and while this study focused on possibility thinking and problem solving from LCC perspective, this present DNA extraction was considered as original or novel to the students.

Classroom Procedure

At the beginning of the session, a supervisor explained about the general overview of DNA extraction and the learning objectives. Here, students acquired information that DNA extraction mainly consists of three stages: extraction, purification, and precipitation. Extraction stage separates DNA from the cell or tissue. Purification separates DNA from any contaminant such as cell debris, protein, and RNA. Finally, the DNA is precipitated out from other biomolecules. Following this explanation, students also received information about functions of common chemicals and instruments used at each stage of standardized DNA extraction. Explanation of standardized DNA extraction protocol and common chemicals/instruments used in DNA extraction function as prior knowledge that allows students to systematically design their own DNA extraction in step-by-step fashion using available household materials. In other words, the use of standardized DNA extraction protocol as prior knowledge was expected to stimulate students to creatively think what could be done with limited range of household materials and what details procedure could be planned to successfully extract DNA.

After early session about DNA extraction protocol, students were randomly assigned into nine groups of five or six students each. The supervisor handed the groups a worksheet about crude extraction of DNA [22]. This worksheet consisted of introduction of learning objective; standardized DNA extraction, including common used chemicals and its function, laboratory scale instruments, and general procedure (Box 1); available materials and tools;

Box 1
Crude extraction of DNA

Aim: To understand the procedure of DNA extraction using household materials.

Introduction: How does the crime scene investigator identify the suspect of murder case? How does the fisherman detect viral disease which causes outbreak in his ponds? How does your blood tell people who your parents are? How does the scientist discover the drought-resistance gene in plants? Those answers can be found in the field work of DNA technology.

DNA technology can be conducted when the DNA has been extracted from the cell or tissue. DNA extraction consists of three stages:

1. Extraction, to separate the DNA from the cell. This stage usually utilizes SDS/CTAB/Triton-X as active detergent and saturated NaCl;
2. Purification, to separate extracted DNA from any contaminant, cell debris, protein, and RNA. Scientists use phenol:chloroform:isoamylethanol (PCIA) for this purpose; and
3. Precipitation, to precipitate the DNA to form thin, transparent or white strands. Ice cold 96% ethanol can be used at this stage.

Basically, DNA extraction techniques are as follows:

1. Grind up 0.5 gram of sample in the sterile mortar and homogenize with the buffer solution,
2. Filter the homogenate using filter paper and put in the sterile centrifuge.
3. Mix the filtrate with 5 mL of SDS 20% and 5 mL of 5M NaCl using vortexer.
4. Centrifuge the suspension to separate cellular components from cell debris.
5. Remove the supernatant into new tube.

Add ice cold 96% ethanol carefully to the new tube through the side of the tube. There will be a white strands appear on the suspension surface if you conduct the DNA extraction correctly.

Box 2

Sample: (choose one)
Chicken liver
Young leaves
Mature leaves
Chicken epidermis
Chicken intestine

Materials:
Table salt
Sugar
Drinking water
Tap water
Liquid soap
Dishes soap
Detergent
90% Ethanol
70% Ethanol
96% Ethanol
Ice cubes in large bowl

Tools:
Filter papers
Test tubes and rack
Mortar and pestle
Pipettes
Graduated cylinder
Spatula
Funnel
Triple beam balance

Instruction:

Now, take a look at materials and instruments which are provided by your teacher. Arrange your own DNA extraction by modifying the instruments and the materials based on techniques above. Although the DNA extracted by those instruments and materials is not pure enough to be used in molecular studies, you are already on one step closer to see the molecules of life!

Think creatively:
1. What sample do you choose? Why do you think you choose that sample instead of others?
2. What material do you choose to replace physiological buffer? Why?
3. What material do you choose to replace the SDS and NaCl? Why?
4. What are the steps of DNA extraction procedure you need to modify? How do you do that?

and several guiding questions to discuss in group (Box 2). Supervisor provided opportunity to the students to creatively design then perform DNA extraction using available household materials. In extraction stage, supervisor provided several commercial home cleaning products containing different concentration of SDS, such as detergent, liquid soap, and dishes soap, to replace the function of SDS in cell disruption and lysis. Following those products, there were also sterile tap water and sterile drinking water to substitute the function of buffer solution in maintaining DNA integrity due to rapid changes of pH during cell lysis. Normally, DNA extraction also requires proteinase K (or other protease) to degrade protein and RNase to degrade RNA. However, to maintain the low cost and wider use in local schools setting because the extracted DNA would not be

used in further process, this extraction procedure did not provide those enzymes. Neither bench centrifuge nor vortexer were available in laboratory. Students would be employed to utilize hand shaking and filter paper filtration for this process. In this activity, there is also no further purification of DNA which is usually treated with phenol, trichloromethane, and isoamyl ethanol, either separately or together. To precipitate out the DNA, supervisor provided three concentrations of ethanol with ice cubes to replace the function of ice cold ethanol. At the end of the lesson, students were expected to obtain white threads as "precipitated DNA," the stereotyping of DNA extraction product; although this "white strands" is more likely nucleic acids (RNA and DNA) with proteins. This key point was explicitly written in the DNA extraction guideline (Box 2).

In designing DNA extraction session, students were allowed to discuss the problem in the worksheet: (1) selecting the sample to be extracted, (2) selecting household materials to replace standardized chemicals which were used in the extraction, purification, and precipitation stage in DNA extraction, and (3) modifying DNA extraction procedures. After DNA extraction design was constructed, the groups conducted the DNA extraction using their designed procedures and selected materials. Students turned in their laboratory reports to the supervisor a week after the laboratory practice. The picture of extracted DNA was also recorded in this laboratory report. At the day of laboratory report's deadline, each group communicated their experiment design and result through classical presentation and the supervisor evaluated their learning experience in whole-class discussion. During this presentation, students had opportunity to compare and discuss DNA extraction results from variations of materials and procedures used in other groups. Students were then asked to answer questionnaire and quiz as a self-assessment about their knowledge domain, social skills domain, and creative thinking skills domain.

Data Collection and Analysis

Students' Creative Thinking

Students' creative thinking in designing and conducting DNA extraction data was obtained from laboratory report. Supervisor also delivered questions to stimulate creative thinking skills to solve problem (Box 2). Students' laboratory reports and responses to those questions were then analysed descriptively to examine their creative thinking. Creative thinking was described as students' collaborative creativity in designing and performing DNA extraction using range of household materials provided by the supervisor.

Students' Understanding About DNA Extraction

Students' understanding was explored with an open-ended quiz given in the end of the session. The quiz asked the students to freely explain what they have learned about DNA extraction. In reviewing the responses, we noted that there were ten major responses which were frequently mentioned by most students. All of these responses are presented in Table II in abbreviated form. We considered these responses as part of our data set in complementing students' personal views about their own knowledge.

Students' Views

Students' views about laboratory practice were observed from blind self-assessment sheet using Likert-type scale: 1 = disagree; 2 = partly agree; 3 = agree; 4 "strongly agree." This self-assessment consisted of knowledge domain, social skills domain, and creative thinking skills domain (fluency, originality, flexibility, elaboration). Score 3.0 or above indicated positive response from the students. Prior to this self-assessment, supervisor also told the students that their answers or responses to the questions would not affect their grade.

Results

Students' Creativity in Designing and Conducting DNA Extraction

Students' creativity in designing and performing DNA extraction was observed using the laboratory report that was turned in by each group. Most of group selected chicken liver to be extracted (Table I), though this sample was

TABLE I *Selected sample and materials (n = 9 groups)*

	Σ *groups*
Selected sample	
Chicken liver	7
Chicken intestine	1
Young leaves	1
Selected materials	
Table salt	9
Drinking water	8
Tap water	1
Liquid soap	3
Dishes soap	5
Detergent	6
90% Ethanol	1
70% Ethanol	1
96% Ethanol	8

TABLE II *How students design and conduct DNA extraction following with its results (n = 9 groups)*

DNA extraction procedure	*Σ groups*
Extraction	
Grinding the sample with water resulting homogenate, filtering the homogenate, then mixing the filtrate with surfactants and salts	3
Grinding the sample with 70% ethanol resulting homogenate, then mixing the homogenate with surfactants and salts	1
Grinding the sample with salt solution resulting homogenate, filtering the homogenate, then mixing the homogenate surfactants and salts	1
Grinding the sample with surfactants and salt then filtering the homogenate	4
Purification	
Stirring thoroughly with spatula and transferring supernatant into new tubes prior to repeated filtration	1
Briskly shaking and transferring supernatant into new tubes prior to repeated filtration	1
Stirring thoroughly and briskly shaking then transferring supernatant into new tubes prior to repeated filtration	1
Repeated filtration and transferring supernatant into new tubes	6
Precipitation	
Slowly pipetting ice cold ethanol through the side of the tube	9
Result/product	
White or transparent threads appeared within aqueous layer	6
No white threads appeared	3

extracted by different modified procedure (Table II), while some groups chose young leaves and chicken intestine. In order to replace buffer solution in early stage of extraction, three groups homogenized chicken liver with drinking water. Other groups decided to choose 70% ethanol and salt solution for the same purpose. In conducting cell lysis and then gaining access to the nuclear DNA, the essential material used is the buffer solution which takes role to maintain DNA structure and prevent its degradation by heavy metal ions and extremes change of pH. Sample consideration and functions of buffer solution were also noticed well by the students as cited in their laboratory reports, though some students assumed that 70% ethanol and salt solution can work the same way:

> "We choose chicken liver as sample because animal cells have no cell wall. This makes crude extraction of DNA much easier." (Group 1 and Group 4)
> "We select young leaves to be source of extracted DNA because they have easily destructed cell wall compared to old leaves." (Group 6)
> "Sterile drinking water is used as buffer solution because the water can prevent rapid changes of pH in the fluid. Substituted buffer solution must be in the range of normal blood pH, which is from 7.37 to 7.42. Drinking water will do." (Group 1)
> "We choose ethanol and/or salt solution to replace the buffer solution since we assume that ethanol 70% and/or salt solution have neutral pH to maintain the cell." (Group 3 and Group 6)

As response for the second question about modified extraction buffer, most groups utilized surfactants (detergent, dishes soap, or liquid soap) and saturated salt solution to replace SDS and sodium chloride (Table II). However, one group might select one type of surfactant or two to three types of surfactants in this stage. High concentration of SDS breaks down the phospholipid membranes surrounding the cytoplasm, releasing the nuclear DNA. Addition of high or saturated sodium chloride (NaCl) binds the negatively charged phosphate group of DNA molecules with positively charged sodium ions (Na^+) forming larger strands of DNA; thereby making the product of extraction more visible. As the groups asserted:

> "At extraction level, we replaced SDS with detergent. Detergent contains high SDS in which destruct the solidity of the cell membrane. With the SDS inside, detergent will break the chemical bonds among lipid molecules in the cell membrane. When the lipid layer is disrupted, cell membranes are no longer intact and the cell comes to be lysed." (Group 2, Group 5, Group 6)
>
> "Combination of detergent, dishes soap, and liquid soap contain high concentration of SDS which is breaking chemical bonds of phospholipid in chicken liver. When we add table salt, sodium ions form chemical bonds with phosphate groups of DNA; resulting visually observed DNA strands." (Group 9)

However, some students were also lack of elaboration regarding to explanation of selecting one material over another. This was consistent as their laboratory report stated:

"Although we decided to use to dishes soap rather than detergent, we ended up in conclusion that detergent might be better to replace the SDS because it has higher cleaning ability than dishes soap to "clean" the DNA from other cell's component." (Group 3)

"The saturated salt solution has function to destruct the cell structure by osmosis mechanism. As saturated salt is added to the filtrate, the solution becomes hypertonic to the cell. The cell becomes lyses and the nuclear DNA can be accessed." (Group 2)

In response to the third question about modified stage of DNA extraction, all groups answered that they modified purification using filter paper-filtration. However, each group demonstrated different number of filtration process with range of once, three times, or five times. Prior to repeated filter paper-filtration, there were three types of method in which students attempted to imitate centrifugation (Table II): briskly shaking or spinning in circle the test tube, immediate stirring the solution with spatula, and combining shaking and stirring. All methods resulted colourless supernatant which was then transferred into new tube.

"In standardized DNA extraction, centrifugation makes cell debris left in pellet, whilst nucleic acid remained in supernatant. We tried to imitate the centrifugation by repeatedly shaking and stirring the solution, resulting colourless part in the upper part of the solution to be filtered." (Group 7)

"To replace centrifugation process during purification process, we shook the tube containing suspension in a quick circle movement. Supernatant formed was then transferred into a new tube." (Group 1)

"We stirred the solution homogenously in purification stage. The homogenate was then filtered three times, resulting colourless filtrate." (Group 9)

Most groups also shared the same precipitation procedure by slowly pouring ice cold 96% ethanol (Table I), which was obtained by putting the 96% ethanol inside large bowl of ice cubes, into the supernatant through the side of the test tube (Table II). Only one group decided to use ice cold 90% ethanol (Table I). When DNA is dissolved in the water, the negatively charged phosphate groups of DNA are surrounded by water molecules. Ethanol, in turn, disrupts interaction between water and DNA molecules, yielding the precipitated out DNA. The colder the ethanol, the less soluble the DNA, the more the DNA is precipitated. Shaking the tube also causes more DNA to be precipitated. As cited in their laboratory report:

"Since DNA is soluble in water, ethanol in a very cold condition accelerates the process of purifying the DNA. Moreover, ice cold ethanol will make the DNA becomes more concentrated." (Group 1)

"Absolute ethanol functions in precipitating DNA out of the solution because there is different polarity between ethanol and DNA. With its phosphate groups, DNA is polar, allowing them to interact with water molecules. This makes DNA dissolves in water (water-soluble). When we add ethanol in high concentration, which is much less polar than water (non-polar), chemical bonds between sodium ions (from adding table salt before) and phosphate groups become strong, causing nucleic acids less water-soluble and forcing it out of aqueous solution. Ethanol is necessarily cold because DNA is precipitated at low temperature." (Group 7)

Most groups successfully obtained white threads within aqueous layer of ice cold ethanol, while some groups did not (Table II). Students reported as followed:

"After pouring ice cold 96% ethanol, we yielded a relatively clear aqueous phase. "Milky" solution in the aqueous phase is the DNA. The DNA looks like a collection of filaments." (Group 1)

"After some drops of ice cold 96% ethanol poured to the filtrate, no white thread appeared instead formation of two layers. Upper white layer was the ethanol substance that had small contact with the filtrate. Lower layer was the filtrate with green colour came from the dishes soap." (Group 3)

Students' Understanding About DNA Extraction

As we examined students' depth of conception about DNA extraction, students demonstrated relevant responses indicating that they understood what exactly should be done at each stage of DNA extraction (Table III). Function of detergent or other surfactants, as substitution of SDS, in breaking down cell membrane was also well-defined by the students. Students also described well about the nature of sample preference and role of table salt in co-precipitating DNA. Quiz result also consistently showed that students showed good understanding about the reason underpinning shaking and spinning movement at purification stage. Moreover, students also showed good understanding concerning the role of ice cold ethanol, stating that ice cold ethanol would cause the DNA more concentrated or precipitated.

Students' Views in Response to the DNA Extraction Activity

Result showed that there was positive view in response to the DNA extraction activity (Table IV). Students were able to acquire new information and clear concept about DNA in which improved their understanding related to the subject material. They also thought that knowledge about DNA extraction was useful information. Table IV also showed positive view in social skills and creative thinking skills after DNA extraction laboratory practice. They had opportunity to brainstorm (*fluency*) and raise original ideas (*originality*) to

TABLE III *Responses from the test concerning knowledge about DNA extraction given by the students (n = 47)*

Responses
DNA extraction consists of three stages: extraction, purification, and precipitation.
In extraction, DNA is separated from the cell using chemicals or mechanic aids
In purification, DNA is removed from protein and cell debris; generally using phenol, chloroform, and/or isoamylethanol following with centrifugation
In precipitation, DNA is precipitated out using ice cold 96% ethanol.
Detergent or any surfactants containing SDS can be used to break lipid layers of cell membrane which protect nuclear DNA
Sample of DNA extraction should be easily crushed; it should be parts of organ/tissues with smooth texture and young-aged
Ice cold ethanol makes the DNA becomes more concentrated
Na^+ from table salt or sodium acetate binds the negatively charged phosphate group of DNA molecules, forming larger strands of DNA; thereby making DNA is easily to be observed.
Each sample needs specified treatment to be extracted. For instance, plants can be treated with liquid nitrogen to degrade the cell wall.
Shaking the tube and spinning the tube in circle may replace the function of vortexer and centrifuge, separating nucleic acids from cell debris and producing more DNA to be precipitated.

think what household materials could replace standardized chemicals and what procedures could imitate the instruments' function. They also had opportunity to modify existing DNA extraction protocol (*flexibility*) and make connections throughout the prior knowledge (*elaboration*).

Discussion

Result showed that laboratory-based learning improves ability to design and conduct an experiment, thereby encouraging students to convey research methods in order to solve problems and think possibilities within LCC framework as described by Craft [17]. This study supports finding from Tarhan and Ayyıldız [23] that solving problem together increases academic achievement and improves skills for creative thinking. Laboratory-based learning also introduces necessary skills and performances ranging from laboratory techniques, research designing, and academic writing [24]. Teaching creativity in laboratory activity fulfils condition in which students are encouraged to believe in their creative potential, engage to realize any possibility, and give them confidence to try [4]. Furthermore, creativity-driven laboratory practice enhances student's awareness to reflect on their skills as shown by the open comment that students wanted to improve creative thinking skills and to conduct more complex DNA technology.

It should be noted that DNA extraction ideas proposed by the students may not original enough in the historical sense, but it is new to student's previous way of thinking and valuable as problem solving. The laboratory practice in this study engages students in three types of creative thinking as defined by Boden [16]. Within combinational creativity (combining old ideas in new ways), students constructed association between their prior knowledge about standardized DNA extraction and limited range of household materials, then combined the knowledge in new ways where they could perform crude DNA extraction. In order to do so, as indicated by their laboratory report, students analyzed the functions of laboratory chemicals like SDS, sodium chloride, ice cold 96% ethanol, and PCIA and evaluated whether the functions of those chemicals could be replaced by household materials provided by the supervisor. Supervisor required attaching ingredients label on each household materials as cue to the students for generating associations. Cuing or providing hints is relevant pedagogical strategy to support creative approach during open practical work [25].

As for exploratory creativity (being creative within the rules of the domain) and transformational creativity (permitting changes to the rules of the conceptual space) [16], students explored the basic protocol of DNA extraction as accepted style or rules of thinking and then involved significant alteration to the protocol, generating certain new ideas. In this study, for instance, students understood the working principle of centrifuge at purification stage in separating the less dense nucleic acids from the cell debris by centrifugal force. Students then improvised this principle by spinning the test tube in quick circle movement. Some of them also significantly stretched the idea of making extraction buffer, which explicitly stated in the worksheet that it made from SDS and saturated sodium chloride, by mixing table salt, dishes soap, liquid soap, and detergent into one solution. Hence, inventing possibility from limited alternatives requires the use of prior knowledge and step-by-step thought, thereby challenging students to overcome potential blockage resulted from unavailability of standardized chemicals and instruments.

TABLE IV ***Students' views involving in response to the DNA extraction activity significance 0.05***

No.	*Questions*	*Average Score ± SD*
Knowledge		
1.	I acquired new information about DNA	3.7 ± 0.5
2.	I acquired clear concept about DNA	3.1 ± 1.0
3.	The new material that I have learned improves my understanding about DNA	3.7 ± 0.5
4.	Materials that I have learned are useful information	3.6 ± 0.5
Social skills		
5.	I worked in group to solve problem	3.9 ± 0.2
6.	I had opportunity to work honestly	3.7 ± 0.5
7.	I had opportunity to work on time	3.5 ± 0.5
8.	I had opportunity to learn carefully	3.4 ± 0.5
9.	I had opportunity to deliver my opinion	3.5 ± 0.5
10.	I conducted laboratory practice which stimulated my curiosity	3.6 ± 0.5
11.	I conducted my DNA extraction enthusiastically	3.6 ± 0.5
Creative thinking skills		
12.	I had opportunity to analyse problem	3.6 ± 0.6
13.	I had opportunity to brainstorm multiple ideas to solve problem (*fluency*)	3.5 ± 0.5
14.	I had opportunity to raise original idea to solve problem (*originality*)	3.3 ± 0.7
15.	I had opportunity to modify materials and procedures of my laboratory practice (*flexibility*)	3.6 ± 0.5
16.	I had opportunity to relate laboratory practice result with the prior knowledge about DNA (*elaboration*)	3.2 ± 0.6

The capability/behavior which want to be improved.

I wanted to learn further about extracting DNA with household materials.

I wanted to improve honesty, discipline, carefulness, and thoroughness in learning.

I wanted to be able to use laboratory instruments and materials including from the simple until complex technology.

Top three comments.

Furthermore, this laboratory practice of DNA extraction also meets with four key elements of creativity. *Fluency*, as ability to raise many ideas, could be seen as students brainstormed together or discussed how they would conduct DNA extraction with household materials. In discussion, members of group had opportunity generate lots of ideas to choose from, play with, and evaluate the best one experiment design to be conducted afterwards. *Flexibility*, as ability to look at an issue from different angle, could be observed when students thought and selected what household materials could replace standardized chemicals or how to modify standardized DNA extraction protocol. *Originality*, as ability to raise new ideas to previous way of thinking, was clearly demonstrated as students discovered novel ways to extract DNA with household materials. *Elaboration*, as ability to develop or add ideas in order to produce more detail ideas, was found when students constructed laboratory report; thereby encouraging students to make connections throughout their prior knowledge or new information from other sources (internet, books, journals).

Students' self-assessment in knowledge domain as well as quiz result showed that students acquired new information and clear concept about DNA that improved their understanding about the subject material. They also found the subject material was useful to be learned. In line with this result, Parry *et al.* [26] also stated that reflexivity that was depicted in self-assessment increased academic knowledge (theoretical knowledge) because they perceived increasing reflection on knowledge needs. This indicates that laboratory practice in the form of creatively design an experiment is able to provide meaningful learning experience to explore their knowledge. Earlier study also reported that creative approach in laboratory practice is effective strategy to communicate complex, often distant, concept [27]. As this study revealed how visualized DNA, resulting from DNA extraction tangible product, made students perceived better concept and understanding about DNA, Boersma, Waarlo, and Klaassen [28] also confirmed that an abstract system which is compared to concrete biological objects constructs holistic entity of systems thinking in biology.

In social skills domain, students reported that they worked collaboratively as a group, actively delivered opinion, maintained enthusiasm, honesty, and carefulness. Creativity-driven laboratory practice nurtured students to solve problem in teamwork by using various household materials and sharing knowledge to construct DNA extraction. As Fisher [29] states, students tend to be creative when they have others to support them. In other words, creativity-driven laboratory practice in partnership fosters learning environment which open up for ideas to be created, examined, shared, and tried out. Discussion among knowledgeable peers was reported to successfully promote new hypotheses and analyses [15]. Therefore, interaction during creativity-driven laboratory practice succeeds to promote creative thinking skills in students.

Solving problem together in practical coursework, as Tarhan and Ayyıldız [23] presents, improves skills for creative thinking by critically evaluates choices and multiple resources. Students viewed that DNA extraction activity made them could brainstorm multiple ideas (*fluency*), modify their own DNA extraction (*flexibility*), analyse problem, raise original ideas for problem-solving (*originality*), and make connections throughout the prior knowledge (*elaboration*). Hearn and Arblaster [18] adds that supervision and encouragement during hardest stage of DNA extraction, in this case are cell disruption and modifying buffer solution at extraction stage, is essential to prevent potential pitfalls in the laboratory activity. It is also important for the teacher to evaluate experiment result and explore the material further to avoid misconceptions resulting from student's assumption in designing their own DNA extraction techniques.

Result of this study indicates that creativity approach in DNA extraction laboratory practice potentially improves creative thinking and obtains positive views from the students in knowledge, social skills, and creative thinking skills domain. In addition, this study also underlines teacher's important role to facilitate holistic elaboration to connect multiple experiment result with prior knowledge. Kılıç and Sağlam [30] have been stated that connecting new information and prior knowledge in genetics concepts improved students' understanding of genetics concepts since there was meaningful orientation among interrelated concepts. Based on the result implies, several things are suggested to be implemented in biological education research and biology learning: (1) DNA extraction activity with household materials can be used to develop students' knowledge, social skills, and creative thinking skills; (2) DNA extraction can be implemented in school using household materials which are easily accessed by students from their environment.

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