# Ill-structured on respiratory system: How does the contextual problem improve students' problem-solving skills by developing electronic worksheet?

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**Abstract:** This research aims to develop an electronic student worksheet based on respiratory problem to improve problem-solving skills on the respiratory system concept. This research and development (R&D) using 4D model proposed by Thiagarajan consist of define, design, develop, and disseminate. E-worksheets were validated by three experts, i.e. the material experts, media experts, and biology teacher as a practitioner. The result of the research showed that the e-worksheet developed had an average validity percentage of 81.85% with a very good category. While the e-worksheet readability was 96.67% (very good). Furthermore, either the teacher or students shows that the field trial test of the e-worksheet had good criteria due to their responses of 94.58% and 88.39%, respectively. The research results shows that there is an increase on students' problem-solving skills based on the N-gain score of 0.47 and classified as medium category. Based on these results, it can be concluded that e-worksheet is very suitable for use in learning activities and can improve student's problem-solving skills.

**Keywords**: e-worksheet; problem-based learning; problem-solving skills; respiratory system concept

## Introduction

Along with the development of technological advances and the digital era, education in the 21st century requires innovation in utilizing technology in learning activities that improve the skills and intelligence of learners. The 21st century skills acquired by learners include creativity, communication, collaboration, critical thinking, and problem-solving (Muzana et al., 2021). Technology can help learners to stimulate creative and critical thinking, as well as stimulating them to making decisions later on in daily life problems. It also helps stimulate learners' reasoning skills, making them better at solving complex problem (Chen et al., 2019; Criollo-C & Luján-Mora, 2019). Learning activities in improving 21st century skills, interest and motivation are very important as a driver of students because they can provide direction, enthusiasm, and perseverance. The low interest and motivation of students can be caused by the environment around students that is less supportive, one of which is a monotonous learning atmosphere (Aryani & Suarjana, 2021).

Innovation in utilizing and developing technology in learning activities can use teaching materials in electronic form, namely e-worksheet which is a form of presentation transformation from student worksheet (Nurulia & Qomariyah, 2022). E-worksheet can be combined with various learning models, one of which is problem-based learning (PBL). As a learning model, PBL can improve students' 21st century skills, especially problem-solving skills (Argaw et al., 2017; Balim et al., 2016). Problem Based Learning is one of the learning models that will help and facilitate teachers in facing the challenges of teaching in the 21st century (Adedoyin & Soykan, 2020; Basilaia & Kvavadze, 2020; Pamela et al., 2013). The process of learning activities with the PBL model is centered on students and teachers as facilitators, so that students will play an active role in learning activities (Munzil et al., 2022). PBL uses problems that exist around students as the beginning of the learning process, the problem will then be analyzed by students so that they able to train to think critically and have problem-solving skills (Barabanova et al., 2019; Rahmadani & Taufina, 2020; Schmidt & Tang, 2020; Shatunova et al., 2021). This is in accordance with the results of Noprianda et al (2016) research, critical thinking skills with classes using the PBL model are better during the learning process. PBL can better train students in critical thinking

because it leads gradually to critical thinking.

Problems that can be raised as the beginning of the learning process using the PBL model consist of two types, namely well-structured and ill-structured. Well-structured problems have all limited elements, involving some rules, principles, and concepts that are organized in an original and perspective manner. Whereas ill-structured problems have many alternative solutions, ambiguous definitions with unclear goals, unspecified constraints, and lack of relevant information. Ill-structured problems invite learners to express their personal opinions on the problem to be solved. Ill-structured problems can be encountered in learners' daily lives (Aguilera-Hermida, 2020; Ferri et al., 2020; Özreçberoğlu & Çağanağa, 2018). Learners who are able to solve ill-structured problems have better cognitive and metacognitive abilities when compared to learners who only solve well-structured problems (Aziziy et al., 2015).

The respiration system in daily life problems can be linked to air pollution in several cities in Indonesia, one of which is South Tangerang City. As reported by Salsabila (2023), South Tangerang and Tangerang in Banten Province, are the two cities with the worst air quality in Indonesia. The air quality and data provider application, Nafas Indonesia, monitors air quality in the area around South Tangerang and Tangerang with the average result of unhealthy air quality for the past two years (Salsabila, 2023). Through the problems, students able to think critically which is related to problem-solving activity. With this critical thinking, students will always have a high curiosity about existing information to achieve a deep understanding of a problem so that they can solve the problem (Bahri & Supahar, 2019).

Based on the observation at State Senior High School (SSHS) 12 of South Tangerang, e-worksheet has never been applied in biology learning, especially on the concept of respiration system. Learning on the concept of respiration system was previously done by practice, presentation, and the use of e-worksheet with PBL has not been done. SSHS 12 of South Tangerang has one of the missions to be achieved, namely creating an active, innovative, creative, effective, fun learning atmosphere by applying various 21st century learning methods that are environmentally sound. The students' worksheets used by schools are printed form publishers in the form of only questions and have not used learning models as the basis for worksheets. Teachers also never used e-worksheet based on PBL. Moreover, the learning methods that are often used on the concept of respiratory system are lectures, discussions, practicum, and group presentations.

Therefore, it is necessary to develop an e-worksheet made by the biology teacher concerned so that it suits the needs and character of students in the classroom. The importance of innovating the presentation of worksheets in electronic form based on certain learning models to support students' 21st century skills, one of which is PBL which is expected to be able to improve students' problem-solving skills and increase students' interest and motivation in learning so that the concepts taught is focused on the application of PBL, improving students' problem-solving skills, and the application electronic-based technology.

## Method

The development model used is a type of research using a 4D model which is consist of define, design, develop, and disseminate. However, this research is limited only to the development stage, considering time and permission of school to conduct research (Figure 1). The stages of the 4D model include: The definition stage which consists of initial analysis, concept analysis, task analysis, and analysis of learning objectives (Thiagarajan et al., 1976). The design stage is designing e-worksheet based on PBL to improve problem-solving skills. The process of making e-worksheet uses the *Canva* application. The e-worksheet format is adjusted to the 2013 learning design which includes basic competencies, indicators, learning objectives, instructions for use, theoretical basis, and six stages of PBL consist of stimulation, problem identification, collecting data, solving problems, evaluating, and communicating.

The e-worksheet was validated by experts at the development stage with the aim of obtaining suggestions and input to improve the e-worksheet. The e-worksheet that has been validated is carried out a limited trial on twenty students of eleventh class. Moreover, a broad trial is carried out by 48 students of math and science class. The research instruments used in this study are interview sheets for biology teachers, questionnaire sheets, validation sheets, student response questionnaire sheets, and pre-test and post-test to measure students' problem-solving skills in. The research instrument in this study is intended to determine the validity of the e-worksheet based on problem based learning developed.
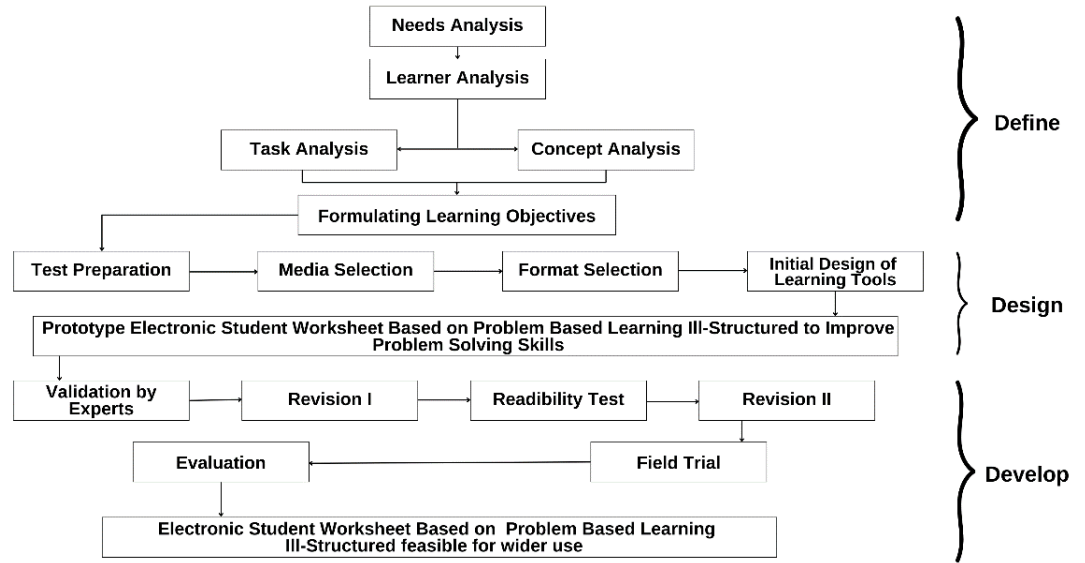
**Figure 1**. Research flow using the 4-D development model

Checklist data processing in this study uses a measurement scale called the Guttman Scale (Table 1). Processing on several instruments such as validity tests, readability tests, and response questionnaires using a Likert scale (Yulia & Setianingsih, 2020). The details of criteria for Likert scale data processing are showed in the Table 2.

**Table 1**. Guttman Scale

| Answer | Score |
|--------|-------|
| Yes | 1 |
| No | 0 |

**Table 2**. Criteria for Likert scale data processing

| Alternative Answer | Score |
|--------------------|-------|
| Very Good | 5 |
| Good | 4 |
| Enough | 3 |
| Not Good | 2 |
| Very Unkind | 1 |

The data obtained based on the percentage was analyzed with presentation interpretation criteria. The data analysis technique used is descriptive statistics. Descriptive statistics are statistics that describe data in the form of graphs, tables, averages, frequencies, or in other forms (Suryani & Hendryadi, 2015). The formula used to process data is below (Formula 1).

$$P = \frac{\Sigma X}{\Sigma Xi} \ x \ 100\% \tag{1}$$

Description:
P = Percentage
$\Sigma X$ = Number of respondents' answer score in one item
$\Sigma Xi$ = Number of maximum scores in the item

In measuring the improvement of students' solving skills, it is done by working on pre-test and post-test questions by students. The increase can be seen through the Normalized-gain (N-gain) test (Kurniawan & Hidayah, 2020). The n-gain (N-gain) Formula 2 is as follows.

$$N - Gain = \frac{\text{Skor Posttest} - \text{Skor Pretest}}{\text{Skor Ideal} - \text{Skor Pretest}} \tag{2}$$

The N-gain points obtained were then analyzed using the criteria in Table 3.

**Table 3**. N-gain criteria

| N-gain Score | Criteria |
|---|---|
| g > 0.7 | High |
| 0.3 ≤ g ≤ 0.7 | Moderate |
| g < 0.3 | Low |

# Results and Discussion

## Define Stage

The defining stage begins with a needs analysis with the aim of identifying basic problems by students and teachers in the learning process at the research location (Elvanuari et al., 2024; Yuanita & Kurnia, 2019). The needs analysis was conducted by conducting interviews with students and teachers by focusing on five aspects, i.e. 2013 curriculum, Ill-structured as a PBL model contextual problem, teaching materials, learning processes, and students' problem-solving skills. The results of interviews shows that e-worksheet has never been applied in biology learning. However, teachers are agree to develop an e-worksheet PBL due to a learning innovation also for additional teaching materials for students. E-worksheet has never been applied, especially on the concept of the respiration system. Learning on this concept was previously done with practice, presentations, group discussions, and the use of e-worksheet with the PBL model has not been done. Interactive e-worksheet can train students' creative thinking skills with questions that are presented to build understanding by being linked to everyday problems that are contextual in nature (Ardiansah & Zulfiani, 2023; Elvanuari et al., 2024). Interactive e-worksheets are integrated with technology so that they can provide meaningful learning for students (Ardiansah & Zulfiani, 2023). The results of interviews with students also show that students agree if there is a development of e-worksheet has an efficiency that saves space and time, makes it easier for students to do tasks and makes it easier for teachers to evaluate what students do, and can contain images and learning videos that are in accordance with the material presented so that they can attract students' learning interests (Puriasih & Rati, 2022).

## Design and Development Stage

This stage begins with the preparation of tests by preparing grids and assessment rubrics, as well as preparing pre-test and post-test questions to measure the improvement of students' problem-solving skills. The e-worksheet is contain information in digital form that can be designed as interesting as possible with text, video, audio and other animations (Taufiqurrohman et al., 2017). E-worksheet is made using the *Canva* application. *Canva* was commonly used by the teachers who want to develop online-based media. Moreover, *Canva* can facilitate students to understand an abstract and difficult subject through the visual form (Pratama et al., 2023). With the ease of using the *Canva* application, e-worksheet can be studied by students anytime and anywhere easily, and teachers are also easy to monitor and evaluate the activities carried out by students in e-worksheet (Mahardika et al., 2021; Rohayati et al., 2023).

The preparation of e-worksheet is equipped with activities with six stages of PBL, initiate with the problem stimulation, problem identification, collecting data, solving problems, evaluating, and communication. PBL uses real-life problems as a context for learning about critical thinking and problem-solving skills, and for gaining knowledge and concepts essential to the subject matter for students (Aini et al., 2019). The use of ill-structured problems invites learners to express their personal opinions on the problems to be solved in the student worksheet (Davidsen et al., 2020; Tawfik, 2017). Teachers who present ill-structured problems will motivate learners to be active in solving problems. learners who are able to solve ill-structured problems have better cognitive and metacognitive abilities than learners who only solve well-structured problems (Aziziy et al., 2015).

Ill-structured problems invite learners to express their personal opinions on a problem to solve (Davidsen et al., 2020; Hong & Kim, 2016). In preparing e-worksheet, it is necessary to pay attention to the curriculum, needs, title, formulate basic competencies, determine assessment instruments, prepare materials, and compile the e-worksheet structure (Rahmawati & Wulandari, 2020). Problem-solving is a skill that requires acquisition and continues to develop and advance. Problem-solving in biology teaching involves introducing problems to students and encouraging them to solve them (Kundariati et al., 2022; Nikolić & Antonijević, 2024). It can be a learning environment that stimulates students in taking risks (Criollo-C & Luján-Mora, 2019), utilizing prior knowledge and experience (Magaji, 2021; Oğuz-Ünver & Arabacioğlu, 2011), discovering new knowledge (Nikolić & Antonijević, 2024), and testing ideas (Hero & Lindfors, 2019). Problem-solving encourages students to think independently and make decisions about possible solutions which further leads them to analyze, estimate, and evaluate outcomes in the context of the decisions made. Factor analysis concluded that problem-solving activities can be grouped into the following five areas, such as: (1) analyzing and planning problem-solving; (2) finding solutions to

problems; (3) problem-solving evaluation activities; (4) additional activities involving discussion of problems; (5) the degree of student independence in the process of finding solutions to a problem (Nikolić & Antonijević, 2024).

After the e-worksheet was completed, the next stage was validation by several experts before the field trial was conducted. E-worksheets were validated by three experts, i.e. the material experts, media experts, and biology teacher as a practitioner. The expert validation aims to obtain input in the form of suggestions and criticisms from several experts so as to produce a product that can be categorized as good and suitable for field trials (Widyasari et al., 2022). The validity test aims to see the accuracy of a measuring instrument (instrument) in carrying out its function (Yusup, 2018).The validated components vary according to each validator's field, such as content feasibility, language, presentation, and others. Details of the overall validity test results can be seen in the Table 4.

**Table 4**. Validity test results

| No | Validators | Percentage (%) | Criteria |
|----|-----------|----------------|----------|
| 1. | Material expert | 73,57 | Good |
| 2. | Media expert | 81,85 | Very Good |
| 3. | Practitioner expert | 90,15 | Very Good |
| | **Total Average** | **81,85** | **Very Good** |

## Limited Trial

The e-worksheet was conducted a limited trial to 20 students to test its readability. E-worksheet received some suggestions and input from students. Summary of the readability test results can be seen in the Table 5.

**Table 5**. Results of readability test

| No | Indicators | Percentage (%) | Criteria |
|----|-----------|----------------|----------|
| 1. | Graphic | 98.75 | Very Good |
| 2. | Practicality | 91.25 | Very Good |
| 3. | Presentation | 100.00 | Very Good |
| 4. | Linguistics | 100.00 | Very Good |
| | **Total Average** | **96.67** | **Very Good** |

It can be concluded that the students' readability test obtained results with a percentage of 96.67% with very good criteria. The indicators that get the highest percentage are presentation and language with a percentage of 100%. Based on the results obtained, it shows that the sentences in e-worksheet are simple and do not cause ambiguity, and the writing is clearly legible and easy to understand. In addition, e-worksheet has an attractive content display design and the instructions in e-worksheet are easy to understand. The indicator that has the lowest percentage is practicality with 91.25%. After the validation test and readability test. The e-worksheet was revised according to the suggestions and comments from the validators and some students.

This e-worksheet is designed interactively and interestingly to make it easier for students to understand the respiration system. With an electronic format, this worksheet presents material explanations supported by informative imaged, so that important concepts are easier to understand (Madeali & Prahani, 2018; Phillips et al., 2012). In addition, there are five special interactive activities that invite students to explore concepts through ill-structured situations, thus challenging them to find solutions and understanding independently. One of the uniqueness of this e-worksheet is on page 9 (Figure 2) which displays information about factors that affect breathing frequency. Each factor is accompanied by a simple illustration that helps students understand the material more easily. This e-worksheet is also equipped with several "Biofact" columns that contain interesting additional information about the respiratory system, thus increasing student's knowledge in an interactive and fun way.

**Figure 2**. Page 9 of the e-worksheet on breathing frequency

## Expanded Trial

Expanded trial were conducted on 48 students and a biology teacher as respondents. The purpose of the expanded trial was to find out the responses of teachers and students to the e-worksheet based on PBL used in learning. Response analysis aims to see the responses of teachers and students to e-worksheets that have been used in learning. The response analysis stage is carried out after the e-worksheet has been used by students in learning. Based on the analysis of the teacher's response questionnaire to e-worksheet, the average percentage result is 94.58% with very feasible criteria. The aspects assessed in the teacher's response are aspects of practicality, feasibility of material content, grammar, and language. The aspects that have the highest percentage value are aspects of grammar and language with a percentage value of 100%. This shows that e-worksheet based on PBL is very feasible and can be used as teaching materials for students in learning activities. The results of the teacher response analysis can be seen in Table 7.

**Table 7**. Results of the teacher response analysis

| No | Aspects | Percentage (%) | Criteria |
|----|---------|----------------|----------|
| 1. | Practicality | 85.00 | Very Good |
| 2. | Feasibility of material content | 93.33 | Very Good |
| 3. | Graphic | 100.00 | Very Good |
| 4. | Linguistics | 100.00 | Very Good |
| | **Total average percentage** | **94.58** | **Very Good** |

It can be seen that the teacher gave a very good response to the e-worksheet. Another study was conducted by Mumtaza and Zulfiani (2023), which developed science process skills-based student worksheets on the concept of the excretory system. The resulting student worksheets have very good criteria. Overall, biology teachers hope that the e-worksheet with PBL can be useful and facilitate learning which can improve students' problem-solving skills. E-worksheet can accelerate learners'

access to certain information and facilitate learners in learning, so as to increase learners' understanding, and e-worksheet can attract and motivate learners in learning (Husna et al., 2022). Problem-solving is a great technique for students to understand learning materials. PBL by raising real-life problems can help learners connect their knowledge with real-world problems (Palennari, 2018). Students also responded to the e-worksheet. The results of the analysis of students' responses can be seen in Table 8.

**Table 8**. Results of students' response analysis

| No | Aspects | Percentage (%) | Criteria |
|---|---|---|---|
| 1. | Materials | 87.70 | Very Good |
| 2. | Graphic | 87.91 | Very Good |
| 3. | Linguistics | 89.57 | Very Good |
| | **Average** | **88.39** | **Very Good** |

The pre-test and post-test questions were given to students before and after working on the e-worksheet. The question consisted of 20 questions and was done by 48 respondents. Problem-solving skills are skills possessed by learners to solve a problem through scientific methods and attitudes such as formulating problems, formulating hypotheses, planning problem-solving procedures, and concluding results. There are four important indicators in organizing students' problem-solving skills, i.e. problem understanding, problem-solving planning, solving problems according to plan, and rechecking or evaluate (Primadani et al., 2017). Problem-solving skills can be defined as the process required in overcoming the difference between a desired situation and the current situation influenced by previously encountered or unencountered variables. Problem-solving can also be defined as the organization of cognitive and behavioral processes that are effective towards a specific target, which is related to creativity (Ince, 2018). Measurement of the improvement of students' problem-solving skills can be seen through the N-gain test. The results of the N-gain test for improving students' problem-solving skills can be seen in the Table 9.

**Table 9**. Results of N-gain Test

| | Pre-Test | Post-Test |
|---|---|---|
| Average Score | 79.17 | 88.75 |
| N-gain | 0.47 | |
| N-gain (%) | 46.51 | |
| Criteria | Very Good | |

There was an increase in the average pre-test and post-test scores of students' problem-solving skills. The pre-test average value was 79.17 and there was an increase in the post-test average value to 88.75. With the average value of the pre-test and post-test, the N-gain test result is 0.47 with moderate criteria. So it can be concluded that there is an increase in problem-solving skills in students. Solving ill-structured problems can improve students' higher-order thinking skills and strengthen students' ability to solve real-life problems (Hong & Kim, 2016). By using e-worksheet PBL in biology learning has effectiveness in improving students' problem-solving skills, especially in the material of the respiration system in eleventh class (Parapat et al., 2023). PBL is learning that is based on a problem in learning. The problem in this learning is used as a starting point to improve learners' solving skills and integrate knowledge. The contextual problem able to stimulate learners to solve problems, through inter-connection with other fields of science, and provide problems solutions (Bahri et al., 2018).

The resulting e-worksheet is also in accordance with the research of Elvanuari et al (2024), which developed an e-worksheet with very feasible or very good results. The developed e-worksheet can improve science process skills on excretory system material by having very good criteria to be applied to biology learning. The use of e-worksheet shows the urgency of adapting technology in learning which is very important to be improved at the educational level. Another research results from (Ardiansah & Zulfiani, 2023), with excellent results when viewed from the results of validity, readability, and practicality. The development of Interactive student worksheet can train students' creative thinking skills, because the questions presented construct students' understanding associated with everyday problems that are contextual in nature. Some relevant research proves that learner worksheets can also be used for distance learning by adapting technology.

## Conclusion

The research shows that the e-worksheet with contextual problem has very good criteria (81.85%). The experts' validation also indicate that the e-worksheet are reliable to be implemented. Moreover, the students' problem-solving skills are uplift from the pre-test (79.17) to post-test (88.75) with N-gain score

of 0.47 in the medium category. To sum up, it can be concluded that e-worksheet based on PBL with contextual problem able to improve students' problem-solving skills on the concept of the respiration system.

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# Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

# Author Contributions

**M. D. Tambunan: conceptualization**, methodology, design, analysis, writing original draft preparation, review, and editing. **Z. Zulfiani:** analysis, evaluation, writing original draft preparation, review, and editing. **E. S. Rosyidatun:** Analysis, evaluation, writing original draft preparation, review, and editing.

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