

#1590 Summary

[Summary](#) [Review](#) [Editing](#)

Submission

Authors	Binar Kurnia Prahani, Iqbal Ainur Rizki, Khoirun Nisa', Nina Fajriyah Citra, Hanan Zaki Alhusni, Firmanul Catur Wibowo
Title	Implementation of online problem-based learning assisted by digital book with 3D animations to improve student's physics problem-solving skills in magnetic field subject
Original file	1590-5455-2-SM.DOCX 2022-01-09
Supp. files	None
Submitter	Dr Binar Kurnia Prahani 
Date submitted	January 9, 2022 - 06:45 PM
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Editor	María Martínez Martínez 
Abstract Views	604

Status

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Submission Metadata

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Title and Abstract

Title Implementation of online problem-based learning assisted by digital book with 3D animations to improve student's physics problem-solving skills in magnetic field subject

Abstract The magnetic field is a more complex and abstract physics subject than other physics subjects, causing students' low ability to solve problems. So there is a need for learning instruments to overcome these problems, especially when online learning during the COVID-19 pandemic. Research creates and implements an online problem-based learning (OPBL) assisted by digital books with 3D animation to improve students' physics problem-solving skills on magnetic field subjects. Research aimed to analyze the validity, effectiveness, and student responses to the learning instruments used. The method used in this research is quantitative by using quasi-experiment and survey methods. The results showed that this learning instrument was valid and reliable to use in terms of content and constructs. According to statistical test results, this learning instrument is also effective in improving students' problem-solving skills on magnetic field subjects. Furthermore, the student's response to this learning instrument was very positive, making this learning activity more innovative and fun. Research implies that an OPBL assisted by digital books with 3D animation instruments can be a solution to improve students' physics problem-solving skills, especially during the online learning period.

Indexing

Keywords Digital book with 3D animations, magnetic field, online problem-based learning, problem-solving skills
Language en

Supporting Agencies

Agencies Thank you to the Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya 2021 has provided funding with contract number B/31516/UN38.3/LT.02/2021.

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VISITORS



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Journal of Technology and Science Education, 2011-2022

Online ISSN: 2013-6374; Print ISSN: 2014-5349; DL: B-2000-2012

Publisher: [OmniaScience](#)

[jotse] Editor Decision

1 message

Journal of Technology and Science Education <info@jotse.org>

Tue, Mar 15, 2022 at 7:10 PM

Reply-To: Dra María Martínez Martínez <rosario.martinez@upc.edu>

To: Dr Binar Kurnia Prahani <binarprahani@gmail.com>

Cc: BINAR PRAHANI <binarprahani@unesa.ac.id>, Iqbal Rizki <iqbalainur19004@gmail.com>, Khoirun Nisa <khoirun.19005@mhs.unesa.ac.id>, Nina Citra <nina.19043@mhs.unesa.ac.id>, Hanan Alhusni <hanan.20068@mhs.unesa.ac.id>

Dear Dr Binar Kurnia Prahani:

We have reached a decision regarding your submission to Journal of Technology and Science Education, "IMPLEMENTATION OF ONLINE PROBLEM-BASED LEARNING ASSISTED BY DIGITAL BOOK WITH 3D ANIMATIONS TO IMPROVE STUDENT'S PHYSICS PROBLEM-SOLVING SKILLS IN MAGNETIC FIELD SUBJECT".

Our decision is to: REVISIONS REQUIRED

When you revise your manuscript please highlight the changes you make in the manuscript by using the track changes mode in MS Word or by using bold or coloured text. In order to expedite the processing of the revised manuscript, please be as specific as possible in your response to the reviewer and revise your manuscript within 15-30 days to avoid any further delay in publishing your article. If we do not receive your response in this deadline, your paper will be archived.

To submit the revision, log into <https://www.jotse.org>. Go to the section "USER HOME" and then to the sub-section "AUTHOR". There, you will find all your manuscripts. Select the manuscript that you want to upload.

Please, do not hesitate to ask if you have any questions or suggestions.

Best regards

Dra María Martínez Martínez
Universitat Politècnica de Catalunya
UPC BARCELONA TECH

rosario.martinez@upc.edu
María Martínez Martínez

Reviewer A:

Reviewer B:

CONTENT (e.g.: Clarity of objective; basis of theory; conclusions drawn; understanding of subject, contribution to technology and Science education.)

Score (out of 20)

Comments

: 15/20 The goals and objectives of the research are rather well stated.

DEGREE OF NOVELTY OR ORIGINALITY (e.g.: presence of new ideas; elsewhere)

Score (out of 10)

Comments

: 6/10 Different schemes around PBL have been around for a while. Maybe the most original part is the use of smartphones/instant messaging as a way to overcome lack of proper computers/networks.

STRUCTURE OF PAPER (e.g.: general layout; use and number of figures/diagrams, etc.)

Score (out of 10)

Comments

: 7.5/10 Layout of the paper is appropriate.

QUALITY OF TEXT (e.g.: Clarity of expression; consistency; readability; number of quotations, quality and quantity of references)

Score (out of 10)

Comments

: 3/10 English usage is not very good and should be improved. Also the text could be more synthetic.

Score (out of 50)

Comments

: 25/50 The authors put a lot of effort to test a software that can aid student to solve problems. The paper is interesting but maybe the statistical methods are a bit overkill for just 2 groups of 30 students. English usage should be improved and the results and discussion section should be more synthetic.

[jotse] Implementation of online problem-based learning assisted by digital book with 3D animations to improve student's physics problem-solving skills in magnetic field subject

6 messages

Journal of Technology and Science Education <info@jotse.org>

Mon, Apr 4, 2022 at 6:20 PM

Reply-To: Irene Trullas <irene.trullas@omniascience.com>

To: Binar Prahani <binarprahani@unesa.ac.id>

Dear Binar,

We contact you in order to inform you that your paper will be published in the next regular issue of JOTSE.

According to the journal's guidelines, for papers received since January 18th, 2019 the publication fee is 295€/article.

Please fill in this form (http://www.omniascience.com/?page_id=1085&lang=en) in order to get your invoice's data.

Best regards,

Irene Trullas, PhD
JOTSE - OmniaScience

Journal of Technology and Science Education

<https://www.jotse.org>**Binar Kurnia Prahani** <binarprahani@unesa.ac.id>

Mon, Apr 4, 2022 at 8:27 PM

To: Irene Trullas <irene.trullas@omniascience.com>, info@jotse.org

Dear Editor JOTSE

We really appreciate the performance of the JOTSE editor.

Following up on the information from the previous email *According to the instructions published on the journal website, if more authors would like to be added, you must pay 50 euros per each one. we want to add 1 author with the attached identity.*

For payment, we will follow all the provisions of JOTSE.

Thank you for the positive response and help

Best Regards,

Binar Kurnia Prahani
Universitas Negeri Surabaya

2 attachments

 article revision 4_1590-5455-2-SM.docx
427K Confirmation (add author).docx
14K**Irene Trullas** <irene.trullas@omniascience.com>

Mon, Apr 4, 2022 at 9:09 PM

To: Binar Kurnia Prahani <binarprahani@unesa.ac.id>

Dear Binar,

ok, there is no problem. So in this case the final invoice will be 295+50 euros. Please fill in the form we have just sent you and we will generate the invoice with both issues.

Regards,

Irene Trullàs, PhD
www.omniascience.com
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Missatge de Binar Kurnia Prahani <binarprahani@unesa.ac.id> del dia dilluns, 4 d'abril 2022 a les 15:27:

[Quoted text hidden]

Binar Kurnia Prahani <binarprahani@unesa.ac.id>

Tue, Apr 5, 2022 at 6:54 AM

To: Irene Trullas <irene.trullas@omniascience.com>

Dear Irene Trullàs, PhD

Thanks for your information.
We have fulfilled the link.

Best Regards,

Binar Kurnia Prahani <binarprahani@unesa.ac.id>
To: Irene Trullas <irene.trullas@omniascience.com>, info@jotse.org

Wed, Apr 6, 2022 at 11:00 AM

Dear Editor JOTSE

We have done the payment. Thank you very much

Best Regards,

Binar Kurnia Prahani
Universitas Negeri Surabaya

[Quoted text hidden]

2 attachments



Invoice - FV22063_Binar Kurnia Prahani_1590 JOTSE.jpeg
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 **Invoice - FV22063_Binar Kurnia Prahani_1590 JOTSE.pdf**
99K

Irene Trullas <irene.trullas@omniascience.com>
To: Binar Kurnia Prahani <binarprahani@unesa.ac.id>

Wed, Apr 6, 2022 at 4:27 PM

Dear Binar,

Payment received. Your paper is now in the editing process. In a few days, we will send you the final version for your review.

Regards,

Irene Trullàs, PhD
www.omniascience.com
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Missatge de Binar Kurnia Prahani <binarprahani@unesa.ac.id> del dia dc., 6 d'abr. 2022 a les 6:00:

[Quoted text hidden]

[jotse] Editor Decision

1 message

Journal of Technology and Science Education <info@jotse.org>

Mon, Apr 4, 2022 at 4:15 PM

Reply-To: Dra María Martínez Martínez <rosario.martinez@upc.edu>

To: Dr Binar Kurnia Prahani <binarprahani@gmail.com>

Cc: BINAR PRAHANI <binarprahani@unesa.ac.id>, Iqbal Rizki <iqbalainur19004@gmail.com>, Khoirun Nisa <khoirun.19005@mhs.unesa.ac.id>, Nina Citra <nina.19043@mhs.unesa.ac.id>, Hanan Alhusni <hanan.20068@mhs.unesa.ac.id>

Dear Dr Binar Kurnia Prahani:

We have reached a decision regarding your submission to Journal of Technology and Science Education, "IMPLEMENTATION OF ONLINE PROBLEM-BASED LEARNING ASSISTED BY DIGITAL BOOK WITH 3D ANIMATIONS TO IMPROVE STUDENT'S PHYSICS PROBLEM-SOLVING SKILLS IN MAGNETIC FIELD SUBJECT".

Our decision is to: ACCEPTED SUBMISSION

Best regards

Dra María Martínez Martínez
Universitat Politècnica de Catalunya
UPC BARCELONA TECH

rosario.martinez@upc.edu

María Martínez Martínez

Journal of Technology and Science Education
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[jotse] Editor Decision

3 messages

Journal of Technology and Science Education <info@jotse.org>

Sun, Mar 20, 2022 at 10:07 PM

Reply-To: Dra María Martínez Martínez <rosario.martinez@upc.edu>

To: Dr Binar Kurnia Prahani <binarprahani@gmail.com>

Cc: BINAR PRAHANI <binarprahani@unesa.ac.id>, Iqbal Rizki <iqbalainur19004@gmail.com>, Khoirun Nisa <khoirun.19005@mhs.unesa.ac.id>, Nina Citra <nina.19043@mhs.unesa.ac.id>, Hanan Alhusni <hanan.20068@mhs.unesa.ac.id>

Dr Binar Kurnia Prahani:

Thanks for the new version..but

We would you be so kind as to send me a document justifying the changes made based on the comments of the reviewers. One of the revisions is that of English, I would need a certificate that guarantees quality.

Best regards
Maria

Journal of Technology and Science Education, "IMPLEMENTATION OF ONLINE PROBLEM-BASED LEARNING ASSISTED BY DIGITAL BOOK WITH 3D ANIMATIONS TO IMPROVE STUDENT'S PHYSICS PROBLEM-SOLVING SKILLS IN MAGNETIC FIELD SUBJECT".

Our decision is to: revisions required

When you revise your manuscript please highlight the changes you make in the manuscript by using the track changes mode in MS Word or by using bold or coloured text. In order to expedite the processing of the revised manuscript, please be as specific as possible in your response to the reviewer and revise your manuscript within 15 days to avoid any further delay in publishing your article. If we do not receive your response in this deadline, your paper will be archived.

To submit the revision, log into <https://www.jotse.org>. Go to the section "USER HOME" and then to the sub-section "AUTHOR". There, you will find all your manuscripts. Select the manuscript that you want to upload.

Please, do not hesitate to ask if you have any questions or suggestions.

Dra María Martínez Martínez
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Journal of Technology and Science Education
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Binar Kurnia Prahani <binarprahani@unesa.ac.id>
To: Dra María Martínez Martínez <rosario.martinez@upc.edu>

Tue, Mar 29, 2022 at 7:15 AM

Dear Editor
Prof. María Martínez Martínez
Universitat Politècnica de Catalunya
UPC BARCELONA TECH

We have the revision and proofread letter (Attachment). We also submit our revision in the account of JOTSE.
Thank you very much

Best Regards,

Binar Kurnia Prahani
Universitas Negeri Surabaya

[Quoted text hidden]

2 attachments

 **030222 - Declaration of Proofreading Services.pdf**
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427K

Maria Del Rosario Martinez Martinez <rosario.martinez@upc.edu>
To: Binar Kurnia Prahani <binarprahani@unesa.ac.id>

Tue, Mar 29, 2022 at 1:45 PM

Dear Binar
Thanks
Best regards
Maria

[Quoted text hidden]

Attention to Binar Kurnia Prahani: JOTSE publication

1 message

Irene Trullàs, PhD <irene.trullas@omniascience.com>
Reply-To: irene.trullas@omniascience.com
To: Binarprahani <binarprahani@unesa.ac.id>

Tue, Jun 7, 2022 at 10:29 PM

Dear Binar Kurnia

We have just published your paper in JOTSE, issue 12(2). You can find it on the journal home page: <http://www.jotse.org/index.php/jotse>

Also we encourage to follow @OmniaScience on Twitter where your paper is announced. A retweet and likes are welcome.

Irene Trullàs, PhD
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#1590 Summary

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Submission

Authors	Binar Kurnia Prahani, Iqbal Ainur Rizki, Khoirun Nisa', Nina Fajriyah Citra, Hanan Zaki Alhusni, Firmanul Catur Wibowo
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Affiliation	Universitas Negeri Surabaya
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Name	Firmanul Catur Wibowo 
ORCID iD	https://orcid.org/0000-0001-9632-6061
Affiliation	Universitas Negeri Jakarta
Country	Indonesia

Title and Abstract

Title Implementation of online problem-based learning assisted by digital book with 3D animations to improve student's physics problem-solving skills in magnetic field subject

Abstract The magnetic field is a more complex and abstract physics subject than other physics subjects, causing students' low ability to solve problems. So there is a need for learning instruments to overcome these problems, especially when online learning during the COVID-19 pandemic. Research creates and implements an online problem-based learning (OPBL) assisted by digital books with 3D animation to improve students' physics problem-solving skills on magnetic field subjects. Research aimed to analyze the validity, effectiveness, and student responses to the learning instruments used. The method used in this research is quantitative by using quasi-experiment and survey methods. The results showed that this learning instrument was valid and reliable to use in terms of content and constructs. According to statistical test results, this learning instrument is also effective in improving students' problem-solving skills on magnetic field subjects. Furthermore, the student's response to this learning instrument was very positive, making this learning activity more innovative and fun. Research implies that an OPBL assisted by digital books with 3D animation instruments can be a solution to improve students' physics problem-solving skills, especially during the online learning period.

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Keywords Digital book with 3D animations, magnetic field, online problem-based learning, problem-solving skills
Language en

Supporting Agencies

Agencies Thank you to the Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya 2021 has provided funding with contract number B/31516/UN38.3/LT.02/2021.

INFORMATION

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Journal of Technology and Science Education, 2011-2022

Online ISSN: 2013-6374; Print ISSN: 2014-5349; DL: B-2000-2012

Publisher: [OmniaScience](#)

1 **IMPLEMENTATION OF ONLINE PROBLEM-BASED LEARNING**
2 **ASSISTED BY DIGITAL BOOK WITH 3D ANIMATIONS TO**
3 **IMPROVE STUDENT'S PHYSICS PROBLEM-SOLVING SKILLS IN**
4 **MAGNETIC FIELD SUBJECT**

5 Binar Kurnia Prahani, Iqbal Ainur Rizki, Khoirun Nisa', Nina Fajriyah Citra,
6 Hanau Zaki Alhusni

7 Universitas Negeri Surabaya (Indonesia)

8 binarprahani@unesa.ac.id

9 **Abstract**

10 The magnetic field is a more complex and abstract physics subject than other physics subjects, causing
11 students' low ability to solve problems. So there is a need for learning instruments to overcome these
12 problems, especially when online learning during the Covid-19 pandemic. This research creates and
13 implements an online model of problem-based learning assisted by digital books with 3D animation to
14 improve students' physics problem-solving skills on magnetic field subjects. This study aimed to analyze
15 the validity, effectiveness, and student responses to the learning instruments used. The method used in
16 this research is quantitative by using quasi-experiment and survey methods. The results showed that this
17 learning instrument was valid and reliable to use in terms of content and constructs. According to
18 statistical test results, this learning instrument is also effective in improving students' problem-solving
19 skills on magnetic field subjects. Furthermore, the student's response to this learning instrument was very
20 positive, making this learning activity more innovative and fun. This research implies that an online
21 problem-based learning model assisted by digital books with 3D animation instruments can be a solution
22 to improve students' physics problem-solving skills, especially during the online learning period.

23 Keywords: Digital book with 3D animations, Online problem-based learning, Magnetic field, Problem-
24 solving skills.

25 **1. Introduction**

26 Problem-Solving Skills (PSS) is one of the important skills needed by students in facing the challenges and
27 demands of the 21st century (Dewi et al., 2017; Ghafar, 2020; Mohd-Yusof et al., 2011; Nurdyansyah et
28 al., 2021; Parno et al., 2020; Ridhwan et al., 2020; Suhirman et al., 2020). This is because PSS can train
29 students in observing, reasoning, analyzing, and thinking creatively to help them solve everyday problems
30 (Devanti et al., 2020). In addition, PSS is essential in physics subjects to improve students' conceptual
31 understanding because it prioritizes contextual understanding (Hudha et al., 2017).

32 In reality, sometimes students have difficulty developing their knowledge in solving a problem (Umara,
33 2019). This is evidenced by the preliminary test results on 59 students, which showed that 52 (88.13%)
34 students had low PSS scores. One of the reasons is the difficulty of visualization, which can obstruct the
35 problem-solving process because there are some abstract and microscopic physics subjects (Cai et al.,
36 2021; İbili et al., 2020), such as magnetic field subjects. Students' PSS tend to be low and have many
37 misconceptions in this subject because of their high complexity and abstraction (Bestiantono et al., 2019;
38 Turgut et al., 2016; Yilmaz & Ince. Furthermore, magnetic field subject is a prerequisite subject for
39 electromagnetic induction with many applications in everyday life, such as power plants, fans, dynamos,
40 and generators. Therefore, students' low understanding of concepts will affect their ability to solve a

41 problem (Gultepe et al., 2013). Consequently, it is necessary to have a learning media that can visualize
42 students on microscopic materials, one of which is a digital book with 3D animations.

43 Currently, the use of digital books as physics learning media has run into a rapid increase and is very much
44 needed when online learning during the Covid-19 pandemic (Abtokhi et al., 2021; Kholiq, 2020; Saraswati
45 et al., 2021). Digital books are electronic versions of printed books that can be read through a device with
46 a specific purpose (Siegenthaler et al., 2010), in this case is to improve the quality of physics learning.
47 Digital books have many advantages, including practical, simple, interactive, and flexible, so it can be
48 integrated with other media such as 3D animation visualization (Siregar et al., 2021). 3D animation will
49 help students provide a clear picture and understanding of a process (Wu & Chiang, 2013). For example,
50 in the abstract magnetic field material, 3D animation can help students clearly visualize the concept of a
51 magnetic field. Therefore, the integration of 3D animation in digital books can be applied in physics
52 learning, especially on abstract and microscopic materials. However, using digital book media with 3D
53 animations requires a supporting learning model that can simultaneously improve students' PSS, one of
54 which is the *problem-based learning* (PBL) model (Chamidy et al., 2020; Surur et al., 2020).

55 PBL is a relevant learning model with the curriculum in Indonesia because it is a student-oriented learning
56 system (Anazifa & Djukri, 2017; Demirel & Dağyar, 2016). Furthermore, this learning model uses a real-
57 life problem as a basis to train students to solve the problems they face (L. Liu, 2017; Setyawan et al.,
58 2020). This is supported by (Simanjuntak et al., 2021; Suastra et al., 2019; Yetri et al., 2019; Yuberti et al.,
59 2019) research which shows that the PBL model is effective in improving students' PSS in physics material.
60 However, during the Covid-19 pandemic, the learning system was done online; thus this learning model
61 was called 'online PBL.' There is no significant difference between online PBL and conventional PBL, and
62 the difference only lies in the use of media and technology used during learning (Erickson et al., 2021).
63 However, the research results by (Dinata et al., 2020) show that Online PBL is more efficient than
64 conventional PBL with the same learning outcome.

65 Previous research has been conducted by (Bakri et al., 2019; Bogusevski et al., 2020; Dimitrienko &
66 Gubareva, 2018; X. Liu et al., 2019; Pirker et al., 2019; Sannikov et al., 2015; Thees et al., 2020) have
67 implemented physics learning media based on 3D visualization in the form of augmented reality and
68 virtual reality. However, when implemented in online learning, the weakness of this media is expensive
69 and requires too many devices to display the visualization. In addition, this research also has not
70 integrated visualization media in specific learning models. There is still no research integrating the PBL
71 model with a digital book with 3D animations/visualization in physics learning.

72 A preliminary survey conducted on 61 research students showed that 39 (63.9%) students stated that the
73 teacher's teaching method when learning online only gave assignments. Furthermore, while the learning
74 media used during online learning, 40 (65.6%) students stated that the contents were not understood, 23
75 (37.7%) students stated that they had difficulty accessing learning media, 11 (18%) students stated that
76 they lacked image visualization regarding the material. Based on the survey, it can be seen that students
77 need more engaging, innovative teaching methods and easy-to-understand learning media, easily
78 accessible, and can provide exciting visualizations of the subject being taught. Supported by a follow-up
79 survey that 7 (11.5%) students strongly agreed, 40 (80.3%) students agreed that online PBL assisted by
80 digital book with 3D animation media needs to be implemented in physics learning.

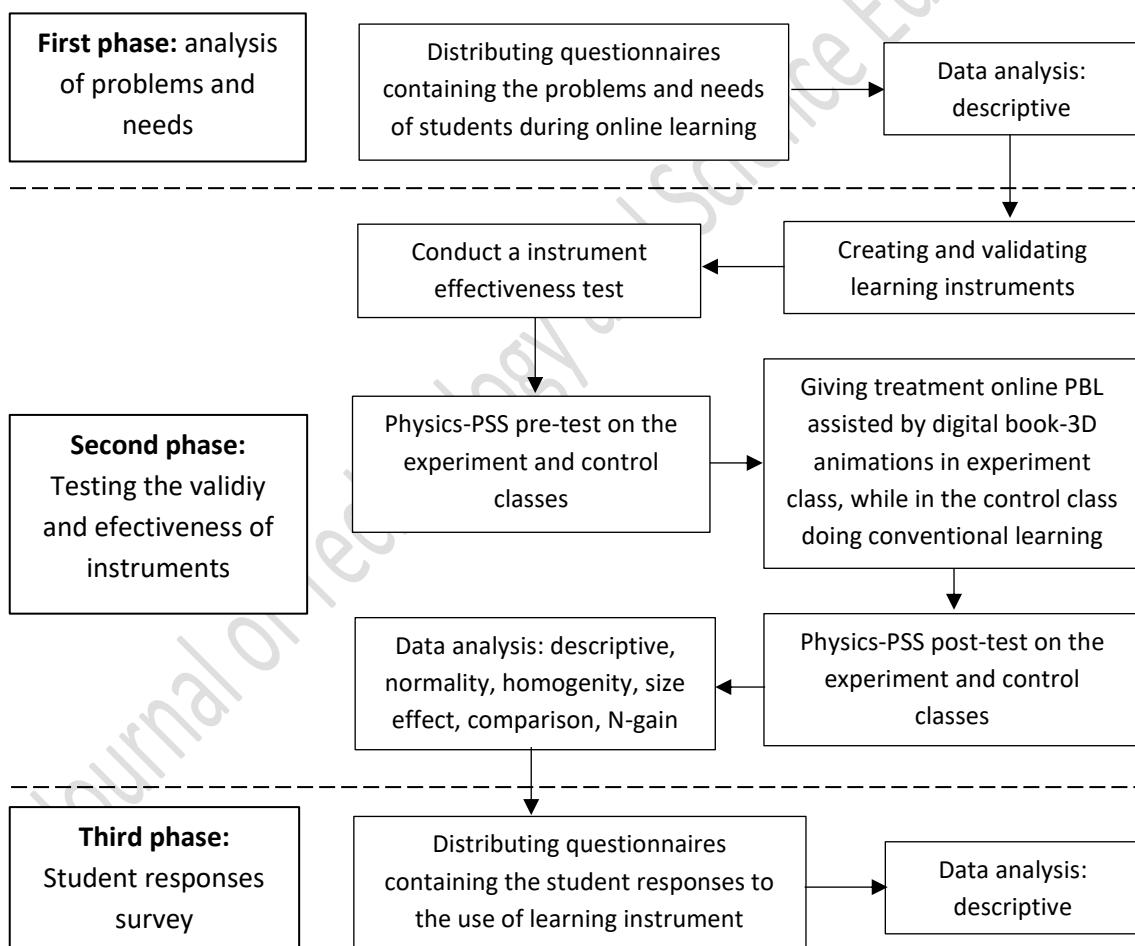
81 Therefore, this research will create and implement an online PBL model assisted by a digital book
82 application assisted with 3D animations so that it is more attractive and can provide learning material
83 visualization to students. This is done to optimize the achievement of students' PSS in physics learning,
84 especially in the Magnetic Field material. With this integrated learning model and media, it is hoped to
85 improve students' physics-PSS as one of the important skills in the 21st century. This study aims to analyze

86 the validity, effectiveness, and student responses to the use of online PBL assisted by digital books with
87 3D animations to improve the ability to solve physics problems on magnetic field materials.

88 **2. Design/methodology/approach:**

89 The research was conducted at SMAN 1 Bangkalan (Madura, Indonesia) during September-October 2021
90 with the learning system applied at school is online learning. The research method used is quantitative.
91 The sample in this study was 65 students of 11th-grade class, consisting of two classes from eight existing
92 classes. However, when data collection has a different number of samples. It is difficult to control the
93 sample because all data collection is done online, and some samples are easily lost. In this study, the
94 sampling technique used was random cluster sampling because the school randomly chose the two
95 classes.

96 This research is divided into three phases of data collection, namely 1) analysis of problems and needs; 2)
97 testing the instrument's effectiveness; 3) evaluation of student responses with the steps as in Figure 1.
98 Each phase is described as follows.



99

100 Figure 1. Stages of research diagram

101 **2.1 First Phase: Analysis of Problems and Needs**

102 This phase was carried out to know the problems in learning physics experienced by students during
103 online learning. In addition, the need for relevant models and learning media can be seen so that online
104 PBL assisted by digital books with 3D animation can be an alternative solution in solving the problems

105 faced. Data collection this phase was carried out using a survey method by distributing questionnaires
106 containing the problems and needs of students during online learning. The sample obtained in this study
107 was 61 students (n=61). The research data were then analyzed descriptively to find out the problems and
108 needs of students.

109

110

111 **2.2 Second Phase: Testing the Validity and Effectiveness of Instruments**

112 Research Design

113 The second phase uses a quasi-experimental type with a non-equivalent control group design (Creswell &
114 Creswell, 2018). The study was conducted in two classes with different treatments, namely the
115 experimental and control classes. At first, both classes were given a pre-test, then given different
116 treatments between them as shown in Table 1. After that, a post-test was given at the end of the lesson.
117 The difference between the two classes only lies in the treatment. Other things, such as materials,
118 curriculum, number of meetings, class hours, and teacher, have the same design. The subject used in this
119 study is a magnetic field. In addition, schools implement the Covid-19 Pandemic Emergency Curriculum
120 with the same allocation of lesson hours but on different days. The number of meetings in both classes is
121 also the same, namely three meetings, and has the same teacher.

Class	Pre-test	Treatment	Post-test
XI MIPA 3 (Experiment)	O_1	X	O_2
XI MIPA 5 (Control)	O_3	-	O_4

122 Note:

O_1 = Pre-test experimental class O_3 = Pre-test control class
 O_2 = Post-test experimental class O_4 = Post-test control class
X = treatment (online PBL assisted digital book)

123 **Table 1.** The difference in treatment between the experimental class and the control class

124 Sample

125 The research sample in the second phase only if students work on pre- and post-test questions, 59
126 students (n = 59) with details: in the experimental class are 29 students, while in the control class are 30
127 students. So that the sample has almost the same number in the experimental class and control class.

128

129 Instruments

130 In this study, several instruments were used: learning implementation plans, digital books with 3D
131 animation, test instruments (pre- and post-test), and expert validation questionnaires.

132 1. Lesson Plans

133 The lesson plans consist of several components: the syllabus, lesson plans, and assessments. The learning
134 syllabus in both classes is adjusted to the current curriculum at school, but the lesson plans in both classes
135 have differences in their learning approaches. The experimental class uses online PBL with five syntaxes,
136 namely: 1) problem orientation; 2) organizing students; 3) guiding group investigations; 4) developing and
137 presenting works and exhibitions; and 5) analyzing and evaluating the problem-solving process; the
138 learning activities can be seen in Table 2 (Arends, 2011). The full syntax can not be separated from the
139 assist of digital books with 3D animation. In the control class, learning is conducted conventionally,
140 consisting of observing magnetic field phenomena, listening to written learning on theories, concepts,
141 and examples of phenomena, working on questions, and discussing with class members. While the
142 assessment is carried out by focusing on students' PSS with the ACCES rubric, namely A) Assen the
143 problem; C) Create a drawing; C) Conceptualize the strategy; E) Execute the solution; S) Scrutinize your

144 result (Teodorescu et al., 2013). Each rubric is assessed based on three categories: correct, logical, and
 145 systematic. All learning activities are carried out online using Whatsapp media because the location of
 146 students is constrained by the internet network, so that there is no video conference in all learning in both
 147 classes.

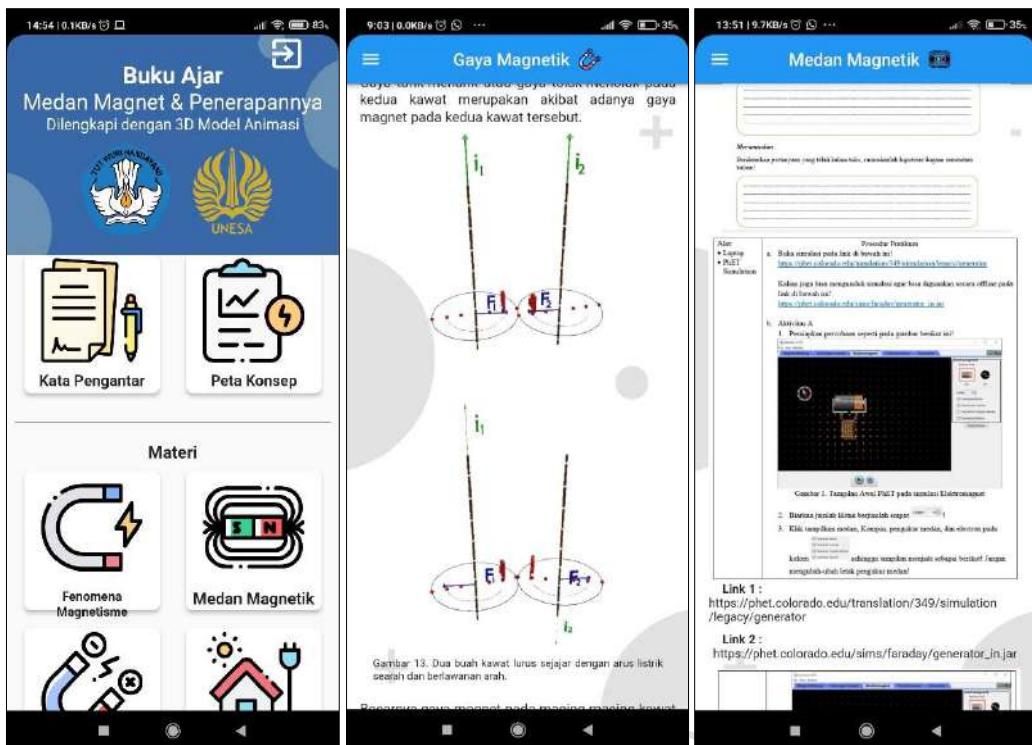
Syntax	Activity		PSS Indicator
	Teacher	Student	
Problem orientation	<ol style="list-style-type: none"> 1. Prepare learning instruments, especially the digital book with 3D animation (DB3DA). 2. Introduce the magnetic field subject and its importance to learning. 3. Orientation to magnetic field problems through contextual phenomena seen in DB3DA. 	<ol style="list-style-type: none"> 1. Download and install the DB3DA application. 2. Listen to the teacher's explanation of the magnetic field subject. 3. Observe and understand the problems to be solved. 	A
Organizing students	<ol style="list-style-type: none"> 1. Divide students into several groups. 2. Ensure students can understand the problem and the problem-solving process 	<ol style="list-style-type: none"> 1. Create groups based on the teacher's instruction. 2. Begin to develop strategies in problem-solving, assisted by BD3DA. 	A, C ₂
Guiding group investigations	Guides students in the problem-solving process through the student worksheet contained in the DB3DA	Conduct investigations, collect data, analyze ways of solving problems (more directed to DB3DA).	C ₁ , C ₂ , E
Developing and presenting works and exhibitions	Monitor discussions and guide problem-solving reports as in the instructions in the DB3DA.	Conduct discussions to produce alternative problem-solving, make reports, and present their ideas	E, S
Analyzing and evaluating the problem-solving process	<ol style="list-style-type: none"> 1. Evaluation and reflection on the results of problem-solving that has been done by students. 2. Conclude the magnetic field learning subject based on BD3DA. 	<ol style="list-style-type: none"> 1. Evaluation of the extent of their acquired understanding. 2. Listen to the conclusion and ask if there are still confused 	S

148 Note: A (Assen the problem); C₁ (Create a drawing); C₂ (Conceptualize the strategy); E (Execute the
 149 solution); S (Scrutinize your result)

150 Table 2. Learning activities in the experimental class (Adapted from Arends, 2011)

151 2. Digital book with 3D animation

152 This book has extension .apk in the form of an application installed via mobile phones with a file size of
 153 67 MB. The application can be accessed offline to minimize network constraints during online learning.
 154 However, this digital book also has weaknesses, such as being not yet integrated with practical simulations
 155 and being less interactive. After the pre-test, this digital book set was used as a treatment for the
 156 experimental class. Some pictures of digital books can be seen in Figure 2. To access this digital book
 157 application, [click here](#).



158
 159 Figure 2. Some screenshots of digital book products with 3D animation.
 160 3. Test instrument
 161 The test instrument consists of two types, pre- and post-test, but both have similarities in the tested
 162 questions. This was done to determine the increase in the PSS of students in the experimental and control
 163 classes. Five questions are tested with the description questions with each ACCES rubric in each number.
 164 Each rubric will be assessed based on correct, logical, and systematic indicators. For example, if the
 165 student's answer represents the three indicators, the student gets a score of 3. If the student's answer
 166 only represents two indicators, then the student gets a score of 2, and so on until the student's answer
 167 does not meet all of the criteria will get a score of 0.

168 4. Expert validation questionnaire
 169 Expert validation questionnaire aims to determine the validity of the content and construct validity of the
 170 learning instruments used, namely the learning implementation plan and the application of digital books.
 171 Validation was carried out by three experts majoring in physics education.
 172
 173 Data Analysis

174 The validity of PBL online learning assisted by digital books with 3D animation models is determined using
 175 experts' average score of the assessment results. After that, the average assessment results will be
 176 adjusted according to the criteria in Table 3 (Erika et al., 2018; Limatahu et al., 2018). In addition, the
 177 instrument's reliability is also assessed using the Cronbach's Alpha coefficient value, namely if the value
 178 of > 0.7 , the instrument can be said to be reliable (Taber, 2018).

179 The effectiveness of these learning instruments is analyzed based on the determined assessment before
 180 and after learning. The instruments can be said to be effective if it meets the following criteria: 1) the
 181 average score of PSS is at least moderate; 2) there is a significant difference in the improvement of
 182 students' PSS abilities; 3) the effect size for the experimental class is at least medium effect; 4) the
 183 minimum n-gain value is middle for the experimental class; and 5) there is a significant difference between
 184 the experimental class and the control class (Prahani et al., 2020). Determination of the value of the PSS
 185 score is done by using descriptive statistics on the pre- and post-test scores. First, the PSS scores were
 186 adjusted based on the criteria in Table 3 (Cindikia et al., 2020). After that, the pre-, post-test, and n-gain
 187 data were analyzed using inferential statistics reviewed for normality using Shapiro-Wilk and homogeneity

188 using Levene Statistic. Finally, paired t-test/Mann-Whitney was performed for the pre-, post-test, and n-
 189 gain values in the experimental and control classes to increase PSS. The N-gain value was determined by:
 190 (post-test score – pre-test score)/(3 – pre-test score) and the results were adjusted according to the
 191 criteria according to Hake as shown in Table 3 (Hake, 1999). In addition, the size of the effect was
 192 determined using Cohen's d-effect size to see the impact of field operations as shown in Table 3 (Morgan
 193 et al., 2012).

Validity Criteria		PSS Criteria		Hake's N-gain		Cohen's d-effect size	
Average Score Validity	Criteria	Score	Criteria	N-gain	Category	D-effect	Category
$3.25 < N \leq 4.00$	Very Valid	0 – 1,0	Low	$g < 0.3$	Low	≥ 1.00	Very Large
$2.50 < N \leq 3.25$	Valid	1,01 – 2,0	Medium	$0.3 \leq g < 0.7$	Middle	0.8	Large
$1.75 < N \leq 2.50$	Less Valid	2,1 – 3,0	High	$g \geq 0.7$	High	0.5	Medium
$1.00 \leq N \leq 1.75$	Invalid					0.2	Small

194 Table 3. The category of learning instrument validity criteria, PSS scoring, Hake's N-gain, and Cohen's d-
 195 effect size

196 **Third Phase: Student Response Survey**

197 This phase was conducted to know student responses to online PBL assisted by the digital book with 3D
 198 animation learning instruments that have been used during learning. Data was collected using the survey
 199 method by distributing questionnaires to the experimental class. This is because only the experimental
 200 class uses these learning instruments. The questionnaire contains ten questions that describe the use of
 201 the instrument to increase the ability of PSS in students. The research sample that filled out the
 202 questionnaire was 32 students ($n = 32$), so there were differences with the second phase. However,
 203 according to attendance results, it turns out that all students in the experimental class always attend every
 204 learning meeting. The results of student responses were analyzed descriptively quantitatively and
 205 adjusted to the following criteria: (1) Response 75% (very positive); (2) 50% Response < 75% (positive); (3)
 206 25% Response < 50% (less positive); and (4) Response < 25% (not positive) (Limatahu et al., 2018; Prahani
 207 et al., 2015).

208 **3. Result and Discussion**

209 **3.1 Validity**

210 Three physics education experts assessed the validity of online PBL assisted by digital book-3D animations
 211 books learning. The instruments assessed are the content and constructs of the lesson plan and the
 212 application of digital books with the assessment results, as shown in Table 4. The assessment of the
 213 content of the lesson plan includes learning steps, conformity with PBL syntax, suitability of the
 214 assessment system with learning objectives, and suitability of time allocation. Assessment of digital book
 215 application content includes the order of delivery of material, practice questions according to indicators,
 216 text, images, and 3D models to support understanding of the material. The assessment of the lesson plan
 217 construct includes the use of language, that is good, correct, clear, and does not cause double
 218 understanding. The digital book application construct assessment includes ease of use of the application,
 219 application appearance, application design, suitability of using 3D animation, clarity of 3D animated
 220 images, and attractiveness of 3D animation design. The validation results show that all aspects have valid
 221 criteria. The same as the reliability value, all aspects are reliable.

Component	Validity and reliability of Online PBL assisted by digital book-3D animation			
	Score	Validity	α	Reliability
<i>Content Validity</i>				
1. Content validity of lesson plan	3.388	Very Valid	0.714	Reliable
2. Content validity of digital book	3.481	Very Valid	0.898	Reliable
<i>Construct Validity</i>				
1. Construct validity of lesson plan	3.333	Very Valid	0.938	Reliable

2. Construct validity of digital book	3.627	Very Valid	0.701	Reliable
---------------------------------------	-------	------------	-------	----------

222 Note: α = Cronbach Alpha

223 Table 4. The results of the assessment of the validity of the instruments by the expert

224 This learning instrument has a novelty in PBL implementation assisted by digital books with 3D animation.
 225 Unlike PBL in general, which requires student worksheets and teaching materials, these two instruments
 226 are already integrated with a digital book, so this digital book application contains complete instruments.
 227 This application has also been integrated with simulation guidelines to assist the problem-solving process.
 228 If all learning instruments can be integrated into one application, this can further optimize the learning
 229 process (Herayanti et al., 2017). The involvement of the digital book application can be seen from its
 230 occurrence in every process in the PBL learning syntax. According to the validator, this learning instrument
 231 is generally valid and feasible to assess the next aspect (effectiveness) after minor revisions have been
 232 made (Plomp, 2013). After corrections were made based on their recommendations, the online PBL model
 233 learning assisted by digital books with 3D animations to improve physics-PSS could be implemented for
 234 SMAN 2 Bangkalan students.

235 **3.2 Effectiveness**

236 To determine the effectiveness of PBL online learning assisted by 3D digital-animated books can be seen
 237 in Table 5, Table 6, Table 7, and Table 8 with the following explanation.

Group	N	Lowest Score			Highest Score		
		<i>Pre-test</i>	<i>Post-test</i>	<i>Average</i>	<i>Pre test</i>	<i>Post test</i>	<i>Average</i>
<i>Experiment</i>	29	0.51	1.35	0.82	1.20	2.64	2.32
<i>Control</i>	30	0.04	0.28	0.47	1.24	2.17	1.26

238 Table 5. Results of descriptive statistical calculations: lowest, highest, and average scores average in both
 239 classes

240 Based on Table 5, it can be seen that there are differences in the pre-test and post-test abilities in both
 241 the experimental and control classes. In the experimental class, the lowest pre-test PSS score was 0.51,
 242 and the highest was 1.20, while the lowest post-test PSS score was 1.35, and the highest was 2.64. There
 243 is also a difference in the pre-test average PSS score is 0.82, while the post-test is 2.32. In the control class,
 244 the lowest PSS score in the pre-test is 0.04, and the highest is 1.24, while the lowest PSS score in the post-
 245 test is 0.28 and the highest is 2.17. In addition, there is also an average difference in the pre-test, which
 246 is 0.47, while in the post-test is 1.26. The low pre-test score is caused by students who still do not
 247 understand the tested material and do not have PSS in solving physics problems. In line with the research
 248 results by (Cindikia et al., 2020; Jua et al., 2018), Indonesian students' physics PSS is still relatively low. But
 249 when on post-test scores, there was an increase in PSS scores in both classes because students had
 250 learned about the subject being tested (magnetic field). When compared between the experimental class
 251 and the control class, there is a difference in values where the experimental class has a higher PSS value
 252 than the control class, especially in the post-test. This is due to the difference in treatment between the
 253 two classes, where the experimental class uses an online PBL model assisted by digital books with 3D
 254 animation, while the control class uses conventional learning.

255 The normality test results showed that the data were not normally distributed in the experimental class,
 256 while the data were normally distributed in the control class. This is due to the online treatment of PBL
 257 with the digital book with 3D animations, which causes the data to skew to the right, or most of the
 258 students' scores are high. In addition, the homogeneity test results indicate that the data is not
 259 homogeneous. Therefore, Mann-Whitney non-parametric statistical inferential analysis ($\alpha = 5\%$) was used
 260 to determine the difference between the two classes.

Shapiro-Wilk Normality Test			
Group	Test	p (Sig.)	Distribution
<i>Experiment Class</i>	<i>Pre-test</i>	0.003	<i>Not Normal</i>
	<i>Post-test</i>	0.000	<i>Not Normal</i>

<i>Control Class</i>	<i>Pre-test</i>	0.025	<i>Normal</i>
	<i>Post-test</i>	0.317	<i>Normal</i>
Levene Statistic Homogeneity Test			
<i>Test</i>	<i>Number of Sample</i>	<i>p (Sig.)</i>	<i>Homogeneity</i>
<i>Pre-test</i>	59	0.002	<i>Not Homogenous</i>
<i>Post-test</i>		0.020	<i>Homogenous</i>
Mann-Whitney Test			
<i>Group</i>	<i>p (sig.)</i>	<i>Hypothesis</i>	
<i>Experiment Class</i>	0.000	<i>There is a significant difference between the pre-test and post-test scores</i>	
<i>Control Class</i>	0.000		
Cohen's d-effect size			
<i>Group</i>	<i>d-effect size</i>	<i>Category</i>	
<i>Experiment Class</i>	1.95	<i>Very Large</i>	
<i>Control Class</i>	1.63	<i>Very Large</i>	

261 Table 6. The test results of Shapiro-Wilk normality, Levene statistic homogeneity, Mann-Whitney, and
 262 Cohen's d-effect size for both classes

263 Based on the results of the Mann-Whitney test as shown in Table 6, it can be seen that the
 264 significance value is $p < 0.05$ so that the hypothesis is accepted. It means a significant difference between
 265 the pre- and post-test results in both classes. This is because there are differences in students'
 266 understanding who initially had not learned about the magnetic field subject. After being given treatment
 267 and learning about the subject, students understood the material and increased learning outcomes. In
 268 line with several research results, using the PBL model can improve their learning outcomes (Amini et al.,
 269 2019; Kawuri et al., 2019; Qomariyah, 2019). If viewed from the effect size, it can be seen that both classes
 270 have a very large effect category. But the experimental class has a higher value than the control class. This
 271 is because in the experimental class, learning focuses more on solving problems using the PBL model
 272 assisted by digital book with 3D animations. While the control class only uses conventional learning. In
 273 line with (Kapi et al., 2017) research, visual media can display more real physical phenomena. The use of
 274 multimedia aims to facilitate learning physics and change the paradigm of students who do not realize
 275 that many everyday events related to physics can encourage students to be actively involved in the
 276 thinking process by linking learning and real-life situations (Jabaliah et al., 2021; Liew & Tan, 2016;
 277 Warsono et al., 2020). The use of digital book media in the experimental class can increase student
 278 learning activities so that students are more motivated than learning in conventional classes (Iskandar et
 279 al., 2018).

<i>Group</i>		<i>Indicators of PSS</i>									
		<i>A</i>		<i>C₁</i>		<i>C₂</i>		<i>E</i>		<i>S</i>	
<i>EC</i>	<i>O₁</i>	0.8	<i>L</i>	0.5	<i>L</i>	0.9	<i>L</i>	1.0	<i>L</i>	0.5	<i>L</i>
	<i>O₂</i>	2.6	<i>H</i>	2.0	<i>M</i>	1.6	<i>M</i>	2.6	<i>H</i>	1.9	<i>M</i>
	<i><g></i>	0.8	<i>H</i>	0.6	<i>M</i>	0.4	<i>M</i>	0.8	<i>H</i>	0.5	<i>M</i>
<i>CC</i>	<i>O₃</i>	0.9	<i>L</i>	0.5	<i>L</i>	0.4	<i>L</i>	0.5	<i>L</i>	0.0	<i>L</i>
	<i>O₄</i>	2.4	<i>H</i>	1.4	<i>M</i>	0.8	<i>L</i>	0.5	<i>L</i>	1.0	<i>L</i>
	<i><g></i>	0.6	<i>M</i>	0.3	<i>M</i>	0.1	<i>L</i>	0.0	<i>L</i>	0.3	<i>M</i>

280 Note:

281 *EC* (Experiment Class); *CC* (Control Class); *O₁* (Pre-test experimental class); *O₂* (Post-test experimental
 282 class); *O₃* (Pre-test control class); *O₄* (Post-test control class); *A* (Assen the problem); *C₁* (Create a drawing);
 283 *C₂* (Conceptualize the strategy); *E* (Execute the solution); *S* (Scrutinize your result); *L* (Low); *M* (Middle); *H*
 284 (High)

285 Table 7. The increase in PSS for each indicator in both classes.

286 In more detail, the increase in PSS for each indicator in both classes can be seen in Table 7. It can be seen
 287 that the results of the pre-test on all PSS indicators for both classes are in a low category. After applying
 288 the online PBL model assisted by digital books in the experimental class, there was an increase in N-gain

289 for all skills into middle and high categories. Increased smallest N-gain contained in the Conceptualize the
 290 Strategy (C₂) indicator. For this indicator, the students are still using strategies by applying the equation
 291 only to solve the problems as generally taught in the classroom. In line with the research results (Ceberio
 292 et al., 2016; Reddy & Panacharoensawad, 2017; Riantoni et al., 2017), students tend not to use physics
 293 concepts to solve problems and only use memorized equations. But they can answer correctly on the
 294 Execute the Solution (E) indicator because some of the students copy each other's answers which are
 295 indicated by the similarity of their answers. As a result, on the Scrutinize your result (S) indicator has the
 296 smallest N-gain second after C₂. While online tests, students more easily cheat on each other, so they
 297 become less confident about their work results (Cindikia et al., 2020). In the control class, the increase in
 298 the N-gain value for each indicator is smaller than the experimental class because this class uses
 299 conventional learning. The lowest increase in N-gain is found in the Execute the Solution (E) indicator
 300 because students cannot apply problem-solving skills in executing solutions to the problems asked.

301 The comparison of the average N-gain results in the experimental class with the control class can be seen
 302 in Table 8. It can be seen that the average N-gain value between the experimental class is 0.688 including
 303 the middle criteria, while in the control class is 0.282 including in the low criteria. So, the N-gain value of
 304 the PSS students in the experimental class is greater than the control class. Furthermore, the results of
 305 the normality test on the N-gain data of both classes showed that the experimental class was not normally
 306 distributed, while the control class had a normal distribution. This is because the N-gain value in the
 307 experimental class is skewed to the right, which means more high-value data. Furthermore, the
 308 homogeneity test results showed that the data were homogeneously distributed. Thus, to determine the
 309 significance of the difference between the N-gain of the two classes, non-parametric inferential statistics
 310 were used, namely the Mann-Whitney test.

Group	Descriptive Statistic		Shapiro-Wilk Normality Test		Levene Statistic Homogeneity Test		Mann-Whitney Test
	Average N-Gain	Criteria	p (Sig.)	Distribution	p (Sig.)	Criteria	p (Sig.)
EC	0.688	Middle	0.000	Not Normal	0.091	Homo-geneous	0.000
CC	0.282	Low	0.601	Normal			

311 Note: EC (Experiment Class); CC (Control Class)

312 Table 7. The test result of descriptive stasistic, Shapiro-Wilk normality, Levene statistic, and Mann-
 313 Whitney for increasing PSS in both classes

314 It can be seen that the p-value < 0.05, which means that there is a significant difference in the N-gain
 315 value between the experimental class and the control class statistically. This is because online PBL models
 316 assisted by digital books with 3D animation can help students improve their PSS. The PBL model that
 317 focuses on problem-solving makes students accustomed to solving problems and applying them to physics
 318 problems. In addition, in learning activities, students are given assignments in the form of physics
 319 questions that must be done in stages with problem-solving indicators. Students who receive online PBL-
 320 based learning also have PSS to easily answer physics problems compared to conventional learning
 321 models who are not trained in problem-solving. In line with some research results that PBL emphasizes
 322 more on PSS aspects such as analyzing in choosing the right concepts and principles needed in solving
 323 problems so that it is better than conventional classes (Docktor et al., 2015; Docktor & Mestre, 2014;
 324 Parno et al., 2019; Valdez & Bungahan, 2019). This is also reinforced by the John Dewey learning theory
 325 that the class should be a laboratory in solving real-life problems (Arends, 2011). In addition, PBL is also
 326 based on cognitive constructivism learning theory by Piaget that through the PBL model, students can
 327 actively construct their own knowledge by interacting with their environment through the assimilation
 328 and accommodation process (Arends, 2011). PBL is also reinforced by Vygotsky which reveals that the
 329 learning process will occur when students work in the Zone of Proximal Development (Schunk, 2011).
 330 During problem-based learning, students will be in a top-down process, where students start with
 331 complex problems to solve and then solve or find (with the teacher's help) the basic skills needed (Slavin,
 332 2011). The results of this study are also supported by Bruner's discovery learning theory, where students
 333 are required to be active in solving existing problems and are assisted by teachers to provide scaffolding
 334 (Moreno, 2010).

336 Digital books also support the online PBL model with 3D animations that make it easier for students to
337 understand the concept because the animation can help students visualize abstract and complex
338 magnetic field subjects. In line with several studies showing that the use of 3D animation can improve
339 visual understanding, cognitive understanding, and student learning outcomes (Bakar et al., 2019; Cai et
340 al., 2013; Dori & Belcher, 2005; Kumar, 2016; Mystakidis & Berki, 2018; Park et al., 2016). This digital book
341 can make physics learning better because the learning media used is the right mix of verbal channels (in
342 material text) and visuals (3D animated images). This is reinforced by the dual coding theory by Paivio that
343 information received by a person is processed through one of two channels, namely verbal and visual
344 channels that can function either independently, parallel, or integrated (Paivio, 2013).

345 In general, the results of the analysis on the effectiveness of the learning instruments show that 1) the
346 average problem-solving score of students in the experimental class is 2.32, which means it is in the high
347 category; 2) the increase in the PSS ability of students has a *p*-value of < 0.05 so that there is a significant
348 difference; 3) the effect size for the experimental class is 1.95, so it is included in the very large category;
349 4) the value of n-gain for the experimental class is middle.; and 5) between the experimental class and
350 the control class has a *p*-value < 0.05 so that there is a significant difference between the two. Thus, PBL
351 online learning assisted by digital books with 3D animation effectively increases students' physics-PSS on
352 magnetic field subjects.

353 **3.3 Student Responses**

354 The results of a survey of a sample of 32 students ($n = 32$) to find out their response to PBL online learning
355 activities assisted by digital books with 3D animation can be seen in Table 9. The calculation results show
356 that the category's average score agrees and strongly agrees by 80.60% while disagreeing and strongly
357 disagree by 19.40%. Thus, according to students, this learning activity is included in the very positive
358 criteria. The use of the online PBL model is a more innovative and exciting learning model because so far,
359 the learning that has been carried out has only focused on working on tasks independently so that
360 students are easily bored. Especially for learning physics which is considered complex and complicated by
361 them. In addition, the use of digital book applications with 3D animation is a new learning medium for
362 them to help create more enjoyable learning through the media provided.

Average Responses	Responses (%)			
	<i>Very Agree</i>	<i>Agree</i>	<i>Disagree</i>	<i>Very Disagree</i>
	16,25	64,35	16,59	2,81

365 Table 9. Average student responses in the experimental class regarding learning activities that have been
366 carried out

368 **3.4 Limitations, Recommendations, and Implications**

369 This research still has limitations, such as 1) still have not tested practically on the models and learning
370 media used; 2) the sample used is only two classes; 3) the validity assessment only focuses on lesson plans
371 and digital book products. In addition, there are also limitations in the products made, such as: 1) the size
372 of the application is still too big, so it requires a large enough storage space; 2) 3D animation is still less
373 interactive; 3) the application is not yet integrated with the practical simulation; 4) it is not known whether
374 it is compatible for all types of operating systems; 4) The material available is only Magnetic Field.

375 So that there are recommendations, including 1) conducting a practical test of the models and learning
376 media used; 2) increasing the number of research samples up to 4 classes; 3) conducting validity
377 assessments for other learning instruments, such as test instruments and survey questionnaires. There
378 are also recommendations for digital book application products: 1) compressing the file size to become
379 smaller; 2) making animations more interesting and interactive; 3) integrating applications with virtual
380 practicums; 4) performing compatibility tests for all kinds of operating systems.

381 This research implies that the results of the research product in the form of an online PBL model assisted
382 by the digital book with 3D animations can be applied by teachers in learning physics material during

383 online learning. It is hoped that the application of these products can improve students' PSS while at the
384 same time solving real-life problems that students will face related to the concept, especially in magnetic
385 field subjects.

386 **4. Conclusions**

387 It can be concluded that the online PBL model assisted with digital book applications with 3D animation
388 learning instruments to improve students' PSS on Magnetic Field material. This learning instrument meets
389 the validity aspect with very valid and reliable criteria both from the content component and the
390 construct. This learning instruments is also effective in improving students' PSS. The survey results to
391 students showed that students responded very positively to this learning instruments. We recommend
392 further researchers conduct practicality tests, develop applications, or test their effects on other 21st
393 century skills.

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395 The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or
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633

1 **IMPLEMENTATION OF ONLINE PROBLEM-BASED LEARNING**
2 **ASSISTED BY DIGITAL BOOK WITH 3D ANIMATIONS TO**
3 **IMPROVE STUDENT'S PHYSICS PROBLEM-SOLVING SKILLS IN**
4 **MAGNETIC FIELD SUBJECT**

5 **Abstract**

6 The magnetic field is a more complex and abstract physics subject than other physics subjects, ~~which~~
7 ~~causes-causing~~ students' low ability to solve problems. So there is a need for learning instruments to
8 overcome these problems, especially when online learning during the COVID-19 pandemic. Research
9 creates and implements an online problem-based learning (OPBL) assisted by digital books with 3D
10 animation to improve students' physics problem-solving skills on magnetic field subjects. Research aimed
11 to analyze the validity, effectiveness, and student responses to the learning instruments used. The
12 method used in this research is quantitative by using quasi-experiment and survey methods. The results
13 showed that this learning instrument was valid and reliable ~~for to~~ use in terms of contents and constructs.
14 According to statistical test results, this learning instrument is also effective in improving students'
15 problem-solving skills on magnetic field subjects. Furthermore, the student's response to this learning
16 instrument was very positive, making this learning activity more innovative and fun. Research implies that
17 an OPBL assisted by digital books with 3D animation instruments can be a solution to improve students'
18 physics problem-solving skills, especially during the online learning period.

19 Keywords: Digital book with 3D animations, Magnetic field, Online problem-based learning, Problem-
20 solving skills.

21 **1. Introduction**

22 Problem-Solving Skills (PSS) ~~are is one of the important skills for needed by~~ students ~~to have in order to~~
23 ~~in-facing~~ the challenges and demands of the 21st century (Ghafar, 2020; Mohd-Yusof et al., 2011;
24 Nurdyansyah et al., 2021; Parno et al., 2020; Ridhwan et al., 2020; Suhirman et al., 2020). PSS can train
25 students in ~~observation observing~~, reasoning, analyzing, and ~~creative~~ thinking ~~creatively~~ to help them
26 solve everyday problems (Devanti et al., 2020). In addition, PSS is essential in physics subjects to improve
27 students' conceptual understanding because it prioritizes contextual understanding (Hudha et al., 2017).

28 In reality, sometimes students have difficulty developing their knowledge ~~when in~~-solving a problem
29 (Umara, 2019). This is evidenced by the preliminary test results on 59 students, which showed that 52
30 (88.13%) students had low PSS scores. One of the reasons is the difficulty of visualization, which can
31 obstruct the problem-solving process because there are some abstract and microscopic physics subjects
32 (Cai et al., 2021; İbili et al., 2020), such as magnetic field subjects. ~~Because of the subject's high complexity~~
33 ~~and abstraction~~, students' PSS tend to be low and ~~they~~ have many misconceptions ~~it in this subject~~
34 ~~because of their high complexity and abstraction~~ (Bestiantono et al., 2019; Turgut et al., 2016; Yilmaz &
35 Ince, 2012). Furthermore, magnetic field subject is a prerequisite subject for electromagnetic induction
36 with many applications in everyday life, such as power plants, fans, dynamos, and generators. Therefore,
37 students' low understanding of concepts will affect their ability to solve a problem (Gultepe et al., 2013).
38 Consequently, it is necessary to have a learning media that can visualize students on microscopic
39 materials, one of which is a digital book with 3D animations.

40 Currently, the use of digital books as physics learning media has ~~seen run into~~ a rapid increase and is very
41 much needed when online learning during the COVID-19 pandemic (Abtokhi et al., 2021; Kholid, 2020;
42 Saraswati et al., 2021). Digital books are electronic versions of printed books that can be read ~~on through~~

43 a device with a specific purpose (Siegenthaler et al., 2010), in this case, ~~is~~ to improve the quality of physics
44 learning. Digital books have many advantages, including being practical, simple, interactive, and flexible,
45 so they it can be integrated with other media such as 3D animation visualization (Siregar et al., 2021a).
46 The 3D animation will help students provide a clear picture and understanding of the a-process (Wu &
47 Chiang, 2013). For example, in the abstract magnetic field material, 3D animation can help students clearly
48 visualize the concept of a magnetic field. Therefore, the integration of 3D animation in digital books can
49 be applied in physics learning, especially in on abstract and microscopic materials. However, using digital
50 book media with 3D animations requires a supporting learning model that can simultaneously improve
51 students' PSS, one of which is the Problem Based Learning (PBL) model (Chamidy et al., 2020; Surur et al.,
52 2020).

53 PBL is a relevant learning model with in the Indonesian curriculum in Indonesia because it is a student-
54 oriented learning system (Anazifa & Djukri, 2017; Demirel & Dağyar, 2016). Furthermore, this learning
55 model uses a real-life problem as a basis to train students to solve the problems they face (L. Liu, 2017;
56 Setyawan et al., 2020). It supported by Simanjuntak et al. (2021); Suastri et al. (2019); Yetri et al. (2019);
57 Yuberti et al. (2019) research which shows that the PBL is effective in improving students' PSS in physics
58 material. However, during the COVID-19 pandemic, the learning system was done online; thus this
59 learning model was called 'Online Problem Based Learning (OPBL).' There is no significant difference
60 between OPBL and conventional PBL, and the difference only lies in the use of media and technology used
61 during learning (Erickson et al., 2021). However, the research results by Dinata et al. (2020) show that
62 OPBL is more efficient than conventional PBL with the same learning outcome.

63 Previous research has been conducted by Bakri et al. (2019); Bogusevski et al. (2020); Dimitrienko &
64 Gubareva, (2018); X. Liu et al. (2019); Pirker et al. (2019); Sannikov et al. (2015); Thees et al. (2020) have
65 implemented physics learning media based on 3D visualization in the form of augmented reality and
66 virtual reality. However, when implemented in online learning, the weakness of this media is expensive
67 and requires too many devices to display the visualization. In addition, this research also has not
68 integrated visualization media into specific learning models. There is still no research integrating the PBL
69 with a digital book with 3D animations or visualizations in physics learning.

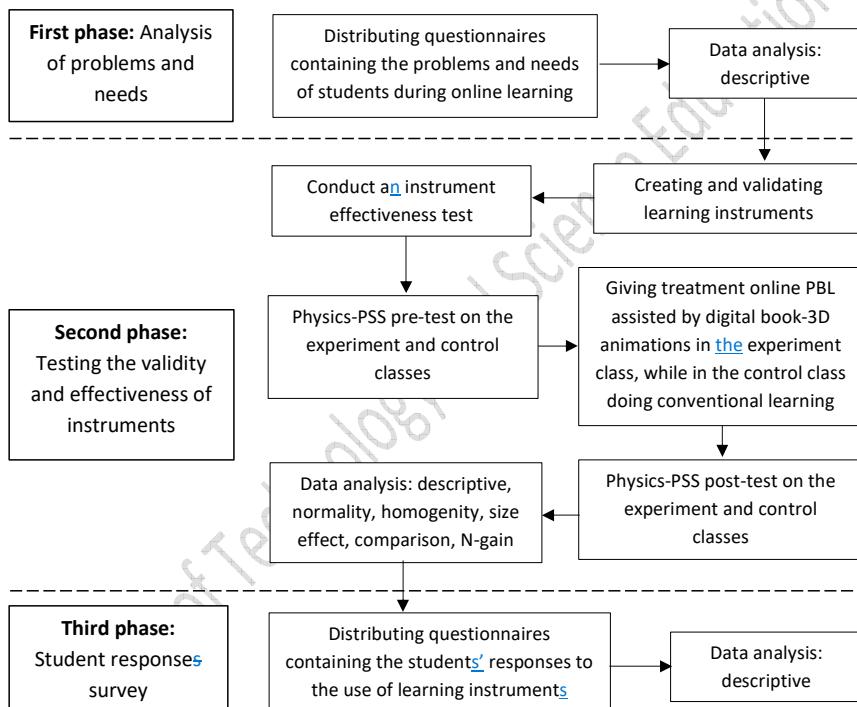
70 According to the A-preliminary research conducted on 61 research students, showed that 39 (63.9%)
71 students stated that the teacher's teaching method when learning online only gave assignments.
72 Furthermore, while using the learning media for used during online learning, 40 (65.6%) students stated
73 that the contents were not understood, 23 (37.7%) students stated that they had difficulty accessing
74 learning media, 11 (18%) students stated that they lacked image visualization of regarding the material.
75 Based on the survey, it can be seen that students need more engaging, innovative teaching methods and
76 easy-to-understand learning media, that are easily accessible, and can provide exciting visualizations of
77 the subject being taught. Supported by a follow-up survey that 7 (11.5%) students strongly agreed, 40
78 (80.3%) students agreed that OPBL assisted by digital book with 3D animation media needs to be
79 implemented in physics learning.

80 Therefore, this research will create and implement an OPBL assisted by a digital book application assisted
81 with 3D animations so that it is more attractive and can provide learning material visualization to students.
82 This is done to optimize the achievement of students' PSS in physics learning, especially in the Magnetic
83 Field material. With this integrated learning model and media, it is hoped to improve students' physics-
84 PSS as one of the important skills in the 21st century. This study aims to analyze the validity, effectiveness,
85 and student responses to the use of OPBL assisted by digital books with 3D animations to improve the
86 ability to solve physics problems on magnetic field materials.

87 **2. Methodology**

88 The research was conducted at State Senior High School 24 Bangkalan (i.e. Indonesia) during September-
89 October 2021 with the learning system applied at the school being is-online learning. The research method
90 used is quantitative. The sample in this study was 65 students from an an 11th-grade class, consisting of
91 two classes from eight existing classes. However, when data collection has a different number of samples.
92 It is difficult to control the sample because all data collection is done online, and some samples are easily
93 lost. In this study, the sampling technique used was random cluster sampling because the school randomly
94 chose the two classes.

95 This research is divided into three phases of data collection, namely: 1) analysis of problems and needs;
96 2) testing the instrument's effectiveness; and 3) evaluation of student responses with the steps as in
97 Figure 1. Each phase is described as follows.



99 Figure 1. Stages of research diagram

100 **2.1 First Phase: Analysis of Problems and Needs**

101 This phase was carried out to determine know the problems in learning physics experienced by students
102 during online learning. In addition, the need for relevant models and learning media can be seen so that
103 OPBL assisted by digital books with 3D animation can be an alternative solution to in solving the problems
104 faced. Data collection during this phase was carried out using a survey method by distributing
105 questionnaires containing the problems and needs of students during online learning. The sample
106 obtained in this research was 61 students ($n = 61$). The research data was were then analyzed descriptively
107 to find out the problems and needs of students.

108

109

110 **2.2 Second Phase: Testing the Validity and Effectiveness of Instruments**

111 *Research Design*

112 The second phase uses a quasi-experimental type with a non-equivalent control group design (Creswell &
113 Creswell, 2018). The study was conducted in two classes with different treatments, namely the
114 experimental and control classes. ~~At~~ first, both classes were given a pre-test, and then they were given
115 different treatments between them as shown in Table 1. After that, a post-test was given at the end of
116 the lesson. The difference between the two classes only lies in the treatment. Other things, such as
117 materials, curriculum, number of meetings, class hours, and teacherss, have the same design. The subject
118 used in this study is a magnetic field. In addition, schools implement the COVID-19 Pandemic Emergency
119 Curriculum with the same allocation of lesson hours but on different days. The number of meetings in
120 both classes have is also the same number of meetings per week, namely three meetings, and they have
121 has the same teacher.

Class	Pre-test	Treatment	Post-test
XI MIPA 3 (Experiment)	O_1	X	O_2
XI MIPA 5 (Control)	O_3	-	O_4

122 Note:

O_1 = Pre-test experimental class O_3 = Pre-test control class
 O_2 = Post-test experimental class O_4 = Post-test control class
 X = treatment (OPBL assisted digital book)

123 Table 1. The difference in treatment between the experimental class and the control class

124

125 *Sample*

126 The research sample in the second phase only if students work on pre- and post-test questions, 59
127 students ($n = 59$) with details: in the experimental class there are 29 students, while in the control class
128 there are 30 students. So that the sample has almost the same number in the experimental class and the
129 control class.

130

131 *Instruments*

132 In this study, several instruments were used: learning implementation plans, digital books with 3D
133 animation, test instruments (pre- and post-test), and expert validation questionnaires.

134 1. Lesson Plans

135 The lesson plans consist of several components: the syllabus, lesson plans, and assessments. The learning
136 syllabus in both classes is adjusted to the current curriculum at school, but the lesson plans in both classes
137 have differences in their learning approaches. The experimental class uses OPBL with five syntaxes,
138 namely: 1) problem orientation; 2) organizing students; 3) guiding group investigations; 4) developing and
139 presenting works and exhibitions; and 5) analyzing and evaluating the problem-solving process; the
140 learning activities can be seen in Table 2 (Arends, 2011). The full syntax cannot be separated from the
141 assistance of digital books with 3D animation. In the control class, learning is conducted conventionally,
142 consisting of observing magnetic field phenomena, listening to written learning on theories, concepts,
143 and examples of phenomena, working on questions, and discussing them with class members. While the
144 assessment is carried out by focusing on students' PSS with the ACCES rubric, namely (A) Asses the
145 problem; (C) Create a drawing; (C) Conceptualize the strategy; (E) Execute the solution; (S) Scrutinize your
146 result (Teodorescu et al., 2013). Each rubric is assessed based on three categories: correct, logical, and
147 systematic. All learning activities are carried out online using WhatsApp media because the location of
148 students is constrained by the internet network, meaning so that there is no video conference for in-all
149 learning in both classes.

Syntax	Activity		PSS Indicator
	Teacher	Student	
Problem orientation	<ol style="list-style-type: none"> 1. Prepare <u>the</u> learning instruments, especially the digital book with 3D animation (DB3DA). 2. Introduce the magnetic field <u>topic subject</u> and its <u>significance</u> in <u>importance to learning</u>. 3. Orientation to magnetic field problems through contextual phenomena seen in DB3DA. 	<ol style="list-style-type: none"> 1. Download and install the DB3DA application. 2. Listen to the teacher's explanation of the magnetic field subject. 3. Observe and understand the problems to be solved. 	A
Organizing students	<ol style="list-style-type: none"> 1. Divide <u>the</u> students into <u>several</u> groups. 2. Ensure <u>that</u>—students <u>can</u> understand the problem <u>as well as</u> <u>and</u> the problem-solving process 	<ol style="list-style-type: none"> 1. Create groups based on the teacher's instruction. 2. Begin <u>to</u>—developing <u>problem solving with the help of in problem-solving, assisted by</u> BD3DA. 	A, C ₂
Guiding group investigations	Guides students in the problem-solving process through the student worksheet contained in the DB3DA	Conduct investigations, collect data, analyze ways of solving problems (more directed <u>at</u> <u>to</u> DB3DA).	C ₁ , C ₂ , E
Developing and presenting works and exhibitions	Monitor discussions and guide problem-solving reports as in the instructions in the DB3DA.	Conduct discussions to produce alternative problem-solving, make reports, and present their ideas	E, S
Analyzing and evaluating the problem-solving process	<ol style="list-style-type: none"> 1. Evaluation and reflection on the results of problem-solving that has been done by students. 2. Conclude the magnetic field learning subject based on BD3DA. 	<ol style="list-style-type: none"> 1. Evaluation of the extent of their acquired understanding. 2. Listen to the conclusion and ask if there are still confused 	S

Note: A (Assen the problem); C₁ (Create a drawing); C₂ (Conceptualize the strategy); E (Execute the solution); S (Scrutinize your result)

Table 2. Learning activities in the experimental class (Adapted from Arends, 2011)

150

151

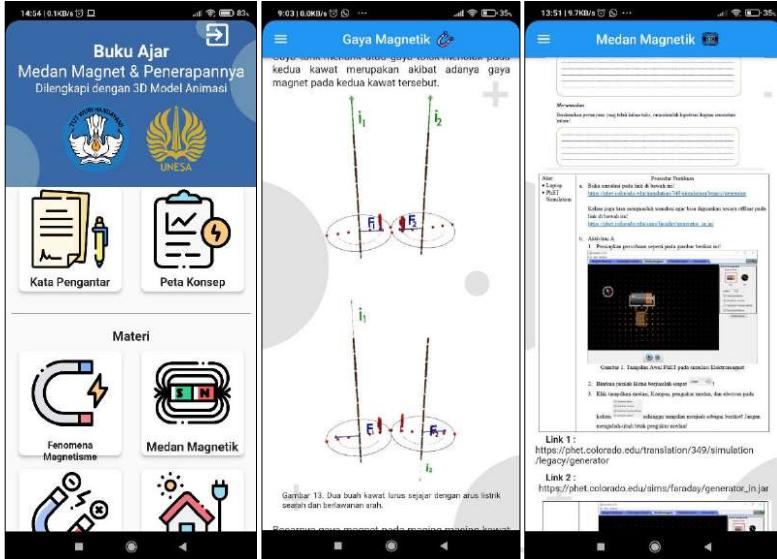
152

153

2. Digital book with 3D animation

154

This book has an extension.apk in the form of an application installed on via mobile phones with a file size of 67 MB. The application can be accessed offline to minimize network constraints during online learning. However, this digital book also has weaknesses, such as being not yet integrated with practical simulations and being less interactive. After the pre-test, this digital book set was used as a treatment for the experimental class. Some pictures of digital books can be seen in Figure 2. To access this digital book application, click [here](#).



(Source: Authors)

Figure 2. Some screenshots of digital book products with 3D animation.

160
161

162

163

3. Test instrument

164 The test instrument is divided into consists of two types, pre-test and post-test, but the tested questions
165 are similar in both have similarities in the tested questions. This was done to determine the increase in
166 the PSS of students in the experimental and control classes. Five questions are tested with the description
167 questions with each ACCES rubric in each number. Each rubric will be assessed based on correct, logical,
168 and systematic indicators. For example, if the student's answer represents the three indicators, the
169 student gets a score of 3. If the student's answer only represents two indicators, then the student gets a
170 score of 2, and so on until the student's answer does not meet all of the criteria, they will get a score of
171 0.

172

4. Expert validation questionnaire

173 The Expert validation questionnaire aims to determine the validity of the content and construct validity
174 of the learning instruments used, namely the learning implementation plan and the application of digital
175 books. Validation was carried out by three experts majoring in physics education.

176

177 Data Analysis

178 The validity of OPBL assisted by digital books with 3D animation models, is determined using the experts'
179 average score of the assessment results. After that, the average assessment results will be adjusted
180 according to the criteria in Table 3. In addition, the instrument's reliability is also assessed using the
181 Cronbach's Alpha coefficient value, namely if the value is greater than $\alpha > 0.7$, the instrument can be said
182 to be reliable (Taber, 2018).

183 The effectiveness of these learning instruments is analyzed based on the determined assessment before
184 and after learning. The instruments can be said to be effective if they meet it meets the following criteria:
185 1) the average score of PSS is at least moderate; 2) there is a significant difference in the improvement of
186 students' PSS abilities; 3) the effect size for the experimental class is at least medium effect; 4) the
187 minimum n-gain value is middle for the experimental class; and 5) there is a significant difference between
188 the experimental class and the control class. Determination of the value of the PSS score is determined
189 done by using descriptive statistics on the pre-test and post-test scores. First, the PSS scores were adjusted

190 based on the criteria in Table 3. After that, the pre-, post-test, and n-gain data were analyzed using
 191 inferential statistics reviewed for normality using Shapiro-Wilk and homogeneity using Levene Statistic.
 192 Finally, to increase PSS, paired t-test/Mann-Whitney was performed for the pre-test, post-test, and n-gain
 193 values in the experimental and control classes were subjected to a paired t-test/Mann-Whitney test to
 194 increase PSS. The N-gain value was calculated by determined by: (post-test score – pre-test
 195 score)/(Maximum Score – pre-test score) and the results were adjusted using Hake's according to the
 196 criteria, according to Hake as shown in Table 3 (Hake, 1999). In addition, the size of the effect was
 197 determined using Cohen's d-effect size to see the impact of field operations as shown in Table 3 (Morgan
 198 et al., 2012).

Validity Criteria		PSS Criteria		Hake's N-gain		Cohen's d-effect size	
Average Score Validity	Criteria	Score	Criteria	N-gain	Category	D-effect	Category
3.25 < N ≤ 4.00	Very Valid	0 – 1,0	Low	g < 0.3	Low	≥1.00	Very Large
2.50 < N ≤ 3.25	Valid	1,01 – 2,0	Medium	0.3 ≤ g < 0.7	Middle	0.8	Large
1.75 < N ≤ 2.50	Less Valid	2,1 – 3,0	High	g ≥ 0.7	High	0.5	Medium
1.00 ≤ N ≤ 1.75	Invalid					0.2	Small

199 Table 3. The category of learning instrument validity criteria, PSS scoring, Hake's N-gain, and Cohen's d-
 200 effect size

201 **Third Phase: Students' Response Survey**

202 This phase was conducted to determine know student responses to OPBL, assisted by the digital book
 203 with 3D animation learning instruments that have been used during learning. Data was collected using
 204 the survey method by distributing questionnaires to the experimental class. This is because only the
 205 experimental class uses these learning instruments. The questionnaire contains ten questions that
 206 describe the use of the instrument to increase the ability of PSS in students. The research sample that
 207 filled out the questionnaire had was 32 students (n = 32), so there were differences with the second phase.
 208 However, according to attendance results, it turns out that all students in the experimental class always
 209 attend every learning meeting. The results of student responses were analyzed descriptively and
 210 quantitatively and adjusted to the following criteria: (1) Response of 75% (very positive); (2) 50% response
 211 < 75% (positive); (3) 25% response < 50% (less positive); and (4) response < 25% (not positive).

212 **3. Result and Discussion**

213 **3.1 Validity**

214 Three physics education experts assessed the validity of OPBL assisted by digital book-3D animations
 215 learning. The instruments assessed are the content and constructs of the lesson plan, the digital book
 216 application, test instruments, and the questionnaire of problems, needs, and responses to with the
 217 assessment results, as shown in Table 4. The validation results show that all aspects have valid criteria.
 218 The same as the reliability value, all aspects are reliable.

Component	Validity and reliability of OPBL assisted by digital book-3D animation			
	Score	Validity	α	Reliability
<i>Content Validity</i>				
1. Lesson plan	3.38	Very Valid	0.71	Reliable
2. Digital book	3.48	Very Valid	0.89	Reliable
3. Test Instruments	3.75	Very Valid	0.88	Reliable
4. Questionnaire of problems, needs, and responses	3.71	Very Valid	0.75	Reliable
<i>Construct Validity</i>				
1. Lesson plan	3.33	Very Valid	0.93	Reliable
2. Digital book	3.62	Very Valid	0.70	Reliable
3. Test Instruments	3.66	Very Valid	0.76	Reliable

4. Questionnaire of problems, needs, and responses	3.77	Very Valid	0.82	Reliable
--	------	------------	------	----------

Note: α = Cronbach Alpha

Table 4. The results of the assessment of the validity of the instruments by the expert

This learning instrument has a novelty in OPBL implementation, assisted by digital books with 3D animation. Unlike PBL in general, which requires student worksheets and teaching materials, these two instruments are already integrated with a digital book, so this digital book application contains complete instruments. This application has also been integrated with simulation guidelines to assist in the problem-solving process. If all learning instruments could be integrated into one application, this could further optimize the learning process (Herayanti et al., 2017). The involvement of the digital book application can be seen from its occurrence in every process in the OPBL syntax. In addition, the test instruments and questionnaires were also declared valid by experts. According to the validator, this learning instrument is generally valid and feasible to assess the next aspect (effectiveness) after minor revisions have been made (Plomp, 2013). After corrections were made based on their recommendations, the OPBL, assisted by digital books with 3D animations to improve physics-PSS, could be implemented for SMAN 2 Bangkalan students.

3.2 Effectiveness

To determine the effectiveness of PBL online learning assisted by 3D digital-animated books, can be seen in Table 5, Table 6, Table 7, and Table 8 with the following explanation.

Group	N	Lowest Score			Highest Score		
		Pre-test	Post-test	Average	Pre test	Post test	Average
Experiment	29	0.51	1.35	0.82	1.20	2.64	2.32
Control	30	0.04	0.28	0.47	1.24	2.17	1.26

Table 5. Results of descriptive statistical calculations: lowest, highest, and average scores average in both classes

Based on Table 5, it can be seen that there are differences in the pre-test and post-test abilities in both the experimental and control classes. In the experimental class, the lowest pre-test PSS score was 0.51, and the highest was 1.20, while the lowest post-test PSS score was 1.35, and the highest was 2.64. There is also a difference in the pre-test. The average PSS score differs between the pre-test and is 0.82, while the post-test: the pre-test average is 0.82, while the post test average is 2.32. In the control class, the lowest PSS score in the pre-test is 0.04, and the highest is 1.24, while the lowest PSS score in the post-test is 0.28 and the highest is 2.17. In addition, there is also an average difference in the pre-test, which is 0.47, while in the post-test it is 1.26. The low pre-test score is caused by students who still do not understand the tested material and do not have PSS in solving physics problems. In line with the research results by Jua et al. (2018), Indonesian students' physics PSS is still relatively low. But when on post-test scores, there was an increase in PSS scores in both classes because students had learned about the subject being tested (magnetic field). When compared between the experimental class and the control class, there is a difference in values where the experimental class has a higher PSS value than the control class, especially in the post-test. This is due to the difference in treatment between the two classes, where the experimental class uses an OPBL assisted by digital books with 3D animation, while the control class uses conventional learning.

The normality test results revealed that showed that the data were not normally distributed in the experimental class, while the data were not normally distributed, whereas the data in the control class were normally distributed. This is due to the online treatment of PBL with the digital book with 3D animations, which causes the data to skew to the right, or most of the students' scores are high. In addition, the homogeneity test results indicate that the data is not homogeneous. Therefore, Mann-Whitney non-parametric statistical inferential analysis ($\alpha = 5\%$) was used to determine the difference between the two classes.

Shapiro-Wilk Normality Test

Group	Test	p (Sig.)	Distribution
Experiment Class	Pre-test	0.003	Not Normal
	Post-test	0.000	Not Normal
Control Class	Pre-test	0.025	Normal
	Post-test	0.317	Normal
Levene Statistic Homogeneity Test			
Test	Number of Sample	p (Sig.)	Homogeneity
Pre-test	59	0.002	Not Homogenous
Post-test		0.020	Homogenous
Mann-Whitney Test			
Group	p (sig.)	Hypothesis	
Experiment Class	0.000	There is a significant difference between the pre-test and post-test scores	
Control Class	0.000		
Cohen's d-effect size			
Group	d-effect size	Category	
Experiment Class	1.95	Very Large	
Control Class	1.63	Very Large	

261 Table 6. The test results of Shapiro-Wilk normality, Levene statistic homogeneity, Mann-Whitney, and
262 Cohen's d-effect size for both classes

263 Based on the results of the Mann-Whitney test as shown in Table 6, it can be seen that the significance
264 value is $p < 0.05$ which means ~~so~~ that the hypothesis is accepted. ~~In both classes, it means there is~~ a
265 significant difference between the pre- and post-test results ~~in both classes~~. It is because there are
266 differences in students' understanding who initially had not learned about the magnetic field subject.
267 After being given treatment and learning about the subject, ~~the~~ students understood the material and
268 increased ~~their~~ learning outcomes. In line with several research results, using the PBL can improve their
269 learning outcomes (Amini et al., 2019; Kawuri et al., 2019; Qomariyah, 2019). If viewed from the effect
270 size, it can be seen that both classes have a very large effect category. But the experimental class has a
271 higher value than the control class. This is because in the experimental class, learning focuses more on
272 solving problems using the PBL assisted by a digital book with 3D animations. While the control class only
273 uses conventional learning. In line with (Kapi et al., 2017) research, visual media can display more real
274 physical phenomena. The use of multimedia aims to facilitate learning physics and change the paradigm
275 of students who do not realize that many everyday events related to physics can encourage students to
276 be actively involved in the thinking process by linking learning to real-life situations (Jabaliah et al.,
277 2021; Liew & Tan, 2016; Warsono et al., 2020). The use of digital book media in the experimental class
278 can increase student learning activities so that students are more motivated than learners in
279 conventional classes (Iskandar et al., 2018).

Group	Indicators of PSS									
	A		C ₁		C ₂		E		S	
EC	O_1	0.80	L	0.50	L	0.90	L	1.00	L	0.50s
	O_2	2.60	H	2.00	M	1.60	M	2.60	H	1.90
	$<g>$	0.80	H	0.60	M	0.40	M	0.80	H	0.50
CC	O_3	0.90	L	0.50	L	0.40	L	0.50	L	0.00
	O_4	2.40	H	1.40	M	0.80	L	0.50	L	1.00
	$<g>$	0.60	M	0.30	M	0.10	L	0.00	L	0.30

280 Note:
281 EC (Experiment Class); CC (Control Class); O_1 (Pre-test experimental class); O_2 (Post-test experimental class); O_3 (Pre-test control
282 class); O_4 (Post-test control class); A (Assess the problem); C₁ (Create a drawing); C₂ (Conceptualize the strategy); E (Execute the
283 solution); S (Scrutinize your result); L (Low); M (Middle); H (High)

284 Table 7. The increase in PSS for each indicator in both classes.

285 In more detail, the increase in PSS for each indicator in both classes can be seen in Table 7. It can be seen
286 that the results of the pre-test on all PSS indicators for both classes are in ~~the a~~ low category. After

287 applying the OPBL₂ assisted by digital books in the experimental class, there was an increase in N-gain for
 288 all skills in the intro—middle and high categories. Increased the smallest N-gain contained in the
 289 Conceptualize the Strategy (C₂) indicator. For this indicator, the students are still using strategies by
 290 applying the equation only to solve the problems as generally taught in the classroom. In line with the
 291 research results (Ceberio et al., 2016; Reddy & Pancharoensawad, 2017; Riantoni et al., 2017), students
 292 tend not to use physics concepts to solve problems and only use memorized equations. But they can
 293 answer correctly on the Execute the Solution (E) indicator because some of the students copy each other's
 294 answers, which is are—indicated by the similarity of their answers. As a result, on the Scrutinize your result
 295 (S) indicator has the smallest N-gain second after C₂. OnWhile online tests, students more easily cheat on
 296 each other, so they become less confident about their work results (Cindikia et al., 2020). In the control
 297 class, the increase in the N-gain value for each indicator is smaller than in the experimental class because
 298 this class uses conventional learning. The lowest increase in N-gain is found in the Execute the Solution
 299 (E) indicator because students cannot apply problem-solving skills in executing solutions to the problems
 300 asked.

301 The comparison of the average N-gain results in the experimental class with the control class can be seen
 302 in Table 8. It can be seen that the average N-gain value between the experimental class is 0.688 including
 303 the middle criteria, while in the control class is 0.282 including in the low criteria. So, the N-gain value of
 304 the PSS students in the experimental class is greater than the control class. Furthermore, the results of
 305 the normality test on the N-gain data of both classes showed that the experimental class was not normally
 306 distributed, while the control class had a normal distribution. This is because the N-gain value in the
 307 experimental class is skewed to the right, which means more high-value data. Furthermore, the
 308 homogeneity test results showed that the data were homogeneously distributed. Thus, to determine the
 309 significance of the difference between the N-gain of the two classes, non-parametric inferential statistics
 310 were used, namely the Mann-Whitney test.

Group	Descriptive Statistic		Shapiro-Wilk Normality Test		Levene Statistic Homogeneity Test		Mann-Whitney Test
	Average N-Gain	Criteria	p (Sig.)	Distribution	p (Sig.)	Criteria	p (Sig.)
EC	0.688	Middle	0.000	Not Normal	0.091	Homogeneous	0.000
CC	0.282	Low	0.601	Normal			

311 Note: EC (Experiment Class); CC (Control Class)

312 Table 7. The test result of descriptive statistic, Shapiro-Wilk normality, Levene statistic, and Mann-
 313 Whitney for increasing PSS in both classes

314 It can be seen that the *p*-value < 0.05, which means that there is a significant difference in the N-gain
 315 value between the experimental class and the control class statistically. This is because OPBL assisted by
 316 digital books with 3D animation can help students improve their PSS. The PBL that focuses on problem-
 317 solving makes students accustomed to solving problems and applying them to physics problems. In
 318 addition, in learning activities, students are given assignments in the form of physics questions that must
 319 be done in stages with problem-solving indicators. Students who receive OPBL-based learning also have
 320 PSS to easily answer physics problems compared to conventional learning models who are not trained in
 321 problem-solving. In line with some research results that PBL emphasizes more on PSS aspects such as
 322 analyzing in choosing the right concepts and principles needed in solving problems so that it is better than
 323 conventional classes (Docktor et al., 2015; Docktor & Mestre, 2014; Parno et al., 2019; Valdez & Bungihan,
 324 2019). This finding is consistent with research by (Sari et al., 2021; Sota & Peltzer, 2017), which reveals
 325 that problem-solving skills need a problem understanding process, whereas the OPBL syntax is found in
 326 the problem orientation process. Through this process, students can be guided to understand the
 327 problem, formulate a solution design, execute problem-solving according to plan, and re-examine the
 328 problem-solving process. Another study by (Septian et al., 2020; Syafii & Yasin, 2013) agrees with
 329 increasing PSS through PBL because this ability can be developed through practice. Students can have
 330 excellent thinking skills and justify with scientific evidence to find alternative problem-solving. Within
 331 OPBL, students will practice problem-solving through student worksheets or structured assignments.

333 In terms of learning theory, this is-findings also reinforced by the John Dewey's learning theory that the
 334 class should be a laboratory in solving real-life problems (Arends, 2011). In addition, PBL is also based on

335 cognitive constructivism learning theory by Piaget. Through the PBL, students can actively construct their
336 own knowledge by interacting with their environment through the assimilation and the accommodation
337 process (Arends, 2011). PBL is also reinforced by Vygotsky, which reveals that the learning process will
338 occur when students work in the Zone of Proximal Development (Schunk, 2011). During problem-based
339 learning, students will be in a top-down process, where students start with complex problems to solve
340 and then solve or find (with the teacher's help) the basic skills needed (Slavin, 2011). The results of this
341 study are also supported by Bruner's discovery learning theory, where students are required to be active
342 in solving existing problems and are assisted by teachers to provide scaffolding (Moreno, 2010).

343 Digital books also support the OPBL with 3D animations that make it easier for students to understand
344 the concept because the animation can help students visualize abstract and complex magnetic field
345 subjects. In line with several studies showing that the use of 3D animation can improve visual
346 understanding, spatial abilities, cognitive understanding, and student learning outcomes (Bakar et al.,
347 2019; Benzer & Yildiz, 2019; Cai et al., 2013; Dori & Belcher, 2005; Kumar, 2016; Mystakidis & Berki, 2018;
348 Park et al., 2016). This finding is supported by (McKnight et al., 2016) research which explains that the use
349 of technology in learning (such as digital books) can replace the roles of teachers and students, where a
350 teacher's guide, ask questions, and facilitate students to find their own answers and construct their
351 knowledge. Meanwhile, students are more flexible, accessible, and active in seeking what knowledge is
352 relevant to learning to become deep learners. This certainly supports the implementation of student-
353 centered OPBL learning. The integration between this digital book and the OPBL model can support the
354 learning process and improve students' PSS. Supported by research by (Chao et al., 2017; Siregar et al.,
355 2021b) also agrees that the use of digital books and 3D animations can help students to solve problems,
356 so it is very relevant when combined with the OPBL model. This digital book can make physics learning
357 better because the learning media used is the right mix of verbal channels (in material text) and visuals
358 (3D animated images). This is reinforced by the dual coding theory by Paivio that information received by
359 a person is processed through one of two channels, namely verbal and visual channels that can function
360 either independently, parallel, or integrated (Paivio, 2013).

361 In general, the results of the analysis on the effectiveness of the learning instruments show that 1) the
362 average problem-solving score of students in the experimental class is 2.32, which means it is in the high
363 category; 2) the increase in the PSS ability of students has a *p*-value of < 0.05 so that there is a significant
364 difference; and 3) the effect size for the experimental class is 1.95, so it is included in the very large
365 category; 4) the value of *n*-gain for the experimental class is middle; and 5) between the experimental
366 class and the control class has a *p*-value < 0.05 indicating so that there is a significant difference between
367 the two. Thus, PBL online learning assisted by digital books with 3D animation effectively increases
368 students' physics-PSS on magnetic field subjects.

369 **3.3 Students' Responses**

370 The results of a survey of a sample of 32 students (*n* = 32) to find out their response to PBL online learning
371 activities assisted by digital books with 3D animation can be seen in Table 9. The calculation results show
372 that the category's average score agrees and strongly agrees with by 80.60%, while disagreeing and
373 strongly disagree with by 19.40%. Thus, according to students, this learning activity is included in the very
374 positive criteria. The use of the OPBL is a more innovative and exciting learning model because so far, the
375 learning that has been carried out has only focused on working on tasks independently so that students
376 are easily bored. Especially for learning physics, which is considered complex and complicated by them.
377 In addition, the use of digital book applications with 3D animation is a new learning medium for them to
378 help create more enjoyable learning through the media provided. This finding is supported by research
379 by (Abdinejad et al., 2021; Sin & Al-Asmari, 2018) that the majority of students agree with the use of 3D
380 animation-based learning media to help their understanding through object visualization. This is because
381 conventional learning methods are limited in describing difficult visual concepts. So the use of 3D
382 animation can be used in magnetic field materials to facilitate the learning process by adding motion and
383 trajectories to describe spatial and visual information effectively (Rieber, 1991).

Average Responses	Responses (%)			
	<i>Very Agree</i>	<i>Agree</i>	<i>Disagree</i>	<i>Very Disagree</i>
	16,25	64,35	16,59	2,81

385 Table 9. Average student responses in the experimental class regarding learning activities that have been
386 carried out.

387

388 **3.4 Limitations, Recommendations, and Implications**

389 This research still has limitations, such as: 1) it has still have not been tested practically on the models
390 and learning media used; 2) the sample used is only two classes; and 3) the validity assessment only
391 focuses on lesson plans and digital book products. In addition, there are also limitations in the products
392 made, such as: 1) the size of the application is still too big, so it requires a large enough storage space; 2)
393 3D animation is still less interactive; 3) the application is not yet integrated with the practical simulation;
394 4) it is not known whether it is compatible with for all types of operating systems; 4) The material available
395 is only Magnetic Field.

396 So that there are recommendations, including 1) conducting a practical test of the models and learning
397 media used; 2) increasing the number of research samples up to 4 classes; and 3) conducting validity
398 assessments for other learning instruments, such as test instruments and survey questionnaires. There
399 are also recommendations for digital book application products: 1) compressing the file size to become
400 smaller; 2) making animations more interesting and interactive; 3) integrating applications with virtual
401 practicums; and 4) performing compatibility tests for all kinds of operating systems.

402 This research implies that the results of the research product in the form of an OPBL assisted by the digital
403 book with 3D animations can be applied by teachers in learning physics material during online learning. It
404 is hoped that the application of these products can improve students' PSS while at the same time solving
405 real-life problems that students will face related to the concept, especially in magnetic field subjects.

406 **4. Conclusions**

407 It can be concluded that the OPBL assisted with digital book applications with 3D animation learning
408 instruments to improve students' PSS on Magnetic Field material. This learning instrument meets the
409 validity aspect with very valid and reliable criteria both from the content component and the construct.
410 This_These learning instruments are is also effective in improving students' PSS. The survey results to
411 students showed that students responded very positively to this learning instruments. We recommend
412 that further researchers conduct practicality tests, develop applications, or test their effects on other 21st
413 century skills.

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691 **IMPLEMENTATION OF ONLINE PROBLEM-BASED LEARNING**
692 **ASSISTED BY DIGITAL BOOK WITH 3D ANIMATIONS TO**
693 **IMPROVE STUDENT'S PHYSICS PROBLEM-SOLVING SKILLS IN**
694 **MAGNETIC FIELD SUBJECT**

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699 **Abstract**

700 The magnetic field is a more complex and abstract physics subject than other physics subjects, causing
701 students' low ability to solve problems. So there is a need for learning instruments to overcome these
702 problems, especially when online learning during the COVID-19 pandemic. Research creates and
703 implements an online problem-based learning (OPBL) assisted by digital books with 3D animation to
704 improve students' physics problem-solving skills on magnetic field subjects. Research aimed to analyze
705 the validity, effectiveness, and student responses to the learning instruments used. The method used in
706 this research is quantitative by using quasi-experiment and survey methods. The results showed that this
707 learning instrument was valid and reliable to use in terms of contents and constructs. According to
708 statistical test results, this learning instrument is also effective in improving students' problem-solving
709 skills on magnetic field subjects. Furthermore, the student's response to this learning instrument was very
710 positive, making this learning activity more innovative and fun. Research implies that an OPBL assisted by
711 digital books with 3D animation instruments can be a solution to improve students' physics problem-
712 solving skills, especially during the online learning period.

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713 Keywords: Digital book with 3D animations, Magnetic field, Online problem-based learning, Problem-
714 solving skills.

715 **1. Introduction**

716 Problem-Solving Skills (PSS) are important skills for students to have in order to the challenges and
717 demands of the 21st century (Ghafar, 2020; Mohd-Yusof et al., 2011; Nurdyansyah et al., 2021; Parno et
718 al., 2020; Ridhwan et al., 2020; Suhirman et al., 2020). PSS can train students in observation, reasoning,
719 analyzing, and creative thinking to help them solve everyday problems (Devanti et al., 2020). In addition,
720 PSS is essential in physics subjects to improve students' conceptual understanding because it prioritizes
721 contextual understanding (Hudha et al., 2017).

722 In reality, sometimes students have difficulty developing their knowledge when solving a problem (Umara,
723 2019). This is evidenced by the preliminary test results on 59 students, which showed that 52 (88.13%)
724 students had low PSS scores. One of the reasons is the difficulty of visualization, which can obstruct the
725 problem-solving process because there are some abstract and microscopic physics subjects (Cai et al.,
726 2021; ibili et al., 2020), such as magnetic field subjects. Because of the subject's high complexity and
727 abstraction, Students' PSS tend to be low and they have many misconceptions it (Bestiantono et al., 2019;
728 Turgut et al., 2016; Yilmaz & Ince, 2012). Furthermore, magnetic field subject is a prerequisite subject for
729 electromagnetic induction with many applications in everyday life, such as power plants, fans, dynamos,
730 and generators. Therefore, students' low understanding of concepts will affect their ability to solve a

731 problem (Gultepe et al., 2013). Consequently, it is necessary to have a learning media that can visualize
732 students on microscopic materials, one of which is a digital book with 3D animations.

733 Currently, the use of digital books as physics learning media has seen a rapid increase and is very much
734 needed when online learning during the COVID-19 pandemic (Abtokhi et al., 2021; Kholid, 2020; Saraswati
735 et al., 2021). Digital books are electronic versions of printed books that can be read on a device with a
736 specific purpose (Siegenthaler et al., 2010), in this case, to improve the quality of physics learning. Digital
737 books have many advantages, including being practical, simple, interactive, and flexible, so they can be
738 integrated with other media such as 3D animation visualization (Siregar et al., 2021a). The 3D animation
739 will help students provide a clear picture and understanding of the process (Wu & Chiang, 2013). For
740 example, in the abstract magnetic field material, 3D animation can help students clearly visualize the
741 concept of a magnetic field. Therefore, the integration of 3D animation in digital books can be applied in
742 physics learning, especially in abstract and microscopic materials. However, using digital book media with
743 3D animations requires a supporting learning model that can simultaneously improve students' PSS, one
744 of which is the Problem Based Learning (PBL) model (Chamidy et al., 2020; Surur et al., 2020).

745 PBL is a relevant learning model within the Indonesian curriculum because it is a student-oriented learning
746 system (Anazifa & Djukri, 2017; Demirel & Dağyar, 2016). Furthermore, this learning model uses a real-
747 life problem as a basis to train students to solve the problems they face (L. Liu, 2017; Setyawan et al.,
748 2020). It supported by Simanjuntak et al. (2021); Suastra et al. (2019); Yetri et al. (2019); Yuberti et al.
749 (2019) research which shows that the PBL is effective in improving students' PSS in physics material.
750 However, during the COVID-19 pandemic, the learning system was done online; thus this learning model
751 was called 'Online Problem Based Learning (OPBL).' There is no significant difference between OPBL and
752 conventional PBL, and the difference only lies in the use of media and technology used during learning
753 (Erickson et al., 2021). However, the research results by Dinata et al. (2020) show that OPBL is more
754 efficient than conventional PBL with the same learning outcome.

755 Previous research has been conducted by Bakri et al. (2019); Bogusevchi et al. (2020); Dimitrienko &
756 Gubareva, (2018); X. Liu et al. (2019); Pirker et al. (2019); Sannikov et al. (2015); Thees et al. (2020) have
757 implemented physics learning media based on 3D visualization in the form of augmented reality and
758 virtual reality. However, when implemented in online learning, the weakness of this media is expensive
759 and requires too many devices to display the visualization. In addition, this research also has not
760 integrated visualization media into specific learning models. There is still no research integrating the PBL
761 with a digital book with 3D animations or visualizations in physics learning.

762 According to the preliminary research conducted on 61 research students, 39 (63.9%) students stated that
763 the teacher's teaching method when learning online only gave assignments. Furthermore, while using
764 learning media for online learning, 40 (65.6%) students stated that the contents were not understood, 23
765 (37.7%) students stated that they had difficulty accessing learning media, 11 (18%) students stated that
766 they lacked image visualization of the material. Based on the survey, it can be seen that students need
767 more engaging, innovative teaching methods and easy-to-understand learning media that are easily
768 accessible and can provide exciting visualizations of the subject being taught. Supported by a follow-up
769 survey that 7 (11.5%) students strongly agreed, 40 (80.3%) students agreed that OPBL assisted by digital
770 book with 3D animation media needs to be implemented in physics learning.

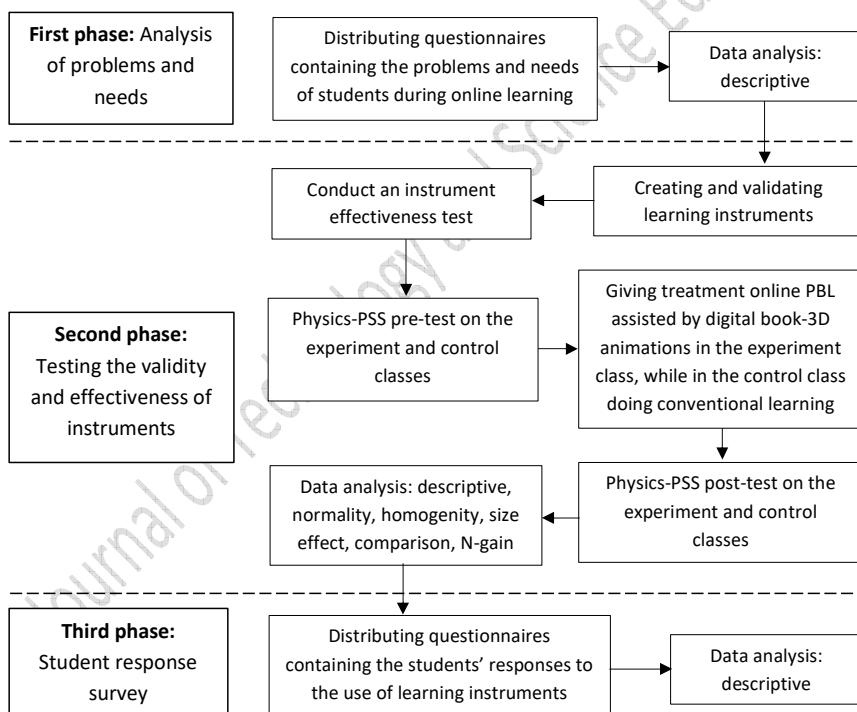
771 Therefore, this research will create and implement an OPBL assisted by a digital book application assisted
772 with 3D animations so that it is more attractive and can provide learning material visualization to students.
773 This is done to optimize the achievement of students' PSS in physics learning, especially in the Magnetic
774 Field material. With this integrated learning model and media, it is hoped to improve students' physics-
775 PSS as one of the important skills in the 21st century. This study aims to analyze the validity, effectiveness,

776 and student responses to the use of OPBL assisted by digital books with 3D animations to improve the
777 ability to solve physics problems on magnetic field materials.

778 **2. Methodology**

779 The research was conducted at State Senior High School 2 Bangkalan (i.e. Indonesia) during September-
780 October 2021 with the learning system applied at the school being online learning. The research method
781 used is quantitative. The sample in this study was 65 students from an 11th-grade class, consisting of two
782 classes from eight existing classes. However, when data collection has a different number of samples. It
783 is difficult to control the sample because all data collection is done online, and some samples are easily
784 lost. In this study, the sampling technique used was random cluster sampling because the school randomly
785 chose the two classes.

786 This research is divided into three phases of data collection, namely: 1) analysis of problems and needs;
787 2) testing the instrument's effectiveness; and 3) evaluation of student responses with the steps as in
788 Figure 1. Each phase is described as follows.



789

Figure 1. Stages of research diagram

791 **2.1 First Phase: Analysis of Problems and Needs**

792 This phase was carried out to determine the problems in learning physics experienced by students during
793 online learning. In addition, the need for relevant models and learning media can be seen so that OPBL
794 assisted by digital books with 3D animation can be an alternative solution to the problems faced. Data

795 collection during this phase was carried out using a survey method by distributing questionnaires
796 containing the problems and needs of students during online learning. The sample obtained in this
797 research was 61 students (n = 61). The research data was then analyzed descriptively to find out the
798 problems and needs of students.

799 **2.2 Second Phase: Testing the Validity and Effectiveness of Instruments**

800 *Research Design*

801 The second phase uses a quasi-experimental type with a non-equivalent control group design (Creswell &
802 Creswell, 2018). The study was conducted in two classes with different treatments, namely the
803 experimental and control classes. first, both classes were given a pre-test, and then they were given
804 different treatments between them as shown in Table 1. After that, a post-test was given at the end of
805 the lesson. The difference between the two classes only lies in the treatment. Other things, such as
806 materials, curriculum, number of meetings, class hours, and teachers, have the same design. The subject
807 used in this study is a magnetic field. In addition, schools implement the COVID-19 Pandemic Emergency
808 Curriculum with the same allocation of lesson hours but on different days. both classes have is also the
809 same number of meetings per week, namely three meetings, and they have the same teacher.

Class	Pre-test	Treatment	Post-test
XI MIPA 3 (Experiment)	O_1	X	O_2
XI MIPA 5 (Control)	O_3	-	O_4

810 Note:

O_1 = Pre-test experimental class O_3 = Pre-test control class
 O_2 = Post-test experimental class O_4 = Post-test control class

X = treatment (OPBL assisted digital book)

811 Table 1. The difference in treatment between the experimental class and the control class

812

813 *Sample*

814 The research sample in the second phase only if students work on pre- and post-test questions, 59
815 students (n = 59) with details: in the experimental class there are 29 students, while in the control class
816 there are 30 students. So that the sample has almost the same number in the experimental class and the
817 control class.

818

819 *Instruments*

820 In this study, several instruments were used: learning implementation plans, digital books with 3D
821 animation, test instruments (pre- and post-test), and expert validation questionnaires.

822 5. Lesson Plans

823 The lesson plans consist of several components: the syllabus, lesson plans, and assessments. The learning
824 syllabus in both classes is adjusted to the current curriculum at school, but the lesson plans in both classes
825 have differences in their learning approaches. The experimental class uses OPBL with five syntaxes,
826 namely: 1) problem orientation; 2) organizing students; 3) guiding group investigations; 4) developing and
827 presenting works and exhibitions; and 5) analyzing and evaluating the problem-solving process; the
828 learning activities can be seen in Table 2 (Arends, 2011). The full syntax cannot be separated from the
829 assistance of digital books with 3D animation. In the control class, learning is conducted conventionally,
830 consisting of observing magnetic field phenomena, listening to written learning on theories, concepts,
831 and examples of phenomena, working on questions, and discussing them with class members. the
832 assessment is carried out by focusing on students' PSS with the ACCES rubric, namely (A) Asses the
833 problem; (C) Create a drawing; (C) Conceptualize the strategy; (E) Execute the solution; (S) Scrutinize your
834 result (Teodorescu et al., 2013). Each rubric is assessed based on three categories: correct, logical, and
835 systematic. All learning activities are carried out online using WhatsApp media because the location of
836 students is constrained by the internet network, meaning there is no video conference for all learning in
837 both classes.

Syntax	Activity		PSS Indicator
	Teacher	Student	
Problem orientation	4. Prepare the learning instruments, especially the digital book with 3D animation (DB3DA). 5. Introduce the magnetic field topic and its significance in learning. 6. Orientation to magnetic field problems through contextual phenomena seen in DB3DA.	4. Download and install the DB3DA application. 5. Listen to the teacher's explanation of the magnetic field subject. 6. Observe and understand the problems to be solved.	A
Organizing students	3. Divide the students into groups. 4. Ensure that students understand the problem as well as the problem-solving process	3. Create groups based on the teacher's instruction. 4. Begin developing problem solving with the help of by BD3DA.	A, C ₂
Guiding group investigations	Guides students in the problem-solving process through the student worksheet contained in the DB3DA	Conduct investigations, collect data, analyze ways of solving problems (more directed at DB3DA).	C ₁ , C ₂ , E
Developing and presenting works and exhibitions	Monitor discussions and guide problem-solving reports as in the instructions in the DB3DA.	Conduct discussions to produce alternative problem-solving, make reports, and present their ideas	E, S
Analyzing and evaluating the problem-solving process	3. Evaluation and reflection on the results of problem-solving that has been done by students. 4. Conclude the magnetic field learning subject based on BD3DA.	3. Evaluation of the extent of their acquired understanding. 4. Listen to the conclusion and ask if there are still confused	S

Note: A (Assen the problem); C₁ (Create a drawing); C₂ (Conceptualize the strategy); E (Execute the solution); S (Scrutinize your result)

Table 2. Learning activities in the experimental class (Adapted from Arends, 2011)

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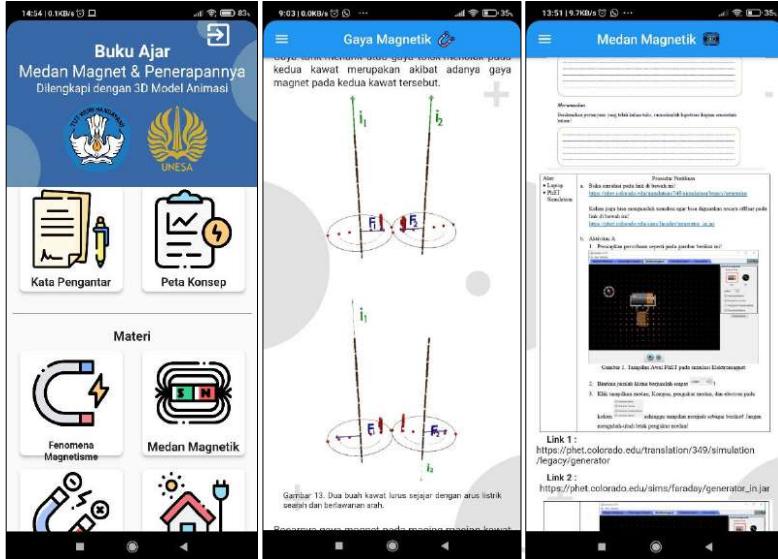
841 6. Digital book with 3D animation

842 This book has an extension.apk in the form of an application installed on mobile phones with a file size of 67 MB. The application can be accessed offline to minimize network constraints during online learning. 843 However, this digital book also has weaknesses, such as being not yet integrated with practical simulations 844 and being less interactive. After the pre-test, this digital book set was used as a treatment for the 845 experimental class. Some pictures of digital books can be seen in Figure 2. To access this digital book 846 application, click here. 847

848 7. Test instrument

849 The test instrument is divided into two types, pre-test and post-test, but the tested questions are similar 850 in both. This was done to determine the increase in the PSS of students in the experimental and control 851 classes. Five questions are tested with the description questions with each ACCES rubric in each number. 852 Each rubric will be assessed based on correct, logical, and systematic indicators. For example, if the 853 student's answer represents the three indicators, the student gets a score of 3. If the student's answer 854 only represents two indicators, then the student gets a score of 2, and so on until the student's answer 855 does not meet all of the criteria, they will get a score of 0.

856



(Source: Authors)

Figure 2. Some screenshots of digital book products with 3D animation.

860 8. Expert validation questionnaire

861 The Expert validation questionnaire aims to determine the validity of the content and construct validity
 862 of the learning instruments used, namely the learning implementation plan and the application of digital
 863 books. Validation was carried out by three experts majoring in physics education.

864

865 *Data Analysis*

866 The validity of OPBL assisted by digital books with 3D animation models, is determined using the experts'
 867 average score of the assessment results. After that, the average assessment results will be adjusted
 868 according to the criteria in Table 3. In addition, the instrument's reliability is also assessed using the
 869 Cronbach's Alpha coefficient value, namely if the value is greater than 0.7, the instrument can be said to
 870 be reliable (Taber, 2018).

871 The effectiveness of these learning instruments is analyzed based on the determined assessment before
 872 and after learning. The instruments can be said to be effective if they meet the following criteria: 1) the
 873 average score of PSS is at least moderate; 2) there is a significant difference in the improvement of
 874 students' PSS abilities; 3) the effect size for the experimental class is at least medium effect; 4) the
 875 minimum n-gain value is middle for the experimental class; and 5) there is a significant difference between
 876 the experimental class and the control class. the value of the PSS score is determined by using descriptive
 877 statistics on the pre-test and post-test scores. First, the PSS scores were adjusted based on the criteria in
 878 Table 3. After that, the pre-, post-test, and n-gain data were analyzed using inferential statistics reviewed
 879 for normality using Shapiro-Wilk and homogeneity using Levene Statistic. Finally, to increase PSS, the pre-
 880 test, post-test, and n-gain values in the experimental and control classes were subjected to a paired t-
 881 test/Mann-Whitney test. The N-gain value was calculated by: (post-test score – pre-test
 882 score)/(Maximum Score – pre-test score) and the results were adjusted using Hake's criteria, as shown
 883 in Table 3 (Hake, 1999). In addition, the size of the effect was determined using Cohen's d-effect size to
 884 see the impact of field operations as shown in Table 3 (Morgan et al., 2012).

885

Validity Criteria		PSS Criteria		Hake's N-gain		Cohen's d-effect size	
<i>Average Score Validity</i>	<i>Criteria</i>	<i>Score</i>	<i>Criteria</i>	<i>N-gain</i>	<i>Category</i>	<i>D-effect</i>	<i>Category</i>
<i>3.25 < N ≤ 4.00</i>	<i>Very Valid</i>	<i>0 – 1,0</i>	<i>Low</i>	<i>g < 0.3</i>	<i>Low</i>	<i>≥1.00</i>	<i>Very Large</i>
<i>2.50 < N ≤ 3.25</i>	<i>Valid</i>	<i>1,01 – 2,0</i>	<i>Medium</i>	<i>0.3 ≤ g < 0.7</i>	<i>Middle</i>	<i>0.8</i>	<i>Large</i>
<i>1.75 < N ≤ 2.50</i>	<i>Less Valid</i>	<i>2,1 – 3,0</i>	<i>High</i>	<i>g ≥ 0.7</i>	<i>High</i>	<i>0.5</i>	<i>Medium</i>
<i>1.00 ≤ N ≤ 1.75</i>	<i>Invalid</i>					<i>0.2</i>	<i>Small</i>

886 Table 3. The category of learning instrument validity criteria, PSS scoring, Hake's N-gain, and Cohen's d-
 887 effect size

888 **Third Phase: Students' Response Survey**

889 This phase was conducted to determine student responses to OPBL, assisted by the digital book with 3D
 890 animation learning instruments that have been used during learning. Data was collected using the survey
 891 method by distributing questionnaires to the experimental class. This is because only the experimental
 892 class uses these learning instruments. The questionnaire contains ten questions that describe the use of
 893 the instrument to increase the ability of PSS in students. The research sample that filled out the
 894 questionnaire had 32 students ($n = 32$), so there were differences with the second phase. However,
 895 according to attendance results, it turns out that all students in the experimental class always attend every
 896 learning meeting. The results of student responses were analyzed descriptively and quantitatively and
 897 adjusted to the following criteria: (1) Response of 75% (very positive); (2) 50% response < 75% (positive);
 898 (3) 25% response < 50% (less positive); and (4) response < 25% (not positive).

899 **3. Result and Discussion**

900 **3.1 Validity**

901 Three physics education experts assessed the validity of OPBL assisted by digital book-3D animation
 902 learning. The instruments assessed are the content and constructs of the lesson plan, the digital book
 903 application, test instruments, and the questionnaire of problems, needs, and responses to the assessment
 904 results, as shown in Table 4. The validation results show that all aspects have valid criteria. The same as
 905 the reliability value, all aspects are reliable.

Component	Validity and reliability of OPBL assisted by digital book-3D animation			
	Score	Validity	A	Reliability
<i>Content Validity</i>				
1. Lesson plan	3.38	Very Valid	0.71	Reliable
2. Digital book	3.48	Very Valid	0.89	Reliable
3. Test Instruments	3.75	Very Valid	0.88	Reliable
4. Questionnaire of problems, needs, and responses	3.71	Very Valid	0.75	Reliable
<i>Construct Validity</i>				
1. Lesson plan	3.33	Very Valid	0.93	Reliable
2. Digital book	3.62	Very Valid	0.70	Reliable
3. Test Instruments	3.66	Very Valid	0.76	Reliable
4. Questionnaire of problems, needs, and responses	3.77	Very Valid	0.82	Reliable

906 Note: $\alpha = \text{Cronbach Alpha}$

907 Table 4. The results of the assessment of the validity of the instruments by the expert

908 This learning instrument has a novelty in OPBL implementation, assisted by digital books with 3D
 909 animation. Unlike PBL in general, which requires student worksheets and teaching materials, these two
 910 instruments are already integrated with a digital book, so this digital book application contains complete
 911 instruments. This application has also been integrated with simulation guidelines to assist in the problem-
 912 solving process. If all learning instruments could be integrated into one application, this could further
 913 optimize the learning process (Herayanti et al., 2017). The involvement of the digital book application can

914 be seen from its occurrence in every process in the OPBL syntax. In addition, the test instruments and
 915 questionnaires were also declared valid by experts. According to the validator, this learning instrument is
 916 generally valid and feasible to assess the next aspect (effectiveness) after minor revisions have been made
 917 (Plomp, 2013). After corrections were made based on their recommendations, the OPBL, assisted by
 918 digital books with 3D animations to improve physics-PSS, could be implemented for SMAN 2 Bangkalan
 919 students.

920 **3.2 Effectiveness**

921 To determine the effectiveness of PBL online learning assisted by 3D digital-animated books, see Table 5,
 922 Table 6, Table 7, and Table 8 with the following explanation.

Group	N	Lowest Score			Highest Score		
		<i>Pre-test</i>	<i>Post-test</i>	<i>Average</i>	<i>Pre test</i>	<i>Post test</i>	<i>Average</i>
<i>Experiment</i>	29	0.51	1.35	0.82	1.20	2.64	2.32
<i>Control</i>	30	0.04	0.28	0.47	1.24	2.17	1.26

923 Table 5. Results of descriptive statistical calculations: lowest, highest, and average scores average in both
 924 classes

925 Based on Table 5, it can be seen that there are differences in the pre-test and post-test abilities in both
 926 the experimental and control classes. In the experimental class, the lowest pre-test PSS score was 0.51,
 927 and the highest was 1.20, while the lowest post-test PSS score was 1.35, and the highest was 2.64. The
 928 average PSS score differs between the pre-test and the post-test: the pre-test average is 0.82, while the
 929 post-test average is 2.32. In the control class, the lowest PSS score on the pre-test is 0.04, and the highest
 930 is 1.24, while the lowest PSS score on the post-test is 0.28 and the highest is 2.17. In addition, there is also
 931 an average difference in the pre-test, which is 0.47, while in the post-test it is 1.26. The low pre-test score
 932 is caused by students who still do not understand the tested material and do not have PSS in solving
 933 physics problems. In line with the research results by Jua et al. (2018), Indonesian students' physics PSS is
 934 still relatively low. But when on post-test scores, there was an increase in PSS scores in both classes
 935 because students had learned about the subject being tested (magnetic field). When compared between
 936 the experimental class and the control class, there is a difference in values where the experimental class
 937 has a higher PSS value than the control class, especially in the post-test. This is due to the difference in
 938 treatment between the two classes, where the experimental class uses an OPBL assisted by digital books
 939 with 3D animation, while the control class uses conventional learning.

Shapiro-Wilk Normality Test			
Group	Test	p (Sig.)	Distribution
<i>Experiment Class</i>	<i>Pre-test</i>	0.003	<i>Not Normal</i>
	<i>Post-test</i>	0.000	<i>Not Normal</i>
<i>Control Class</i>	<i>Pre-test</i>	0.025	<i>Normal</i>
	<i>Post-test</i>	0.317	<i>Normal</i>
Levene Statistic Homogeneity Test			
Test	Number of Sample	p (Sig.)	Homogeneity
<i>Pre-test</i>	59	0.002	<i>Not Homogenous</i>
<i>Post-test</i>		0.020	<i>Homogenous</i>
Mann-Whitney Test			
Group	p (sig.)	Hypothesis	
<i>Experiment Class</i>	0.000	<i>There is a significant difference between the pre-test and post-test scores</i>	
<i>Control Class</i>	0.000		
Cohen's d-effect size			
Group	d-effect size	Category	
<i>Experiment Class</i>	1.95	<i>Very Large</i>	
<i>Control Class</i>	1.63	<i>Very Large</i>	

940 Table 6. The test results of Shapiro-Wilk normality, Levene statistic homogeneity, Mann-Whitney, and
 941 Cohen's d-effect size for both classes

942 The normality test results revealed that the data in the experimental class were not normally distributed,
 943 whereas the data in the control class were normally distributed. This is due to the online treatment of PBL
 944 with the digital book with 3D animations, which causes the data to skew to the right, or most of the
 945 students' scores are high. In addition, the homogeneity test results indicate that the data is not
 946 homogeneous. Therefore, Mann-Whitney non-parametric statistical inferential analysis ($\alpha = 5\%$) was used
 947 to determine the difference between the two classes.

948 Based on the results of the Mann-Whitney test as shown in Table 6, it can be seen that the significance
 949 value is $p < 0.05$ which means that the hypothesis is accepted. In both classes, there is a significant
 950 difference between the pre- and post-test results. It is because there are differences in students'
 951 understanding who initially had not learned about the magnetic field subject. After being given treatment
 952 and learning about the subject, the students understood the material and increased their learning
 953 outcomes. In line with several research results, using the PBL can improve their learning outcomes (Amini
 954 et al., 2019; Kawuri et al., 2019; Qomariyah, 2019). If viewed from the effect size, it can be seen that both
 955 classes have a very large effect category. But the experimental class has a higher value than the control
 956 class. This is because in the experimental class, learning focuses more on solving problems using the PBL,
 957 assisted by a digital book with 3D animations. While the control class only uses conventional learning. In
 958 line with (Kapi et al., 2017) research, visual media can display more real physical phenomena. The use of
 959 multimedia aims to facilitate learning physics and change the paradigm of students who do not realize
 960 that many everyday events related to physics can encourage students to be actively involved in the
 961 thinking process by linking learning to real-life situations (Jabaliah et al., 2021; Liew & Tan, 2016; Warsono
 962 et al., 2020). The use of digital book media in the experimental class can increase student learning
 963 activities so that students are more motivated than learners in conventional classes (Iskandar et al., 2018).

Group		Indicators of PSS									
		A		C ₁		C ₂		E		S	
EC	O ₁	0.80	L	0.50	L	0.90	L	1.00	L	0.50s	L
	O ₂	2.60	H	2.00	M	1.60	M	2.60	H	1.90	M
	<g>	0.80	H	0.60	M	0.40	M	0.80	H	0.50	M
CC	O ₃	0.90	L	0.50	L	0.40	L	0.50	L	0.00	L
	O ₄	2.40	H	1.40	M	0.80	L	0.50	L	1.00	L
	<g>	0.60	M	0.30	M	0.10	L	0.00	L	0.30	M

964 Note:
 965 EC (Experiment Class); CC (Control Class); O₁ (Pre-test experimental class); O₂ (Post-test experimental class); O₃ (Pre-test control
 966 class); O₄ (Post-test control class); A (Assess the problem); C₁ (Create a drawing); C₂ (Conceptualize the
 967 solution); E (Execute the solution); S (Scrutinize your result); L (Low); M (Middle); H (High)

968 Table 7. The increase in PSS for each indicator in both classes.

969 In more detail, the increase in PSS for each indicator in both classes can be seen in Table 7. It can be seen
 970 that the results of the pre-test on all PSS indicators for both classes are in the low category. After applying
 971 the OPBL, assisted by digital books in the experimental class, there was an increase in N-gain for all skills
 972 in the middle and high categories. Increased the smallest N-gain contained in the Conceptualize the
 973 Strategy (C₂) indicator. For this indicator, the students are still using strategies by applying the equation
 974 only to solve the problems as generally taught in the classroom. In line with the research results (Ceberio
 975 et al., 2016; Reddy & Pancharoensawad, 2017; Riantoni et al., 2017), students tend not to use physics
 976 concepts to solve problems and only use memorized equations. But they can answer correctly on the
 977 Execute the Solution (E) indicator because some of the students copy each other's answers, which is
 978 indicated by the similarity of their answers. As a result, on the Scrutinize your result (S) indicator has the
 979 smallest N-gain second after C₂. On online tests, students more easily cheat on each other, so they become
 980 less confident about their work results (Cindikia et al., 2020). In the control class, the increase in the N-
 981 gain value for each indicator is smaller than in the experimental class because this class uses conventional
 982 learning. The lowest increase in N-gain is found in Execute the Solution (E) indicator because students
 983 cannot apply problem-solving skills in executing solutions to the problems asked.

984 The comparison of the average N-gain results in the experimental class with the control class can be seen
 985 in Table 8. It can be seen that the average N-gain value between the experimental class is 0.688 including
 986 the middle criteria, while in the control class is 0.282 including in the low criteria. So, the N-gain value of
 987 the PSS students in the experimental class is greater than the control class. Furthermore, the results of
 988 the normality test on the N-gain data of both classes showed that the experimental class was not normally
 989 distributed, while the control class had a normal distribution. This is because the N-gain value in the
 990 experimental class is skewed to the right, which means more high-value data. Furthermore, the
 991 homogeneity test results showed that the data were homogeneously distributed. Thus, to determine the
 992 significance of the difference between the N-gain of the two classes, non-parametric inferential statistics
 993 were used, namely the Mann-Whitney test.

Group	Descriptive Statistic		Shapiro-Wilk Normality Test		Levene Statistic Homogeneity Test		Mann-Whitney Test	
	Average N-Gain	Criteria	p (Sig.)	Distribution	p (Sig.)	Criteria	p (Sig.)	
	EC	0.688	Middle	0.000	Not Normal	0.091	Homo-geneous	0.000
	CC	0.282	Low	0.601	Normal			

Note: EC (Experiment Class); CC (Control Class)

Table 7. The test result of descriptive statistic, Shapiro-Wilk normality, Levene statistic, and Mann-Whitney for increasing PSS in both classes

994
 995
 996
 997
 998 It can be seen that the *p*-value < 0.05, which means that there is a significant difference in the N-gain
 999 value between the experimental class and the control class statistically. This is because OPBL assisted by
 1000 digital books with 3D animation can help students improve their PSS. The PBL that focuses on problem-
 1001 solving makes students accustomed to solving problems and applying them to physics problems. In
 1002 addition, in learning activities, students are given assignments in the form of physics questions that must
 1003 be done in stages with problem-solving indicators. Students who receive OPBL-based learning also have
 1004 PSS to easily answer physics problems compared to conventional learning models who are not trained in
 1005 problem-solving. In line with some research results that PBL emphasizes more on PSS aspects such as
 1006 analyzing in choosing the right concepts and principles needed in solving problems so that it is better than
 1007 conventional classes (Docktor et al., 2015; Docktor & Mestre, 2014; Parno et al., 2019; Valdez & Bungihan,
 1008 2019). This finding is consistent with research by (Sari et al., 2021; Sota & Peltzer, 2017), which reveals
 1009 that problem-solving skills need a problem understanding process, whereas the OPBL syntax is found in
 1010 the problem orientation process. Through this process, students can be guided to understand the
 1011 problem, formulate a solution design, execute problem-solving according to plan, and re-examine the
 1012 problem-solving process. Another study by (Septian et al., 2020; Syafii & Yasin, 2013) agrees with
 1013 increasing PSS through PBL because this ability can be developed through practice. Students can have
 1014 excellent thinking skills and justify with scientific evidence to find alternative problem-solving. With OPBL,
 1015 students will practice problem-solving through student worksheets or structured assignments.

1016 In terms of learning theory, this findings also reinforced by the John Dewey's learning theory that the class
 1017 should be a laboratory in solving real-life problems (Arends, 2011). In addition, PBL is also based on
 1018 cognitive constructivism learning theory by Piaget. Through the PBL, students can actively construct their
 1019 own knowledge by interacting with their environment through the assimilation and the accommodation
 1020 process (Arends, 2011). PBL is also reinforced by Vygotsky, which reveals that the learning process will
 1021 occur when students work in the Zone of Proximal Development (Schunk, 2011). During problem-based
 1022 learning, students will be in a top-down process, where students start with complex problems to solve
 1023 and then solve or find (with the teacher's help) the basic skills needed (Slavin, 2011). The results of this
 1024 study are also supported by Bruner's discovery learning theory, where students are required to be active
 1025 in solving existing problems and are assisted by teachers to provide scaffolding (Moreno, 2010).

1026 Digital books also support the OPBL with 3D animation that make it easier for students to understand the
 1027 concept because the animation can help students visualize abstract and complex magnetic field subjects.
 1028 In line with several studies showing that the use of 3D animation can improve visual understanding, spatial
 1029 abilities, cognitive understanding, and student learning outcomes (Bakar et al., 2019; Benzer & Yildiz,
 1030 2019; Cai et al., 2013; Dori & Belcher, 2005; Kumar, 2016; Myslakidis & Berki, 2018; Park et al., 2016). This
 1031 finding is supported by (McKnight et al., 2016) research which explains that the use of technology in

1032 learning (such as digital books) can replace the roles of teachers and students, where a teacher's guide,
1033 ask questions, and facilitate students to find their own answers and construct their knowledge.
1034 Meanwhile, students are more flexible, accessible, and active in seeking what knowledge is relevant to
1035 learning to become deep learners. This certainly supports the implementation of student-centered OPBL
1036 learning. The integration between this digital book and the OPBL model can support the learning process
1037 and improve students' PSS. Supported by research by (Chao et al., 2017; Siregar et al., 2021b) also agrees
1038 that the use of digital books and 3D animation can help students to solve problems, so it is very relevant
1039 when combined with the OPBL model. This digital book can make physics learning better because the
1040 learning media used is the right mix of verbal channels (in material text) and visuals (3D animated images).
1041 This is reinforced by the dual coding theory by Paivio that information received by a person is processed
1042 through one of two channels, namely verbal and visual channels that can function either independently,
1043 parallel, or integrated (Paivio, 2013).

1044 In general, the results of the analysis on the effectiveness of the learning instruments show that 1) the
1045 average problem-solving score of students in the experimental class is 2.32, which means it is in the high
1046 category; 2) the increase in the PSS ability of students has a *p*-value of < 0.05 so that there is a significant
1047 difference; and 3) the effect size for the experimental class is 1.95, so it is included in the very large
1048 category; 4) the value of n-gain for the experimental class is middle; and 5) between the experimental
1049 class and the control class has a *p*-value < 0.05 indicating that there is a significant difference between the
1050 two. Thus, PBL online learning assisted by digital books with 3D animation effectively increases students'
1051 physics-PSS on magnetic field subjects.

1052 **3.3 Students' Responses**

1053 The results of a survey of a sample of 32 students ($n = 32$) to find out their response to PBL online learning
1054 activities assisted by digital books with 3D animation can be seen in Table 9. The calculation results show
1055 that the category's average score agrees and strongly agrees with 80.60%, while disagreeing and strongly
1056 disagree with 19.40%. Thus, according to students, this learning activity is included in the very positive
1057 criteria. The use of the OPBL is a more innovative and exciting learning model because so far, the learning
1058 that has been carried out has only focused on working on tasks independently so that students are easily
1059 bored. Especially for learning physics, which is considered complex and complicated by them. In addition,
1060 the use of digital book applications with 3D animation is a new learning medium for them to help create
1061 more enjoyable learning through the media provided. This finding is supported by research by (Abdinejad
1062 et al., 2021; Sin & Al-Asmari, 2018) that the majority of students agree with the use of 3D animation-based
1063 learning media to help their understanding through object visualization. This is because conventional
1064 learning methods are limited in describing difficult visual concepts. So the use of 3D animation can be
1065 used in magnetic field materials to facilitate the learning process by adding motion and trajectories to
1066 describe spatial and visual information effectively (Rieber, 1991).

Average Responses	Responses (%)			
	Very Agree	Agree	Disagree	Very Disagree
	16,25	64,35	16,59	2,81

1067 Table 9. Average student responses in the experimental class regarding learning activities that have been
1068 carried out.

1069 **3.4 Limitations, Recommendations, and Implications**

1070 This research still has limitations, such as: 1) It has not been tested practically on the models and learning
1071 media used; 2) the sample used is only two classes; and 3) the validity assessment only focuses on lesson
1072 plans and digital book products. In addition, there are also limitations in the products made, such as: 1)
1073 the size of the application is still too big, so it requires a large enough storage space; 2) 3D animation is
1074 still less interactive; 3) the application is not yet integrated with the practical simulation; 4) it is not known
1075 whether it is compatible with for all types of operating systems; 4) The material available is only Magnetic
1076 Field.

1077 There are recommendations, including 1) conducting a practical test of the models and learning media
1078 used; 2) increasing the number of research samples up to 4 classes; and 3) conducting validity assessments

1081 for other learning instruments, such as test instruments and survey questionnaires. There are also
1082 recommendations for digital book application products: 1) compressing the file size to become smaller;
1083 2) making animations more interesting and interactive; 3) integrating applications with virtual practicums;
1084 and 4) performing compatibility tests for all kinds of operating systems.

1085 This research implies that the results of the research product in the form of an OPBL assisted by the digital
1086 book with 3D animations can be applied by teachers in learning physics material during online learning. It
1087 is hoped that the application of these products can improve students' PSS while at the same time solving
1088 real-life problems that students will face related to the concept, especially in magnetic field subjects.

1089 **4. Conclusions**

1090 It can be concluded that the OPBL assisted with digital book applications with 3D animation learning
1091 instruments to improve students' PSS on Magnetic Field material. This learning instrument meets the
1092 validity aspect with very valid and reliable criteria both from the content component and the construct.
1093 These learning instruments are also effective in improving students' PSS. The survey results to students
1094 showed that students responded very positively to this learning instrument. We recommend that further
1095 researchers conduct practicality tests, develop applications, or test their effects on other 21st century
1096 skills.

1097 **Declaration of Conflicting Interests**

1098 The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or
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1349

1 **IMPLEMENTATION OF ONLINE PROBLEM-BASED LEARNING**
2 **ASSISTED BY DIGITAL BOOK WITH 3D ANIMATIONS TO**
3 **IMPROVE STUDENT'S PHYSICS PROBLEM-SOLVING SKILLS IN**
4 **MAGNETIC FIELD SUBJECT**

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9 **Abstract**

10 The magnetic field is a more complex and abstract physics subject than other physics subjects, **causing**
11 students' low ability to solve problems. So there is a need for learning instruments to overcome these
12 problems, especially when online learning during the COVID-19 pandemic. Research creates and
13 implements an online problem-based learning (OPBL) assisted by digital books with 3D animation to
14 improve students' physics problem-solving skills on magnetic field subjects. Research aimed to analyze
15 the validity, effectiveness, and student responses to the learning instruments used. The method used in
16 this research is quantitative by using quasi-experiment and survey methods. The results showed that this
17 learning instrument was valid and reliable **to** use in terms of contents and constructs. According to
18 statistical test results, this learning instrument is also effective in improving students' problem-solving
19 skills on magnetic field subjects. Furthermore, the student's response to this learning instrument was very
20 positive, making this learning activity more innovative and fun. Research implies that an OPBL assisted by
21 digital books with 3D animation instruments can be a solution to improve students' physics problem-
22 solving skills, especially during the online learning period.

23 Keywords: Digital book with 3D animations, Magnetic field, Online problem-based learning, Problem-
24 solving skills.

25 **1. Introduction**

26 Problem-Solving Skills (PSS) **are** important skills **for** students to **have in order to** the challenges and
27 demands of the 21st century (Ghafar, 2020; Mohd-Yusof et al., 2011; Nurdyansyah et al., 2021; Parno et
28 al., 2020; Ridhwan et al., 2020; Suhirman et al., 2020). PSS can train students in **observation**, reasoning,
29 analyzing, and **creative** thinking to help them solve everyday problems (Devanti et al., 2020). In addition,
30 PSS is essential in physics subjects to improve students' conceptual understanding because it prioritizes
31 contextual understanding (Hudha et al., 2017).

32 In reality, sometimes students have difficulty developing their knowledge **when** solving a problem (Umara,
33 2019). This is evidenced by the preliminary test results on 59 students, which showed that 52 (88.13%)
34 students had low PSS scores. One of the reasons is the difficulty of visualization, which can obstruct the
35 problem-solving process because there are some abstract and microscopic physics subjects (Cai et al.,
36 2021; İbili et al., 2020), such as magnetic field subjects. **Because of the subject's high complexity and**
37 **abstraction**, students' PSS tend to be low and **they** have many misconceptions **it** (Bestiantono et al., 2019;
38 Turgut et al., 2016; Yilmaz & Ince, 2012). Furthermore, magnetic field subject is a prerequisite subject for
39 electromagnetic induction with many applications in everyday life, such as power plants, fans, dynamos,
40 and generators. Therefore, students' low understanding of concepts will affect their ability to solve a

41 problem (Gultepe et al., 2013). Consequently, it is necessary to have a learning media that can visualize
42 students on microscopic materials, one of which is a digital book with 3D animations.

43 Currently, the use of digital books as physics learning media has **seen** a rapid increase and is very much
44 needed when online learning during the COVID-19 pandemic (Abtokhi et al., 2021; Kholid, 2020; Saraswati
45 et al., 2021). Digital books are electronic versions of printed books that can be read **on** a device with a
46 specific purpose (Siegenthaler et al., 2010), in this case, to improve the quality of physics learning. Digital
47 books have many advantages, including **being** practical, simple, interactive, and flexible, so **they** can be
48 integrated with other media such as 3D animation visualization (Siregar et al., 2021a). The 3D animation
49 will help students provide a clear picture and understanding of **the** process (Wu & Chiang, 2013). For
50 example, in the abstract magnetic field material, 3D animation can help students clearly visualize the
51 concept of a magnetic field. Therefore, the integration of 3D animation in digital books can be applied in
52 physics learning, especially **in** abstract and microscopic materials. However, using digital book media with
53 3D animations requires a supporting learning model that can simultaneously improve students' PSS, one
54 of which is the Problem Based Learning (PBL) model (Chamidy et al., 2020; Surur et al., 2020).

55 PBL is a relevant learning model **within** the **Indonesian** curriculum because it is a student-oriented learning
56 system (Anazifa & Djukri, 2017; Demirel & Dağyar, 2016). Furthermore, this learning model uses a real-
57 life problem as a basis to train students to solve the problems they face (L. Liu, 2017; Setyawan et al.,
58 2020). It supported by Simanjuntak et al. (2021); Suastra et al. (2019); Yetri et al. (2019); Yuberti et al.
59 (2019) research which shows that the PBL is effective in improving students' PSS in physics material.
60 However, during the COVID-19 pandemic, the learning system was done online; thus this learning model
61 was called 'Online Problem Based Learning (OPBL).' There is no significant difference between OPBL and
62 conventional PBL, and the difference only lies in the use of media and technology used during learning
63 (Erickson et al., 2021). However, the research results by Dinata et al. (2020) show that OPBL is more
64 efficient than conventional PBL with the same learning outcome.

65 Previous research has been conducted by Bakri et al. (2019); Bogusevski et al. (2020); Dimitrienko &
66 Gubareva, (2018); X. Liu et al. (2019); Pirker et al. (2019); Sannikov et al. (2015); Thees et al. (2020) have
67 implemented physics learning media based on 3D visualization in the form of augmented reality and
68 virtual reality. However, when implemented in online learning, the weakness of this media is expensive
69 and requires too many devices to display the visualization. In addition, this research also has not
70 integrated visualization media **into** specific learning models. There is still no research integrating the PBL
71 with a digital book with 3D animations or **visualizations** in physics learning.

72 **According** to the preliminary research conducted on 61 research students, 39 (63.9%) students stated that
73 the teacher's teaching method when learning online only gave assignments. Furthermore, while **using**
74 learning media **for** online learning, 40 (65.6%) students stated that the contents were not understood, 23
75 (37.7%) students stated that they had difficulty accessing learning media, 11 (18%) students stated that
76 they lacked image visualization **of** the material. Based on the survey, it can be seen that students need
77 more engaging, innovative teaching methods and easy-to-understand learning media that **are** easily
78 accessible and can provide exciting visualizations of the subject being taught. Supported by a follow-up
79 survey that 7 (11.5%) students strongly agreed, 40 (80.3%) students agreed that OPBL assisted by digital
80 book with 3D animation media needs to be implemented in physics learning.

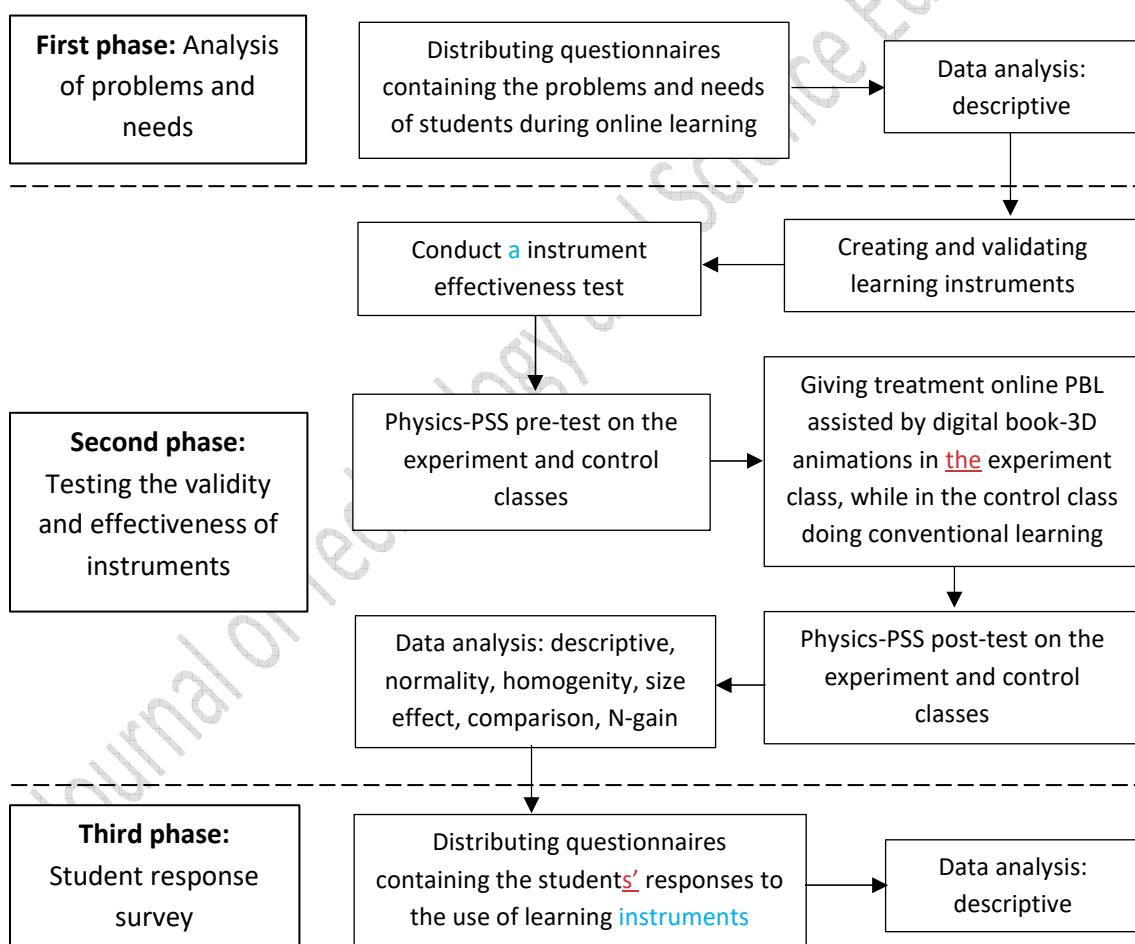
81 Therefore, this research will create and implement an OPBL assisted by a digital book application assisted
82 with 3D animations so that it is more attractive and can provide learning material visualization to students.
83 This is done to optimize the achievement of students' PSS in physics learning, especially in the Magnetic
84 Field material. With this integrated learning model and media, it is hoped to improve students' physics-
85 PSS as one of the important skills in the 21st century. This study aims to analyze the validity, effectiveness,

86 and student responses to the use of OPBL assisted by digital books with 3D animations to improve the
87 ability to solve physics problems on magnetic field materials.

88 **2. Methodology**

89 The research was conducted at State Senior High School 2 Bangkalan (i.e. Indonesia) during September-
90 October 2021 with the learning system applied at the school being online learning. The research method
91 used is quantitative. The sample in this study was 65 students from an 11th-grade class, consisting of two
92 classes from eight existing classes. However, when data collection has a different number of samples. It
93 is difficult to control the sample because all data collection is done online, and some samples are easily
94 lost. In this study, the sampling technique used was random cluster sampling because the school randomly
95 chose the two classes.

96 This research is divided into three phases of data collection, namely: 1) analysis of problems and needs;
97 2) testing the instrument's effectiveness; **and** 3) evaluation of student responses with the steps as in
98 Figure 1. Each phase is described as follows.



100 Figure 1. Stages of research diagram

101 **2.1 First Phase: Analysis of Problems and Needs**

102 This phase was carried out to **determine** the problems in learning physics experienced by students during
103 online learning. In addition, the need for relevant models and learning media can be seen so that OPBL
104 assisted by digital books with 3D animation can be an alternative solution **to** the problems faced. Data

105 collection **during** this phase was carried out using a survey method by distributing questionnaires
106 containing the problems and needs of students during online learning. The sample obtained in this
107 research was 61 students ($n = 61$). The research data **was** then analyzed descriptively to find out the
108 problems and needs of students.

109

110 **2.2 Second Phase: Testing the Validity and Effectiveness of Instruments**

111 *Research Design*

112 The second phase uses a quasi-experimental type with a non-equivalent control group design (Creswell &
113 Creswell, 2018). The study was conducted in two classes with different treatments, namely the
114 experimental and control classes. **First**, both classes were given a pre-test, **and then they were** given
115 different treatments between them as shown in Table 1. After that, a post-test was given at the end of
116 the lesson. The difference between the two classes only lies in the treatment. Other things, such as
117 materials, curriculum, number of meetings, class hours, and teachers, have the same design. The subject
118 used in this study is a magnetic field. In addition, schools implement the COVID-19 Pandemic Emergency
119 Curriculum with the same allocation of lesson hours but on different days. both classes **have** is also the
120 same **number of meetings per week**, namely three meetings, and **they have** the same teacher.

<i>Class</i>	<i>Pre-test</i>	<i>Treatment</i>	<i>Post-test</i>
<i>XI MIPA 3 (Experiment)</i>	O_1	X	O_2
<i>XI MIPA 5 (Control)</i>	O_3	-	O_4

121 Note:

O_1 = Pre-test experimental class O_3 = Pre-test control class
 O_2 = Post-test experimental class O_4 = Post-test control class
 X = treatment (OPBL assisted digital book)

122 Table 1. The difference in treatment between the experimental class and the control class

123

124 *Sample*

125 The research sample in the second phase only if students work on pre- and post-test questions, 59
126 students ($n = 59$) with details: in the experimental class **there** are 29 students, while in the control class
127 **there** are 30 students. So that the sample has almost the same number in the experimental class and **the**
128 control class.

129

130 *Instruments*

131 In this study, several instruments were used: learning implementation plans, digital books with 3D
132 animation, test instruments (pre- and post-test), and expert validation questionnaires.

133 1. Lesson Plans

134 The lesson plans consist of several components: the syllabus, lesson plans, and assessments. The learning
135 syllabus in both classes is adjusted to the current curriculum at school, but the lesson plans in both classes
136 have differences in their learning approaches. The experimental class uses OPBL with five syntaxes,
137 namely: 1) problem orientation; 2) organizing students; 3) guiding group investigations; 4) developing and
138 presenting works and exhibitions; and 5) analyzing and evaluating the problem-solving process; the
139 learning activities can be seen in Table 2 (Arends, 2011). The full syntax cannot be separated from the
140 **assistance** of digital books with 3D animation. In the control class, learning is conducted conventionally,
141 consisting of observing magnetic field phenomena, listening to written learning on theories, concepts,
142 and examples of phenomena, working on questions, and discussing **them** with class members. The
143 assessment is carried out by focusing on students' PSS with the ACCES rubric, namely (A) Asses the
144 problem; (C) Create a drawing; (C) Conceptualize the strategy; (E) Execute the solution; (S) Scrutinize your
145 result (Teodorescu et al., 2013). Each rubric is assessed based on three categories: correct, logical, and
146 systematic. All learning activities are carried out online using WhatsApp media because the location of

147 students is constrained by the internet network, meaning there is no video conference for all learning in
 148 both classes.

Syntax	Activity		PSS Indicator
	Teacher	Student	
Problem orientation	<ol style="list-style-type: none"> 1. Prepare the learning instruments, especially the digital book with 3D animation (DB3DA). 2. Introduce the magnetic field topic and its significance in learning. 3. Orientation to magnetic field problems through contextual phenomena seen in DB3DA. 	<ol style="list-style-type: none"> 1. Download and install the DB3DA application. 2. Listen to the teacher's explanation of the magnetic field subject. 3. Observe and understand the problems to be solved. 	A
Organizing students	<ol style="list-style-type: none"> 1. Divide the students into groups. 2. Ensure that students understand the problem as well as the problem-solving process 	<ol style="list-style-type: none"> 1. Create groups based on the teacher's instruction. 2. Begin developing problem solving with the help of by BD3DA. 	A, C ₂
Guiding group investigations	Guides students in the problem-solving process through the student worksheet contained in the DB3DA	Conduct investigations, collect data, analyze ways of solving problems (more directed at DB3DA).	C ₁ , C ₂ , E
Developing and presenting works and exhibitions	Monitor discussions and guide problem-solving reports as in the instructions in the DB3DA.	Conduct discussions to produce alternative problem-solving, make reports, and present their ideas	E, S
Analyzing and evaluating the problem-solving process	<ol style="list-style-type: none"> 1. Evaluation and reflection on the results of problem-solving that has been done by students. 2. Conclude the magnetic field learning subject based on BD3DA. 	<ol style="list-style-type: none"> 1. Evaluation of the extent of their acquired understanding. 2. Listen to the conclusion and ask if there are still confused 	S

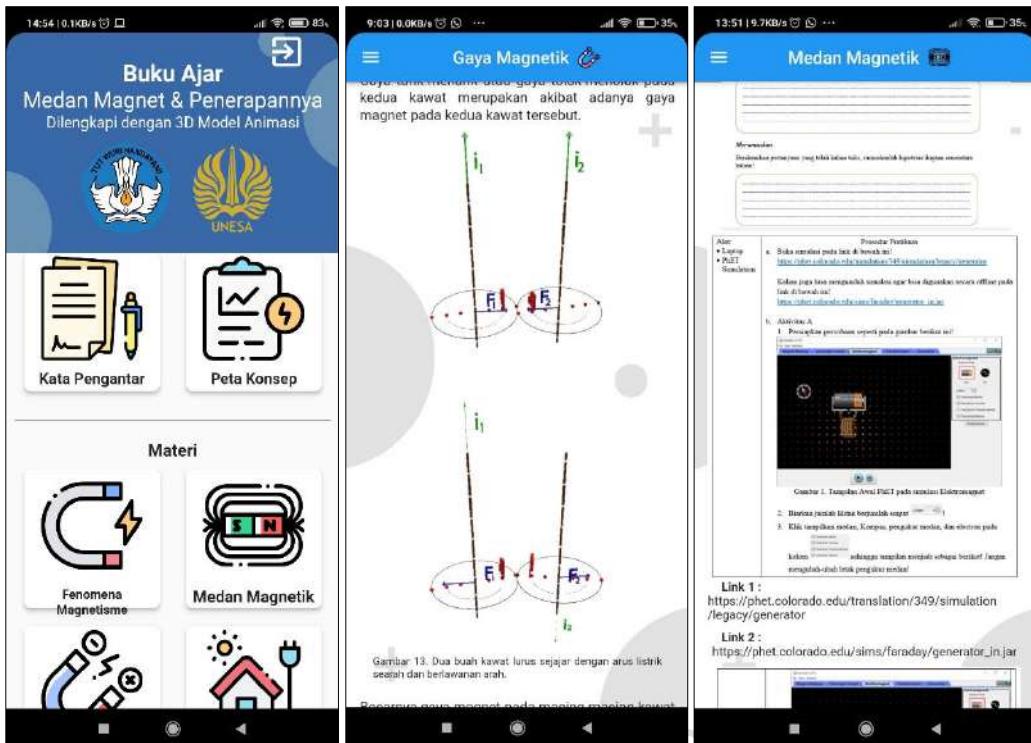
149 Note: A (Assen the problem); C₁ (Create a drawing); C₂ (Conceptualize the strategy); E (Execute the solution); S (Scrutinize your result)

150 Table 2. Learning activities in the experimental class (Adapted from Arends, 2011)

151

152 2. Digital book with 3D animation

153 This book has an extension.apk in the form of an application installed on mobile phones with a file size of
 154 67 MB. The application can be accessed offline to minimize network constraints during online learning.
 155 However, this digital book also has weaknesses, such as being not yet integrated with practical simulations
 156 and being less interactive. After the pre-test, this digital book set was used as a treatment for the
 157 experimental class. Some pictures of digital books can be seen in Figure 2. To access this digital book
 158 application, click here.



(Source: Authors)

Figure 2. Some screenshots of digital book products with 3D animation.

3. Test instrument

The test instrument is divided into two types, pre-test and post-test, but the tested questions are similar in both. This was done to determine the increase in the PSS of students in the experimental and control classes. Five questions are tested with the description questions with each ACCES rubric in each number. Each rubric will be assessed based on correct, logical, and systematic indicators. For example, if the student's answer represents the three indicators, the student gets a score of 3. If the student's answer only represents two indicators, then the student gets a score of 2, and so on until the student's answer does not meet all of the criteria, they will get a score of 0.

4. Expert validation questionnaire

The Expert validation questionnaire aims to determine the validity of the content and construct validity of the learning instruments used, namely the learning implementation plan and the application of digital books. Validation was carried out by three experts majoring in physics education.

Data Analysis

The validity of OPBL assisted by digital books with 3D animation models, is determined using the experts' average score of the assessment results. After that, the average assessment results will be adjusted according to the criteria in Table 3. In addition, the instrument's reliability is also assessed using the Cronbach's Alpha coefficient value, namely if the value is greater than 0.7, the instrument can be said to be reliable (Taber, 2018).

The effectiveness of these learning instruments is analyzed based on the determined assessment before and after learning. The instruments can be said to be effective if they meet the following criteria: 1) the average score of PSS is at least moderate; 2) there is a significant difference in the improvement of students' PSS abilities; 3) the effect size for the experimental class is at least medium effect; 4) the minimum n-gain value is middle for the experimental class; and 5) there is a significant difference between the experimental class and the control class. The value of the PSS score is determined by using descriptive statistics on the pre-test and post-test scores. First, the PSS scores were adjusted based on the criteria in Table 3. After that, the pre-, post-test, and n-gain data were analyzed using inferential statistics reviewed

189 for normality using Shapiro-Wilk and homogeneity using Levene Statistic. Finally, to increase PSS, the pre-
 190 test, post-test, and n-gain values in the experimental and control classes were subjected to a paired t-
 191 test/Mann-Whitney test. The N-gain value was calculated by : (post-test score – pre-test
 192 score)/(Maximum Score – pre-test score) and the results were adjusted using Hake's criteria, as shown
 193 in Table 3 (Hake, 1999). In addition, the size of the effect was determined using Cohen's d-effect size to
 194 see the impact of field operations as shown in Table 3 (Morgan et al., 2012).

Validity Criteria		PSS Criteria		Hake's N-gain		Cohen's d-effect size	
Average Score Validity	Criteria	Score	Criteria	N-gain	Category	D-effect	Category
$3.25 < N \leq 4.00$	Very Valid	0 – 1,0	Low	$g < 0.3$	Low	≥ 1.00	Very Large
$2.50 < N \leq 3.25$	Valid	1,01 – 2,0	Medium	$0.3 \leq g < 0.7$	Middle	0.8	Large
$1.75 < N \leq 2.50$	Less Valid	2,1 – 3,0	High	$g \geq 0.7$	High	0.5	Medium
$1.00 \leq N \leq 1.75$	Invalid					0.2	Small

195 Table 3. The category of learning instrument validity criteria, PSS scoring, Hake's N-gain, and Cohen's d-
 196 effect size

197 **Third Phase: Students' Response Survey**

198 This phase was conducted to determine student responses to OPBL, assisted by the digital book with 3D
 199 animation learning instruments that have been used during learning. Data was collected using the survey
 200 method by distributing questionnaires to the experimental class. This is because only the experimental
 201 class uses these learning instruments. The questionnaire contains ten questions that describe the use of
 202 the instrument to increase the ability of PSS in students. The research sample that filled out the
 203 questionnaire had 32 students ($n = 32$), so there were differences with the second phase. However,
 204 according to attendance results, it turns out that all students in the experimental class always attend every
 205 learning meeting. The results of student responses were analyzed descriptively and quantitatively and
 206 adjusted to the following criteria: (1) Response of 75% (very positive); (2) 50% response < 75% (positive);
 207 (3) 25% response < 50% (less positive); and (4) response < 25% (not positive).

208 **3. Result and Discussion**

209 **3.1 Validity**

210 Three physics education experts assessed the validity of OPBL assisted by digital book-3D animation
 211 learning. The instruments assessed are the content and constructs of the lesson plan, the digital book
 212 application, test instruments, and the questionnaire of problems, needs, and responses to the assessment
 213 results, as shown in Table 4. The validation results show that all aspects have valid criteria. The same as
 214 the reliability value, all aspects are reliable.

Component	Validity and reliability of OPBL assisted by digital book-3D animation			
	Score	Validity	α	Reliability
<i>Content Validity</i>				
1. Lesson plan	3.38	Very Valid	0.71	Reliable
2. Digital book	3.48	Very Valid	0.89	Reliable
3. Test Instruments	3.75	Very Valid	0.88	Reliable
4. Questionnaire of problems, needs, and responses	3.71	Very Valid	0.75	Reliable
<i>Construct Validity</i>				
1. Lesson plan	3.33	Very Valid	0.93	Reliable
2. Digital book	3.62	Very Valid	0.70	Reliable
3. Test Instruments	3.66	Very Valid	0.76	Reliable
4. Questionnaire of problems, needs, and responses	3.77	Very Valid	0.82	Reliable

215 Note: α = Cronbach Alpha

216 Table 4. The results of the assessment of the validity of the instruments by the expert

217 This learning instrument has a novelty in OPBL implementation, assisted by digital books with 3D
 218 animation. Unlike PBL in general, which requires student worksheets and teaching materials, these two
 219 instruments are already integrated with a digital book, so this digital book application contains complete
 220 instruments. This application has also been integrated with simulation guidelines to assist in the problem-
 221 solving process. If all learning instruments could be integrated into one application, this could further
 222 optimize the learning process (Herayanti et al., 2017). The involvement of the digital book application can
 223 be seen from its occurrence in every process in the OPBL syntax. In addition, the test instruments and
 224 questionnaires were also declared valid by experts. According to the validator, this learning instrument is
 225 generally valid and feasible to assess the next aspect (effectiveness) after minor revisions have been made
 226 (Plomp, 2013). After corrections were made based on their recommendations, the OPBL, assisted by
 227 digital books with 3D animations to improve physics-PSS, could be implemented for SMAN 2 Bangkalan
 228 students.

229 **3.2 Effectiveness**

230 To determine the effectiveness of PBL online learning assisted by 3D digital-animated books, see Table 5,
 231 Table 6, Table 7, and Table 8 with the following explanation.

Group	N	Lowest Score			Highest Score		
		<i>Pre-test</i>	<i>Post-test</i>	<i>Average</i>	<i>Pre test</i>	<i>Post test</i>	<i>Average</i>
<i>Experiment</i>	29	0.51	1.35	0.82	1.20	2.64	2.32
<i>Control</i>	30	0.04	0.28	0.47	1.24	2.17	1.26

232 Table 5. Results of descriptive statistical calculations: lowest, highest, and average scores average in both
 233 classes

234 Based on Table 5, it can be seen that there are differences in the pre-test and post-test abilities in both
 235 the experimental and control classes. In the experimental class, the lowest pre-test PSS score was 0.51,
 236 and the highest was 1.20, while the lowest post-test PSS score was 1.35, and the highest was 2.64. The
 237 average PSS score differs between the pre-test and the post-test: the pre-test average is 0.82, while the
 238 post test average is 2.32. In the control class, the lowest PSS score on the pre-test is 0.04, and the highest
 239 is 1.24, while the lowest PSS score on in the post-test is 0.28 and the highest is 2.17. In addition, there is
 240 also an average difference in the pre-test, which is 0.47, while in the post-test it is 1.26. The low pre-test
 241 score is caused by students who still do not understand the tested material and do not have PSS in solving
 242 physics problems. In line with the research results by Jua et al. (2018), Indonesian students' physics PSS is
 243 still relatively low. But when on post-test scores, there was an increase in PSS scores in both classes
 244 because students had learned about the subject being tested (magnetic field). When compared between
 245 the experimental class and the control class, there is a difference in values where the experimental class
 246 has a higher PSS value than the control class, especially in the post-test. This is due to the difference in
 247 treatment between the two classes, where the experimental class uses an OPBL assisted by digital books
 248 with 3D animation, while the control class uses conventional learning.

249 The normality test results revealed that the data in the experimental class were not normally distributed,
 250 whereas the data in the control class were normally distributed. This is due to the online treatment of PBL
 251 with the digital book with 3D animations, which causes the data to skew to the right, or most of the
 252 students' scores are high. In addition, the homogeneity test results indicate that the data is not
 253 homogeneous. Therefore, Mann-Whitney non-parametric statistical inferential analysis ($\alpha = 5\%$) was used
 254 to determine the difference between the two classes.

Shapiro-Wilk Normality Test			
Group	Test	p (Sig.)	Distribution
<i>Experiment Class</i>	<i>Pre-test</i>	0.003	<i>Not Normal</i>
	<i>Post-test</i>	0.000	<i>Not Normal</i>
<i>Control Class</i>	<i>Pre-test</i>	0.025	<i>Normal</i>
	<i>Post-test</i>	0.317	<i>Normal</i>

Levene Statistic Homogeneity Test			
Test	Number of Sample	p (Sig.)	Homogeneity
Pre-test	59	0.002	Not Homogenous
Post-test		0.020	Homogenous
Mann-Whitney Test			
Group	p (sig.)	Hypothesis	
Experiment Class	0.000	There is a significant difference between the pre-test and post-test scores	
Control Class	0.000		
Cohen's d-effect size			
Group	d-effect size	Category	
Experiment Class	1.95	Very Large	
Control Class	1.63	Very Large	

255 Table 6. The test results of Shapiro-Wilk normality, Levene statistic homogeneity, Mann-Whitney, and
 256 Cohen's d-effect size for both classes

257 Based on the results of the Mann-Whitney test as shown in Table 6, it can be seen that the significance
 258 value is $p < 0.05$ which means that the hypothesis is accepted. In both classes, there is a significant
 259 difference between the pre- and post-test results. It is because there are differences in students'
 260 understanding who initially had not learned about the magnetic field subject. After being given treatment
 261 and learning about the subject, the students understood the material and increased their learning
 262 outcomes. In line with several research results, using the PBL can improve their learning outcomes (Amini
 263 et al., 2019; Kawuri et al., 2019; Qomariyah, 2019). If viewed from the effect size, it can be seen that both
 264 classes have a very large effect category. But the experimental class has a higher value than the control
 265 class. This is because in the experimental class, learning focuses more on solving problems using the PBL,
 266 assisted by a digital book with 3D animations. While the control class only uses conventional learning. In
 267 line with (Kapi et al., 2017) research, visual media can display more real physical phenomena. The use of
 268 multimedia aims to facilitate learning physics and change the paradigm of students who do not realize
 269 that many everyday events related to physics can encourage students to be actively involved in the
 270 thinking process by linking learning to real-life situations (Jabaliah et al., 2021; Liew & Tan, 2016; Warsono
 271 et al., 2020). The use of digital book media in the experimental class can increase student learning
 272 activities so that students are more motivated than learners in conventional classes (Iskandar et al., 2018).

Group		Indicators of PSS									
		A		C₁		C₂		E		S	
<i>EC</i>	<i>O₁</i>	0.80	<i>L</i>	0.50	<i>L</i>	0.90	<i>L</i>	1.00	<i>L</i>	0.50s	<i>L</i>
	<i>O₂</i>	2.60	<i>H</i>	2.00	<i>M</i>	1.60	<i>M</i>	2.60	<i>H</i>	1.90	<i>M</i>
	<i><g></i>	0.80	<i>H</i>	0.60	<i>M</i>	0.40	<i>M</i>	0.80	<i>H</i>	0.50	<i>M</i>
<i>CC</i>	<i>O₃</i>	0.90	<i>L</i>	0.50	<i>L</i>	0.40	<i>L</i>	0.50	<i>L</i>	0.00	<i>L</i>
	<i>O₄</i>	2.40	<i>H</i>	1.40	<i>M</i>	0.80	<i>L</i>	0.50	<i>L</i>	1.00	<i>L</i>
	<i><g></i>	0.60	<i>M</i>	0.30	<i>M</i>	0.10	<i>L</i>	0.00	<i>L</i>	0.30	<i>M</i>

273 Note:
 274 EC (Experiment Class); CC (Control Class); O₁ (Pre-test experimental class); O₂ (Post-test experimental class); O₃ (Pre-test control
 275 class); O₄ (Post-test control class); A (Assen the problem); C₁ (Create a drawing); C₂ (Conceptualize the strategy); E (Execute the
 276 solution); S (Scrutinize your result); L (Low); M (Middle); H (High)

277 Table 7. The increase in PSS for each indicator in both classes.

278 In more detail, the increase in PSS for each indicator in both classes can be seen in Table 7. It can be seen
 279 that the results of the pre-test on all PSS indicators for both classes are in the low category. After applying
 280 the OPBL, assisted by digital books in the experimental class, there was an increase in N-gain for all skills
 281 in the middle and high categories. Increased the smallest N-gain contained in the Conceptualize the
 282 Strategy (C₂) indicator. For this indicator, the students are still using strategies by applying the equation
 283 only to solve the problems as generally taught in the classroom. In line with the research results (Ceberio
 284 et al., 2016; Reddy & Panacharoensawad, 2017; Riantoni et al., 2017), students tend not to use physics
 285 concepts to solve problems and only use memorized equations. But they can answer correctly on the
 286 Execute the Solution (E) indicator because some of the students copy each other's answers, which is

287 indicated by the similarity of their answers. As a result, on the Scrutinize your result (S) indicator has the
288 smallest N-gain second after C₂. On online tests, students more easily cheat on each other, so they become
289 less confident about their work results (Cindikia et al., 2020). In the control class, the increase in the N-
290 gain value for each indicator is smaller than in the experimental class because this class uses conventional
291 learning. The lowest increase in N-gain is found in Execute the Solution (E) indicator because students
292 cannot apply problem-solving skills in executing solutions to the problems asked.

293 The comparison of the average N-gain results in the experimental class with the control class can be seen
294 in Table 8. It can be seen that the average N-gain value between the experimental class is 0.688 including
295 the middle criteria, while in the control class is 0.282 including in the low criteria. So, the N-gain value of
296 the PSS students in the experimental class is greater than the control class. Furthermore, the results of
297 the normality test on the N-gain data of both classes showed that the experimental class was not normally
298 distributed, while the control class had a normal distribution. This is because the N-gain value in the
299 experimental class is skewed to the right, which means more high-value data. Furthermore, the
300 homogeneity test results showed that the data were homogeneously distributed. Thus, to determine the
301 significance of the difference between the N-gain of the two classes, non-parametric inferential statistics
302 were used, namely the Mann-Whitney test.

Group	Descriptive Statistic		Shapiro-Wilk Normality Test		Levene Statistic Homogeneity Test		Mann-Whitney Test
	<i>Average N-Gain</i>	<i>Criteria</i>	<i>p (Sig.)</i>	<i>Distribution</i>	<i>p (Sig.)</i>	<i>Criteria</i>	<i>p (Sig.)</i>
EC	0.688	Middle	0.000	Not Normal	0.091	Homo-geneous	0.000
CC	0.282	Low	0.601	Normal			

303 Note: EC (Experiment Class); CC (Control Class)

304 Table 7. The test result of descriptive statistic, Shapiro-Wilk normality, Levene statistic, and Mann-
305 Whitney for increasing PSS in both classes

306 It can be seen that the *p*-value < 0.05, which means that there is a significant difference in the N-gain
307 value between the experimental class and the control class statistically. This is because OPBL assisted by
308 digital books with 3D animation can help students improve their PSS. The PBL that focuses on problem-
309 solving makes students accustomed to solving problems and applying them to physics problems. In
310 addition, in learning activities, students are given assignments in the form of physics questions that must
311 be done in stages with problem-solving indicators. Students who receive OPBL-based learning also have
312 PSS to easily answer physics problems compared to conventional learning models who are not trained in
313 problem-solving. In line with some research results that PBL emphasizes more on PSS aspects such as
314 analyzing in choosing the right concepts and principles needed in solving problems so that it is better than
315 conventional classes (Docktor et al., 2015; Docktor & Mestre, 2014; Parno et al., 2019; Valdez & Bungihan,
316 2019). This finding is consistent with research by (Sari et al., 2021; Sota & Peltzer, 2017), which reveals
317 that problem-solving skills need a problem understanding process, whereas the OPBL syntax is found in
318 the problem orientation process. Through this process, students can be guided to understand the
319 problem, formulate a solution design, execute problem-solving according to plan, and re-examine the
320 problem-solving process. Another study by (Septian et al., 2020; Syafii & Yasin, 2013) agrees with
321 increasing PSS through PBL because this ability can be developed through practice. Students can have
322 excellent thinking skills and justify with scientific evidence to find alternative problem-solving. With OPBL,
323 students will practice problem-solving through student worksheets or structured assignments.

324 In terms of learning theory, this findings also reinforced by the John Dewey's learning theory that the class
325 should be a laboratory in solving real-life problems (Arends, 2011). In addition, PBL is also based on
326 cognitive constructivism learning theory by Piaget. Through the PBL, students can actively construct their
327 own knowledge by interacting with their environment through the assimilation and the accommodation
328 process (Arends, 2011). PBL is also reinforced by Vygotsky, which reveals that the learning process will
329 occur when students work in the Zone of Proximal Development (Schunk, 2011). During problem-based
330 learning, students will be in a top-down process, where students start with complex problems to solve
331 and then solve or find (with the teacher's help) the basic skills needed (Slavin, 2011). The results of this
332 study are also supported by Bruner's discovery learning theory, where students are required to be active
333 in solving existing problems and are assisted by teachers to provide scaffolding (Moreno, 2010).

335 Digital books also support the OPBL with 3D animation that make it easier for students to understand the
336 concept because the animation can help students visualize abstract and complex magnetic field subjects.
337 In line with several studies showing that the use of 3D animation can improve visual understanding, **spatial**
338 **abilities**, cognitive understanding, and student learning outcomes (Bakar et al., 2019; Benzer & Yildiz,
339 2019; Cai et al., 2013; Dori & Belcher, 2005; Kumar, 2016; Mysakidis & Berki, 2018; Park et al., 2016). **This**
340 **finding is supported by (McKnight et al., 2016) research which explains that the use of technology in**
341 **learning (such as digital books) can replace the roles of teachers and students, where a teacher's guide,**
342 **ask questions, and facilitate students to find their own answers and construct their knowledge.**
343 Meanwhile, students are more flexible, accessible, and active in seeking what knowledge is relevant to
344 learning to become deep learners. This certainly supports the implementation of student-centered OPBL
345 learning. The integration between this digital book and the OPBL model can support the learning process
346 and improve students' PSS. Supported by research by (Chao et al., 2017; Siregar et al., 2021b) also agrees
347 that the use of digital books and 3D animation can help students to solve problems, so it is very relevant
348 when combined with the OPBL model. This digital book can make physics learning better because the
349 learning media used is the right mix of verbal channels (in material text) and visuals (3D animated images).
350 This is reinforced by the dual coding theory by Paivio that information received by a person is processed
351 through one of two channels, namely verbal and visual channels that can function either independently,
352 parallel, or integrated (Paivio, 2013).

353 In general, the results of the analysis on the effectiveness of the learning instruments show that 1) the
354 average problem-solving score of students in the experimental class is 2.32, which means it is in the high
355 category; 2) the increase in the PSS ability of students has a *p*-value of < 0.05 so that there is a significant
356 difference; **and** 3) the effect size for the experimental class is 1.95, so it is included in the very large
357 category; 4) the value of n-gain for the experimental class is middle; and 5) between the experimental
358 class and the control class has a *p*-value < 0.05 **indicating** that there is a significant difference between the
359 two. Thus, PBL online learning assisted by digital books with 3D animation effectively increases students'
360 physics-PSS on magnetic field subjects.

361 **3.3 Students' Responses**

362 The results of a survey of a sample of 32 students (*n* = 32) to find out their response to PBL online learning
363 activities assisted by digital books with 3D animation can be seen in Table 9. The calculation results show
364 that the category's average score agrees and strongly agrees **with** 80.60%, while disagreeing and strongly
365 disagree **with** 19.40%. Thus, according to students, this learning activity is included in the very positive
366 criteria. The use of the OPBL is a more innovative and exciting learning model because so far, the learning
367 that has been carried out has only focused on working on tasks independently so that students are easily
368 bored. Especially for learning physics, which is considered complex and complicated by them. In addition,
369 the use of digital book applications with 3D animation is a new learning medium for them to help create
370 more enjoyable learning through the media provided. **This finding is supported by research by (Abdinejad**
371 **et al., 2021; Sin & Al-Asmari, 2018) that the majority of students agree with the use of 3D animation-based**
372 **learning media to help their understanding through object visualization. This is because conventional**
373 **learning methods are limited in describing difficult visual concepts. So the use of 3D animation can be**
374 **used in magnetic field materials to facilitate the learning process by adding motion and trajectories to**
375 **describe spatial and visual information effectively (Rieber, 1991).**

Average Responses	Responses (%)			
	Very Agree	Agree	Disagree	Very Disagree
	16,25	64,35	16,59	2,81

377 Table 9. Average student responses in the experimental class regarding learning activities that have been
378 carried out.

379

380 **3.4 Limitations, Recommendations, and Implications**

381 This research still has limitations, such as: 1) **It has not been** tested practically on the models and learning
382 media used; 2) the sample used is only two classes; **and** 3) the validity assessment only focuses on lesson
383 plans and digital book products. In addition, there are also limitations in the products made, such as: 1)
384 the size of the application is still too big, so it requires a large enough storage space; 2) 3D animation is

385 still less interactive; 3) the application is not yet integrated with the practical simulation; 4) it is not known
386 whether it is compatible [with](#) for all types of operating systems; 4) The material available is only Magnetic
387 Field.

388 there are recommendations, including 1) conducting a practical test of the models and learning media
389 used; 2) increasing the number of research samples up to 4 classes; [and](#) 3) conducting validity assessments
390 for other learning instruments, such as test instruments and survey questionnaires. There are also
391 recommendations for digital book application products: 1) compressing the file size to become smaller;
392 2) making animations more interesting and interactive; 3) integrating applications with virtual practicums;
393 [and](#) 4) performing compatibility tests for all kinds of operating systems.

394 This research implies that the results of the research product in the form of an OPBL assisted by the digital
395 book with 3D animations can be applied by teachers in learning physics material during online learning. It
396 is hoped that the application of these products can improve students' PSS while at the same time solving
397 real-life problems that students will face related to the concept, especially in magnetic field subjects.

398 **4. Conclusions**

399 It can be concluded that the OPBL assisted with digital book applications with 3D animation learning
400 instruments to improve students' PSS on Magnetic Field material. This learning instrument meets the
401 validity aspect with very valid and reliable criteria both from the content component and the construct.
402 [These](#) learning instruments [are](#) also effective in improving students' PSS. The survey results to students
403 showed that students responded very positively to this learning instrument. We recommend [that](#) further
404 researchers conduct practicality tests, develop applications, or test their effects on other 21st century
405 skills.

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Journal of Technology and Science Education

1 **IMPLEMENTATION OF ONLINE PROBLEM-BASED LEARNING**
2 **ASSISTED BY DIGITAL BOOK WITH 3D ANIMATIONS TO**
3 **IMPROVE STUDENT'S PHYSICS PROBLEM-SOLVING SKILLS IN**
4 **MAGNETIC FIELD SUBJECT**

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11 **Abstract**

12 The magnetic field is a more complex and abstract physics subject than other physics subjects, **causing**
13 students' low ability to solve problems. So there is a need for learning instruments to overcome these
14 problems, especially when online learning during the COVID-19 pandemic. Research creates and
15 implements an online problem-based learning (OPBL) assisted by digital books with 3D animation to
16 improve students' physics problem-solving skills on magnetic field subjects. Research aimed to analyze
17 the validity, effectiveness, and student responses to the learning instruments used. The method used in
18 this research is quantitative by using quasi-experiment and survey methods. The results showed that this
19 learning instrument was valid and reliable **to** use in terms of contents and constructs. According to
20 statistical test results, this learning instrument is also effective in improving students' problem-solving
21 skills on magnetic field subjects. Furthermore, the student's response to this learning instrument was very
22 positive, making this learning activity more innovative and fun. Research implies that an OPBL assisted by
23 digital books with 3D animation instruments can be a solution to improve students' physics problem-
24 solving skills, especially during the online learning period.

25 Keywords: Digital book with 3D animations, Magnetic field, Online problem-based learning, Problem-
26 solving skills.

27 **1. Introduction**

28 Problem-Solving Skills (PSS) **are** important skills **for** students to **have in order to** the challenges and
29 demands of the 21st century (Ghafar, 2020; Mohd-Yusof et al., 2011; Nurdyansyah et al., 2021; Parno et
30 al., 2020; Ridhwan et al., 2020; Suhirman et al., 2020). PSS can train students in **observation**, reasoning,
31 analyzing, and **creative** thinking to help them solve everyday problems (Devanti et al., 2020). In addition,
32 PSS is essential in physics subjects to improve students' conceptual understanding because it prioritizes
33 contextual understanding (Hudha et al., 2017).

34 In reality, sometimes students have difficulty developing their knowledge **when** solving a problem (Umara,
35 2019). This is evidenced by the preliminary test results on 59 students, which showed that 52 (88.13%)
36 students had low PSS scores. One of the reasons is the difficulty of visualization, which can obstruct the
37 problem-solving process because there are some abstract and microscopic physics subjects (Cai et al.,
38 2021; İbili et al., 2020), such as magnetic field subjects. **Because of the subject's high complexity and**
39 **abstraction**, students' PSS tend to be low and **they** have many misconceptions **it** (Bestiantono et al., 2019;

40 Turgut et al., 2016; Yilmaz & Ince, 2012). Furthermore, magnetic field subject is a prerequisite subject for
41 electromagnetic induction with many applications in everyday life, such as power plants, fans, dynamos,
42 and generators. Therefore, students' low understanding of concepts will affect their ability to solve a
43 problem (Gultepe et al., 2013). Consequently, it is necessary to have a learning media that can visualize
44 students on microscopic materials, one of which is a digital book with 3D animations.

45 Currently, the use of digital books as physics learning media has **seen** a rapid increase and is very much
46 needed when online learning during the COVID-19 pandemic (Abtokhi et al., 2021; Kholid, 2020; Saraswati
47 et al., 2021). Digital books are electronic versions of printed books that can be read **on** a device with a
48 specific purpose (Siegenthaler et al., 2010), in this case, to improve the quality of physics learning. Digital
49 books have many advantages, including **being** practical, simple, interactive, and flexible, so **they** can be
50 integrated with other media such as 3D animation visualization (Siregar et al., 2021a). The 3D animation
51 will help students provide a clear picture and understanding of **the** process (Wu & Chiang, 2013). For
52 example, in the abstract magnetic field material, 3D animation can help students clearly visualize the
53 concept of a magnetic field. Therefore, the integration of 3D animation in digital books can be applied in
54 physics learning, especially **in** abstract and microscopic materials. However, using digital book media with
55 3D animations requires a supporting learning model that can simultaneously improve students' PSS, one
56 of which is the Problem Based Learning (PBL) model (Chamidy et al., 2020; Surur et al., 2020).

57 PBL is a relevant learning model **within** the **Indonesian** curriculum because it is a student-oriented learning
58 system (Anazifa & Djukri, 2017; Demirel & Dağyar, 2016). Furthermore, this learning model uses a real-
59 life problem as a basis to train students to solve the problems they face (L. Liu, 2017; Setyawan et al.,
60 2020). It supported by Simanjuntak et al. (2021); Suastra et al. (2019); Yetri et al. (2019); Yuberti et al.
61 (2019) research which shows that the PBL is effective in improving students' PSS in physics material.
62 However, during the COVID-19 pandemic, the learning system was done online; thus this learning model
63 was called 'Online Problem Based Learning (OPBL).' There is no significant difference between OPBL and
64 conventional PBL, and the difference only lies in the use of media and technology used during learning
65 (Erickson et al., 2021). However, the research results by Dinata et al. (2020) show that OPBL is more
66 efficient than conventional PBL with the same learning outcome.

67 Previous research has been conducted by Bakri et al. (2019); Bogusevski et al. (2020); Dimitrienko &
68 Gubareva, (2018); X. Liu et al. (2019); Pirker et al. (2019); Sannikov et al. (2015); Thees et al. (2020) have
69 implemented physics learning media based on 3D visualization in the form of augmented reality and
70 virtual reality. However, when implemented in online learning, the weakness of this media is expensive
71 and requires too many devices to display the visualization. In addition, this research also has not
72 integrated visualization media **into** specific learning models. There is still no research integrating the PBL
73 with a digital book with 3D animations or **visualizations** in physics learning.

74 **According** to the preliminary research conducted on 61 research students, 39 (63.9%) students stated that
75 the teacher's teaching method when learning online only gave assignments. Furthermore, while **using**
76 learning media **for** online learning, 40 (65.6%) students stated that the contents were not understood, 23
77 (37.7%) students stated that they had difficulty accessing learning media, 11 (18%) students stated that
78 they lacked image visualization **of** the material. Based on the survey, it can be seen that students need
79 more engaging, innovative teaching methods and easy-to-understand learning media that **are** easily
80 accessible and can provide exciting visualizations of the subject being taught. Supported by a follow-up
81 survey that 7 (11.5%) students strongly agreed, 40 (80.3%) students agreed that OPBL assisted by digital
82 book with 3D animation media needs to be implemented in physics learning.

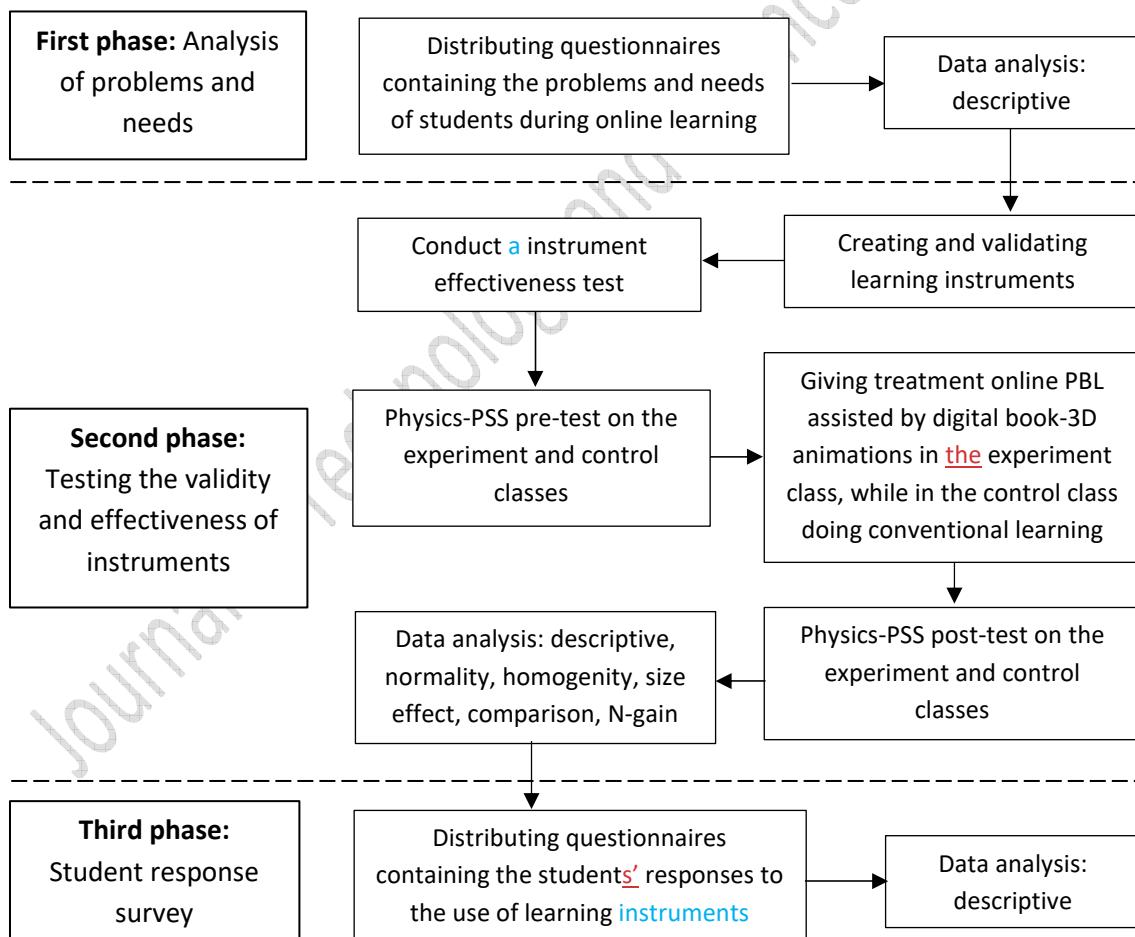
83 Therefore, this research will create and implement an OPBL assisted by a digital book application assisted
84 with 3D animations so that it is more attractive and can provide learning material visualization to students.
85 This is done to optimize the achievement of students' PSS in physics learning, especially in the Magnetic

86 Field material. With this integrated learning model and media, it is hoped to improve students' physics-
87 PSS as one of the important skills in the 21st century. This study aims to analyze the validity, effectiveness,
88 and student responses to the use of OPBL assisted by digital books with 3D animations to improve the
89 ability to solve physics problems on magnetic field materials.

90 **2. Methodology**

91 The research was conducted at State Senior High School 2 Bangkalan (i.e. Indonesia) during September-
92 October 2021 with the learning system applied at the school being online learning. The research method
93 used is quantitative. The sample in this study was 65 students from an 11th-grade class, consisting of two
94 classes from eight existing classes. However, when data collection has a different number of samples. It
95 is difficult to control the sample because all data collection is done online, and some samples are easily
96 lost. In this study, the sampling technique used was random cluster sampling because the school randomly
97 chose the two classes.

98 This research is divided into three phases of data collection, namely: 1) analysis of problems and needs;
99 2) testing the instrument's effectiveness; **and** 3) evaluation of student responses with the steps as in
100 Figure 1. Each phase is described as follows.



102 Figure 1. Stages of research diagram

103 **2.1 First Phase: Analysis of Problems and Needs**

104 This phase was carried out to determine the problems in learning physics experienced by students during
105 online learning. In addition, the need for relevant models and learning media can be seen so that OPBL
106 assisted by digital books with 3D animation can be an alternative solution to the problems faced. Data
107 collection during this phase was carried out using a survey method by distributing questionnaires
108 containing the problems and needs of students during online learning. The sample obtained in this
109 research was 61 students ($n = 61$). The research data was then analyzed descriptively to find out the
110 problems and needs of students.

111

112 **2.2 Second Phase: Testing the Validity and Effectiveness of Instruments**

113 *Research Design*

114 The second phase uses a quasi-experimental type with a non-equivalent control group design (Creswell &
115 Creswell, 2018). The study was conducted in two classes with different treatments, namely the
116 experimental and control classes. First, both classes were given a pre-test, and then they were given
117 different treatments between them as shown in Table 1. After that, a post-test was given at the end of
118 the lesson. The difference between the two classes only lies in the treatment. Other things, such as
119 materials, curriculum, number of meetings, class hours, and teachers, have the same design. The subject
120 used in this study is a magnetic field. In addition, schools implement the COVID-19 Pandemic Emergency
121 Curriculum with the same allocation of lesson hours but on different days. both classes have is also the
122 same number of meetings per week, namely three meetings, and they have the same teacher.

<i>Class</i>	<i>Pre-test</i>	<i>Treatment</i>	<i>Post-test</i>
<i>XI MIPA 3 (Experiment)</i>	O_1	X	O_2
<i>XI MIPA 5 (Control)</i>	O_3	-	O_4

123 Note:

O_1 = Pre-test experimental class O_3 = Pre-test control class
 O_2 = Post-test experimental class O_4 = Post-test control class
 X = treatment (OPBL assisted digital book)

124 Table 1. The difference in treatment between the experimental class and the control class

125

126 *Sample*

127 The research sample in the second phase only if students work on pre- and post-test questions, 59
128 students ($n = 59$) with details: in the experimental class there are 29 students, while in the control class
129 there are 30 students. So that the sample has almost the same number in the experimental class and the
130 control class.

131

132 *Instruments*

133 In this study, several instruments were used: learning implementation plans, digital books with 3D
134 animation, test instruments (pre- and post-test), and expert validation questionnaires.

135 1. Lesson Plans

136 The lesson plans consist of several components: the syllabus, lesson plans, and assessments. The learning
137 syllabus in both classes is adjusted to the current curriculum at school, but the lesson plans in both classes
138 have differences in their learning approaches. The experimental class uses OPBL with five syntaxes,
139 namely: 1) problem orientation; 2) organizing students; 3) guiding group investigations; 4) developing and
140 presenting works and exhibitions; and 5) analyzing and evaluating the problem-solving process; the
141 learning activities can be seen in Table 2 (Arends, 2011). The full syntax cannot be separated from the
142 assistance of digital books with 3D animation. In the control class, learning is conducted conventionally,
143 consisting of observing magnetic field phenomena, listening to written learning on theories, concepts,
144 and examples of phenomena, working on questions, and discussing them with class members. The

145 assessment is carried out by focusing on students' PSS with the ACCES rubric, namely (A) Asses the
 146 problem; (C) Create a drawing; (C) Conceptualize the strategy; (E) Execute the solution; (S) Scrutinize your
 147 result (Teodorescu et al., 2013). Each rubric is assessed based on three categories: correct, logical, and
 148 systematic. All learning activities are carried out online using WhatsApp media because the location of
 149 students is constrained by the internet network, meaning there is no video conference for all learning in
 150 both classes.

Syntax	Activity		PSS Indicator
	Teacher	Student	
Problem orientation	<ol style="list-style-type: none"> 1. Prepare the learning instruments, especially the digital book with 3D animation (DB3DA). 2. Introduce the magnetic field topic and its significance in learning. 3. Orientation to magnetic field problems through contextual phenomena seen in DB3DA. 	<ol style="list-style-type: none"> 1. Download and install the DB3DA application. 2. Listen to the teacher's explanation of the magnetic field subject. 3. Observe and understand the problems to be solved. 	A
Organizing students	<ol style="list-style-type: none"> 1. Divide the students into groups. 2. Ensure that students understand the problem as well as the problem-solving process 	<ol style="list-style-type: none"> 1. Create groups based on the teacher's instruction. 2. Begin developing problem solving with the help of by BD3DA. 	A, C ₂
Guiding group investigations	Guides students in the problem-solving process through the student worksheet contained in the DB3DA	Conduct investigations, collect data, analyze ways of solving problems (more directed at DB3DA).	C ₁ , C ₂ , E
Developing and presenting works and exhibitions	Monitor discussions and guide problem-solving reports as in the instructions in the DB3DA.	Conduct discussions to produce alternative problem-solving, make reports, and present their ideas	E, S
Analyzing and evaluating the problem-solving process	<ol style="list-style-type: none"> 1. Evaluation and reflection on the results of problem-solving that has been done by students. 2. Conclude the magnetic field learning subject based on BD3DA. 	<ol style="list-style-type: none"> 1. Evaluation of the extent of their acquired understanding. 2. Listen to the conclusion and ask if there are still confused 	S

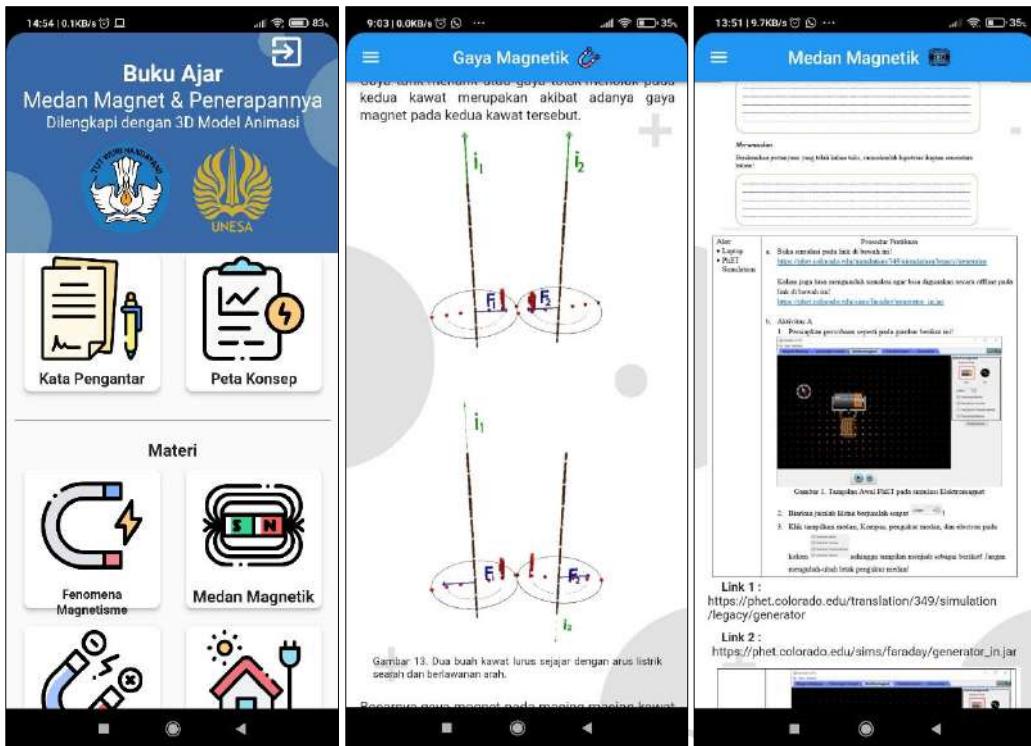
151 Note: A (Asses the problem); C₁ (Create a drawing); C₂ (Conceptualize the strategy); E (Execute the solution); S (Scrutinize your result)

152 Table 2. Learning activities in the experimental class (Adapted from Arends, 2011)

153

154 2. Digital book with 3D animation

155 This book has an extension.apk in the form of an application installed on mobile phones with a file size of
 156 67 MB. The application can be accessed offline to minimize network constraints during online learning.
 157 However, this digital book also has weaknesses, such as being not yet integrated with practical simulations
 158 and being less interactive. After the pre-test, this digital book set was used as a treatment for the
 159 experimental class. Some pictures of digital books can be seen in Figure 2. To access this digital book
 160 application, click here.



(Source: Authors)

Figure 2. Some screenshots of digital book products with 3D animation.

3. Test instrument

The test instrument is divided into two types, pre-test and post-test, but the tested questions are similar in both. This was done to determine the increase in the PSS of students in the experimental and control classes. Five questions are tested with the description questions with each ACCES rubric in each number. Each rubric will be assessed based on correct, logical, and systematic indicators. For example, if the student's answer represents the three indicators, the student gets a score of 3. If the student's answer only represents two indicators, then the student gets a score of 2, and so on until the student's answer does not meet all of the criteria, they will get a score of 0.

4. Expert validation questionnaire

The Expert validation questionnaire aims to determine the validity of the content and construct validity of the learning instruments used, namely the learning implementation plan and the application of digital books. Validation was carried out by three experts majoring in physics education.

Data Analysis

The validity of OPBL assisted by digital books with 3D animation models, is determined using the experts' average score of the assessment results. After that, the average assessment results will be adjusted according to the criteria in Table 3. In addition, the instrument's reliability is also assessed using the Cronbach's Alpha coefficient value, namely if the value is greater than 0.7, the instrument can be said to be reliable (Taber, 2018).

The effectiveness of these learning instruments is analyzed based on the determined assessment before and after learning. The instruments can be said to be effective if they meet the following criteria: 1) the average score of PSS is at least moderate; 2) there is a significant difference in the improvement of students' PSS abilities; 3) the effect size for the experimental class is at least medium effect; 4) the minimum n-gain value is middle for the experimental class; and 5) there is a significant difference between the experimental class and the control class. The value of the PSS score is determined by using descriptive statistics on the pre-test and post-test scores. First, the PSS scores were adjusted based on the criteria in Table 3. After that, the pre-, post-test, and n-gain data were analyzed using inferential statistics reviewed

191 for normality using Shapiro-Wilk and homogeneity using Levene Statistic. Finally, to increase PSS, the pre-
 192 test, post-test, and n-gain values in the experimental and control classes were subjected to a paired t-
 193 test/Mann-Whitney test. The N-gain value was calculated by : (post-test score – pre-test
 194 score)/(Maximum Score – pre-test score) and the results were adjusted using Hake's criteria, as shown
 195 in Table 3 (Hake, 1999). In addition, the size of the effect was determined using Cohen's d-effect size to
 196 see the impact of field operations as shown in Table 3 (Morgan et al., 2012).

Validity Criteria		PSS Criteria		Hake's N-gain		Cohen's d-effect size	
Average Score Validity	Criteria	Score	Criteria	N-gain	Category	D-effect	Category
$3.25 < N \leq 4.00$	Very Valid	0 – 1,0	Low	$g < 0.3$	Low	≥ 1.00	Very Large
$2.50 < N \leq 3.25$	Valid	1,01 – 2,0	Medium	$0.3 \leq g < 0.7$	Middle	0.8	Large
$1.75 < N \leq 2.50$	Less Valid	2,1 – 3,0	High	$g \geq 0.7$	High	0.5	Medium
$1.00 \leq N \leq 1.75$	Invalid					0.2	Small

197 Table 3. The category of learning instrument validity criteria, PSS scoring, Hake's N-gain, and Cohen's d-
 198 effect size

199 **Third Phase: Students' Response Survey**

200 This phase was conducted to determine student responses to OPBL, assisted by the digital book with 3D
 201 animation learning instruments that have been used during learning. Data was collected using the survey
 202 method by distributing questionnaires to the experimental class. This is because only the experimental
 203 class uses these learning instruments. The questionnaire contains ten questions that describe the use of
 204 the instrument to increase the ability of PSS in students. The research sample that filled out the
 205 questionnaire had 32 students ($n = 32$), so there were differences with the second phase. However,
 206 according to attendance results, it turns out that all students in the experimental class always attend every
 207 learning meeting. The results of student responses were analyzed descriptively and quantitatively and
 208 adjusted to the following criteria: (1) Response of 75% (very positive); (2) 50% response < 75% (positive);
 209 (3) 25% response < 50% (less positive); and (4) response < 25% (not positive).

210 **3. Result and Discussion**

211 **3.1 Validity**

212 Three physics education experts assessed the validity of OPBL assisted by digital book-3D animation
 213 learning. The instruments assessed are the content and constructs of the lesson plan, the digital book
 214 application, test instruments, and the questionnaire of problems, needs, and responses to the assessment
 215 results, as shown in Table 4. The validation results show that all aspects have valid criteria. The same as
 216 the reliability value, all aspects are reliable.

Component	Validity and reliability of OPBL assisted by digital book-3D animation			
	Score	Validity	α	Reliability
<i>Content Validity</i>				
1. Lesson plan	3.38	Very Valid	0.71	Reliable
2. Digital book	3.48	Very Valid	0.89	Reliable
3. Test Instruments	3.75	Very Valid	0.88	Reliable
4. Questionnaire of problems, needs, and responses	3.71	Very Valid	0.75	Reliable
<i>Construct Validity</i>				
1. Lesson plan	3.33	Very Valid	0.93	Reliable
2. Digital book	3.62	Very Valid	0.70	Reliable
3. Test Instruments	3.66	Very Valid	0.76	Reliable
4. Questionnaire of problems, needs, and responses	3.77	Very Valid	0.82	Reliable

217 Note: α = Cronbach Alpha

218 Table 4. The results of the assessment of the validity of the instruments by the expert

219 This learning instrument has a novelty in OPBL implementation, assisted by digital books with 3D
 220 animation. Unlike PBL in general, which requires student worksheets and teaching materials, these two
 221 instruments are already integrated with a digital book, so this digital book application contains complete
 222 instruments. This application has also been integrated with simulation guidelines to assist in the problem-
 223 solving process. If all learning instruments could be integrated into one application, this could further
 224 optimize the learning process (Herayanti et al., 2017). The involvement of the digital book application can
 225 be seen from its occurrence in every process in the OPBL syntax. In addition, the test instruments and
 226 questionnaires were also declared valid by experts. According to the validator, this learning instrument is
 227 generally valid and feasible to assess the next aspect (effectiveness) after minor revisions have been made
 228 (Plomp, 2013). After corrections were made based on their recommendations, the OPBL, assisted by
 229 digital books with 3D animations to improve physics-PSS, could be implemented for SMAN 2 Bangkalan
 230 students.

231 **3.2 Effectiveness**

232 To determine the effectiveness of PBL online learning assisted by 3D digital-animated books, see Table 5,
 233 Table 6, Table 7, and Table 8 with the following explanation.

Group	N	Lowest Score			Highest Score		
		<i>Pre-test</i>	<i>Post-test</i>	<i>Average</i>	<i>Pre test</i>	<i>Post test</i>	<i>Average</i>
<i>Experiment</i>	29	0.51	1.35	0.82	1.20	2.64	2.32
<i>Control</i>	30	0.04	0.28	0.47	1.24	2.17	1.26

234 Table 5. Results of descriptive statistical calculations: lowest, highest, and average scores average in both
 235 classes

236 Based on Table 5, it can be seen that there are differences in the pre-test and post-test abilities in both
 237 the experimental and control classes. In the experimental class, the lowest pre-test PSS score was 0.51,
 238 and the highest was 1.20, while the lowest post-test PSS score was 1.35, and the highest was 2.64. The
 239 average PSS score differs between the pre-test and the post-test: the pre-test average is 0.82, while the
 240 post test average is 2.32. In the control class, the lowest PSS score on the pre-test is 0.04, and the highest
 241 is 1.24, while the lowest PSS score on in the post-test is 0.28 and the highest is 2.17. In addition, there is
 242 also an average difference in the pre-test, which is 0.47, while in the post-test it is 1.26. The low pre-test
 243 score is caused by students who still do not understand the tested material and do not have PSS in solving
 244 physics problems. In line with the research results by Jua et al. (2018), Indonesian students' physics PSS is
 245 still relatively low. But when on post-test scores, there was an increase in PSS scores in both classes
 246 because students had learned about the subject being tested (magnetic field). When compared between
 247 the experimental class and the control class, there is a difference in values where the experimental class
 248 has a higher PSS value than the control class, especially in the post-test. This is due to the difference in
 249 treatment between the two classes, where the experimental class uses an OPBL assisted by digital books
 250 with 3D animation, while the control class uses conventional learning.

251 The normality test results revealed that the data in the experimental class were not normally distributed,
 252 whereas the data in the control class were normally distributed. This is due to the online treatment of PBL
 253 with the digital book with 3D animations, which causes the data to skew to the right, or most of the
 254 students' scores are high. In addition, the homogeneity test results indicate that the data is not
 255 homogeneous. Therefore, Mann-Whitney non-parametric statistical inferential analysis ($\alpha = 5\%$) was used
 256 to determine the difference between the two classes.

Shapiro-Wilk Normality Test			
Group	Test	p (Sig.)	Distribution
<i>Experiment Class</i>	<i>Pre-test</i>	0.003	<i>Not Normal</i>
	<i>Post-test</i>	0.000	<i>Not Normal</i>
<i>Control Class</i>	<i>Pre-test</i>	0.025	<i>Normal</i>
	<i>Post-test</i>	0.317	<i>Normal</i>

Levene Statistic Homogeneity Test			
Test	Number of Sample	p (Sig.)	Homogeneity
Pre-test	59	0.002	Not Homogenous
Post-test		0.020	Homogenous
Mann-Whitney Test			
Group	p (sig.)	Hypothesis	
Experiment Class	0.000	There is a significant difference between the pre-test and post-test scores	
Control Class	0.000		
Cohen's d-effect size			
Group	d-effect size	Category	
Experiment Class	1.95	Very Large	
Control Class	1.63	Very Large	

257 Table 6. The test results of Shapiro-Wilk normality, Levene statistic homogeneity, Mann-Whitney, and
 258 Cohen's d-effect size for both classes

259 Based on the results of the Mann-Whitney test as shown in Table 6, it can be seen that the significance
 260 value is $p < 0.05$ which means that the hypothesis is accepted. In both classes, there is a significant
 261 difference between the pre- and post-test results. It is because there are differences in students'
 262 understanding who initially had not learned about the magnetic field subject. After being given treatment
 263 and learning about the subject, the students understood the material and increased their learning
 264 outcomes. In line with several research results, using the PBL can improve their learning outcomes (Amini
 265 et al., 2019; Kawuri et al., 2019; Qomariyah, 2019). If viewed from the effect size, it can be seen that both
 266 classes have a very large effect category. But the experimental class has a higher value than the control
 267 class. This is because in the experimental class, learning focuses more on solving problems using the PBL,
 268 assisted by a digital book with 3D animations. While the control class only uses conventional learning. In
 269 line with (Kapi et al., 2017) research, visual media can display more real physical phenomena. The use of
 270 multimedia aims to facilitate learning physics and change the paradigm of students who do not realize
 271 that many everyday events related to physics can encourage students to be actively involved in the
 272 thinking process by linking learning to real-life situations (Jabaliah et al., 2021; Liew & Tan, 2016; Warsono
 273 et al., 2020). The use of digital book media in the experimental class can increase student learning
 274 activities so that students are more motivated than learners in conventional classes (Iskandar et al., 2018).

Group		Indicators of PSS									
		A		C₁		C₂		E		S	
<i>EC</i>	<i>O₁</i>	0.80	<i>L</i>	0.50	<i>L</i>	0.90	<i>L</i>	1.00	<i>L</i>	0.50s	<i>L</i>
	<i>O₂</i>	2.60	<i>H</i>	2.00	<i>M</i>	1.60	<i>M</i>	2.60	<i>H</i>	1.90	<i>M</i>
	<i><g></i>	0.80	<i>H</i>	0.60	<i>M</i>	0.40	<i>M</i>	0.80	<i>H</i>	0.50	<i>M</i>
<i>CC</i>	<i>O₃</i>	0.90	<i>L</i>	0.50	<i>L</i>	0.40	<i>L</i>	0.50	<i>L</i>	0.00	<i>L</i>
	<i>O₄</i>	2.40	<i>H</i>	1.40	<i>M</i>	0.80	<i>L</i>	0.50	<i>L</i>	1.00	<i>L</i>
	<i><g></i>	0.60	<i>M</i>	0.30	<i>M</i>	0.10	<i>L</i>	0.00	<i>L</i>	0.30	<i>M</i>

275 Note:
 276 EC (Experiment Class); CC (Control Class); O₁ (Pre-test experimental class); O₂ (Post-test experimental class); O₃ (Pre-test control
 277 class); O₄ (Post-test control class); A (Assen the problem); C₁ (Create a drawing); C₂ (Conceptualize the strategy); E (Execute the
 278 solution); S (Scrutinize your result); L (Low); M (Middle); H (High)

279 Table 7. The increase in PSS for each indicator in both classes.

280 In more detail, the increase in PSS for each indicator in both classes can be seen in Table 7. It can be seen
 281 that the results of the pre-test on all PSS indicators for both classes are in the low category. After applying
 282 the OPBL, assisted by digital books in the experimental class, there was an increase in N-gain for all skills
 283 in the middle and high categories. Increased the smallest N-gain contained in the Conceptualize the
 284 Strategy (C₂) indicator. For this indicator, the students are still using strategies by applying the equation
 285 only to solve the problems as generally taught in the classroom. In line with the research results (Ceberio
 286 et al., 2016; Reddy & Panacharoensawad, 2017; Riantoni et al., 2017), students tend not to use physics
 287 concepts to solve problems and only use memorized equations. But they can answer correctly on the
 288 Execute the Solution (E) indicator because some of the students copy each other's answers, which is

289 indicated by the similarity of their answers. As a result, on the Scrutinize your result (S) indicator has the
290 smallest N-gain second after C₂. On online tests, students more easily cheat on each other, so they become
291 less confident about their work results (Cindikia et al., 2020). In the control class, the increase in the N-
292 gain value for each indicator is smaller than in the experimental class because this class uses conventional
293 learning. The lowest increase in N-gain is found in Execute the Solution (E) indicator because students
294 cannot apply problem-solving skills in executing solutions to the problems asked.

295 The comparison of the average N-gain results in the experimental class with the control class can be seen
296 in Table 8. It can be seen that the average N-gain value between the experimental class is 0.688 including
297 the middle criteria, while in the control class is 0.282 including in the low criteria. So, the N-gain value of
298 the PSS students in the experimental class is greater than the control class. Furthermore, the results of
299 the normality test on the N-gain data of both classes showed that the experimental class was not normally
300 distributed, while the control class had a normal distribution. This is because the N-gain value in the
301 experimental class is skewed to the right, which means more high-value data. Furthermore, the
302 homogeneity test results showed that the data were homogeneously distributed. Thus, to determine the
303 significance of the difference between the N-gain of the two classes, non-parametric inferential statistics
304 were used, namely the Mann-Whitney test.

Group	Descriptive Statistic		Shapiro-Wilk Normality Test		Levene Statistic Homogeneity Test		Mann-Whitney Test
	<i>Average N-Gain</i>	<i>Criteria</i>	<i>p (Sig.)</i>	<i>Distribution</i>	<i>p (Sig.)</i>	<i>Criteria</i>	<i>p (Sig.)</i>
EC	0.688	Middle	0.000	Not Normal	0.091	Homo-geneous	0.000
CC	0.282	Low	0.601	Normal			

305 Note: EC (Experiment Class); CC (Control Class)

306 Table 7. The test result of descriptive statistic, Shapiro-Wilk normality, Levene statistic, and Mann-
307 Whitney for increasing PSS in both classes

308 It can be seen that the *p*-value < 0.05, which means that there is a significant difference in the N-gain
309 value between the experimental class and the control class statistically. This is because OPBL assisted by
310 digital books with 3D animation can help students improve their PSS. The PBL that focuses on problem-
311 solving makes students accustomed to solving problems and applying them to physics problems. In
312 addition, in learning activities, students are given assignments in the form of physics questions that must
313 be done in stages with problem-solving indicators. Students who receive OPBL-based learning also have
314 PSS to easily answer physics problems compared to conventional learning models who are not trained in
315 problem-solving. In line with some research results that PBL emphasizes more on PSS aspects such as
316 analyzing in choosing the right concepts and principles needed in solving problems so that it is better than
317 conventional classes (Docktor et al., 2015; Docktor & Mestre, 2014; Parno et al., 2019; Valdez & Bungihan,
318 2019). This finding is consistent with research by (Sari et al., 2021; Sota & Peltzer, 2017), which reveals
319 that problem-solving skills need a problem understanding process, whereas the OPBL syntax is found in
320 the problem orientation process. Through this process, students can be guided to understand the
321 problem, formulate a solution design, execute problem-solving according to plan, and re-examine the
322 problem-solving process. Another study by (Septian et al., 2020; Syafii & Yasin, 2013) agrees with
323 increasing PSS through PBL because this ability can be developed through practice. Students can have
324 excellent thinking skills and justify with scientific evidence to find alternative problem-solving. With OPBL,
325 students will practice problem-solving through student worksheets or structured assignments.

326 In terms of learning theory, this findings also reinforced by the John Dewey's learning theory that the class
327 should be a laboratory in solving real-life problems (Arends, 2011). In addition, PBL is also based on
328 cognitive constructivism learning theory by Piaget. Through the PBL, students can actively construct their
329 own knowledge by interacting with their environment through the assimilation and the accommodation
330 process (Arends, 2011). PBL is also reinforced by Vygotsky, which reveals that the learning process will
331 occur when students work in the Zone of Proximal Development (Schunk, 2011). During problem-based
332 learning, students will be in a top-down process, where students start with complex problems to solve
333 and then solve or find (with the teacher's help) the basic skills needed (Slavin, 2011). The results of this
334 study are also supported by Bruner's discovery learning theory, where students are required to be active
335 in solving existing problems and are assisted by teachers to provide scaffolding (Moreno, 2010).

Digital books also support the OPBL with 3D animation that make it easier for students to understand the concept because the animation can help students visualize abstract and complex magnetic field subjects. In line with several studies showing that the use of 3D animation can improve visual understanding, **spatial abilities**, cognitive understanding, and student learning outcomes (Bakar et al., 2019; Benzer & Yildiz, 2019; Cai et al., 2013; Dori & Belcher, 2005; Kumar, 2016; Mysakidis & Berki, 2018; Park et al., 2016). **This finding is supported by (McKnight et al., 2016) research which explains that the use of technology in learning (such as digital books) can replace the roles of teachers and students, where a teacher's guide, ask questions, and facilitate students to find their own answers and construct their knowledge.** Meanwhile, students are more flexible, accessible, and active in seeking what knowledge is relevant to learning to become deep learners. This certainly supports the implementation of student-centered OPBL learning. The integration between this digital book and the OPBL model can support the learning process and improve students' PSS. **Supported by research by (Chao et al., 2017; Siregar et al., 2021b) also agrees that the use of digital books and 3D animation can help students to solve problems, so it is very relevant when combined with the OPBL model.** This digital book can make physics learning better because the learning media used is the right mix of verbal channels (in material text) and visuals (3D animated images). This is reinforced by the dual coding theory by Paivio that information received by a person is processed through one of two channels, namely verbal and visual channels that can function either independently, parallel, or integrated (Paivio, 2013).

In general, the results of the analysis on the effectiveness of the learning instruments show that 1) the average problem-solving score of students in the experimental class is 2.32, which means it is in the high category; 2) the increase in the PSS ability of students has a *p*-value of < 0.05 so that there is a significant difference; **and** 3) the effect size for the experimental class is 1.95, so it is included in the very large category; 4) the value of n-gain for the experimental class is middle; and 5) between the experimental class and the control class has a *p*-value < 0.05 **indicating** that there is a significant difference between the two. Thus, PBL online learning assisted by digital books with 3D animation effectively increases students' physics-PSS on magnetic field subjects.

3.3 Students' Responses

The results of a survey of a sample of 32 students (*n* = 32) to find out their response to PBL online learning activities assisted by digital books with 3D animation can be seen in Table 9. The calculation results show that the category's average score agrees and strongly agrees **with** 80.60%, while disagreeing and strongly disagree **with** 19.40%. Thus, according to students, this learning activity is included in the very positive criteria. The use of the OPBL is a more innovative and exciting learning model because so far, the learning that has been carried out has only focused on working on tasks independently so that students are easily bored. Especially for learning physics, which is considered complex and complicated by them. In addition, the use of digital book applications with 3D animation is a new learning medium for them to help create more enjoyable learning through the media provided. **This finding is supported by research by (Abdinejad et al., 2021; Sin & Al-Asmari, 2018) that the majority of students agree with the use of 3D animation-based learning media to help their understanding through object visualization. This is because conventional learning methods are limited in describing difficult visual concepts. So the use of 3D animation can be used in magnetic field materials to facilitate the learning process by adding motion and trajectories to describe spatial and visual information effectively (Rieber, 1991).**

Average Responses	Responses (%)			
	Very Agree	Agree	Disagree	Very Disagree
	16,25	64,35	16,59	2,81

Table 9. Average student responses in the experimental class regarding learning activities that have been carried out.

3.4 Limitations, Recommendations, and Implications

This research still has limitations, such as: 1) **It has not been** tested practically on the models and learning media used; 2) the sample used is only two classes; **and** 3) the validity assessment only focuses on lesson plans and digital book products. In addition, there are also limitations in the products made, such as: 1) the size of the application is still too big, so it requires a large enough storage space; 2) 3D animation is

387 still less interactive; 3) the application is not yet integrated with the practical simulation; 4) it is not known
388 whether it is compatible **with** for all types of operating systems; 4) The material available is only Magnetic
389 Field.

390 there are recommendations, including 1) conducting a practical test of the models and learning media
391 used; 2) increasing the number of research samples up to 4 classes; **and** 3) conducting validity assessments
392 for other learning instruments, such as test instruments and survey questionnaires. There are also
393 recommendations for digital book application products: 1) compressing the file size to become smaller;
394 2) making animations more interesting and interactive; 3) integrating applications with virtual practicums;
395 **and** 4) performing compatibility tests for all kinds of operating systems.

396 This research implies that the results of the research product in the form of an OPBL assisted by the digital
397 book with 3D animations can be applied by teachers in learning physics material during online learning. It
398 is hoped that the application of these products can improve students' PSS while at the same time solving
399 real-life problems that students will face related to the concept, especially in magnetic field subjects.

400 **4. Conclusions**

401 It can be concluded that the OPBL assisted with digital book applications with 3D animation learning
402 instruments to improve students' PSS on Magnetic Field material. This learning instrument meets the
403 validity aspect with very valid and reliable criteria both from the content component and the construct.
404 **These** learning instruments **are** also effective in improving students' PSS. The survey results to students
405 showed that students responded very positively to this learning instrument. We recommend **that** further
406 researchers conduct practicality tests, develop applications, or test their effects on other 21st century
407 skills.

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Journal of Technology and Science Education

1 **IMPLEMENTATION OF ONLINE PROBLEM-BASED LEARNING**
2 **ASSISTED BY DIGITAL BOOK WITH 3D ANIMATIONS TO**
3 **IMPROVE STUDENT'S PHYSICS PROBLEM-SOLVING SKILLS IN**
4 **MAGNETIC FIELD SUBJECT**

5 **Abstract**

6 The magnetic field is a more complex and abstract physics subject than other physics subjects, ~~which~~
7 ~~causes-causing~~ students' low ability to solve problems. So there is a need for learning instruments to
8 overcome these problems, especially when online learning during the COVID-19 pandemic. Research
9 creates and implements an online problem-based learning (OPBL) assisted by digital books with 3D
10 animation to improve students' physics problem-solving skills on magnetic field subjects. Research aimed
11 to analyze the validity, effectiveness, and student responses to the learning instruments used. The
12 method used in this research is quantitative by using quasi-experiment and survey methods. The results
13 showed that this learning instrument was valid and reliable ~~for-to~~ use in terms of contents and constructs.
14 According to statistical test results, this learning instrument is also effective in improving students'
15 problem-solving skills on magnetic field subjects. Furthermore, the student's response to this learning
16 instrument was very positive, making this learning activity more innovative and fun. Research implies that
17 an OPBL assisted by digital books with 3D animation instruments can be a solution to improve students'
18 physics problem-solving skills, especially during the online learning period.

19 Keywords: Digital book with 3D animations, Magnetic field, Online problem-based learning, Problem-
20 solving skills.

21 **1. Introduction**

22 Problem-Solving Skills (PSS) ~~are is one of the~~ important skills ~~for needed by~~ students ~~to have in order to~~
23 ~~in-facing~~ the challenges and demands of the 21st century (Ghafar, 2020; Mohd-Yusof et al., 2011;
24 Nurdyansyah et al., 2021; Parno et al., 2020; Ridhwan et al., 2020; Suhirman et al., 2020). PSS can train
25 students in ~~observation-observing~~, reasoning, analyzing, and ~~creative~~ thinking ~~creatively~~ to help them
26 solve everyday problems (Devanti et al., 2020). In addition, PSS is essential in physics subjects to improve
27 students' conceptual understanding because it prioritizes contextual understanding (Hudha et al., 2017).

28 In reality, sometimes students have difficulty developing their knowledge ~~when in-~~solving a problem
29 (Umara, 2019). This is evidenced by the preliminary test results on 59 students, which showed that 52
30 (88.13%) students had low PSS scores. One of the reasons is the difficulty of visualization, which can
31 obstruct the problem-solving process because there are some abstract and microscopic physics subjects
32 (Cai et al., 2021; İbili et al., 2020), such as magnetic field subjects. ~~Because of the subject's high cpmplexity~~
33 ~~and abstraction~~. Students' PSS tend to be low and ~~they~~ have many misconceptions ~~it in this subject~~
34 ~~because of their high-complexity and abstraction~~ (Bestiantono et al., 2019; Turgut et al., 2016; Yilmaz &
35 Ince, 2012). Furthermore, magnetic field subject is a prerequisite subject for electromagnetic induction
36 with many applications in everyday life, such as power plants, fans, dynamos, and generators. Therefore,
37 students' low understanding of concepts will affect their ability to solve a problem (Gultepe et al., 2013).
38 Consequently, it is necessary to have a learning media that can visualize students on microscopic
39 materials, one of which is a digital book with 3D animations.

40 Currently, the use of digital books as physics learning media has ~~seen run into~~a rapid increase and is very
41 much needed when online learning during the COVID-19 pandemic (Abtokhi et al., 2021; Kholid, 2020;
42 Saraswati et al., 2021). Digital books are electronic versions of printed books that can be read ~~on through~~

43 a device with a specific purpose (Siegenthaler et al., 2010), in this case, ~~is~~ to improve the quality of physics
44 learning. Digital books have many advantages, including being practical, simple, interactive, and flexible,
45 so they ~~it~~ can be integrated with other media such as 3D animation visualization (Siregar et al., 2021a).
46 The 3D animation will help students provide a clear picture and understanding of the a-process (Wu &
47 Chiang, 2013). For example, in the abstract magnetic field material, 3D animation can help students clearly
48 visualize the concept of a magnetic field. Therefore, the integration of 3D animation in digital books can
49 be applied in physics learning, especially in en-abstract and microscopic materials. However, using digital
50 book media with 3D animations requires a supporting learning model that can simultaneously improve
51 students' PSS, one of which is the Problem Based Learning (PBL) model (Chamidy et al., 2020; Surur et al.,
52 2020).

53 PBL is a relevant learning model within the Indonesian curriculum in-Indonesia-because it is a student-
54 oriented learning system (Anazifa & Djukri, 2017; Demirel & Dağyar, 2016). Furthermore, this learning
55 model uses a real-life problem as a basis to train students to solve the problems they face (L. Liu, 2017;
56 Setyawan et al., 2020). It supported by Simanjuntak et al. (2021); Suastra et al. (2019); Yetri et al. (2019);
57 Yuberti et al. (2019) research which shows that the PBL is effective in improving students' PSS in physics
58 material. However, during the COVID-19 pandemic, the learning system was done online; thus this
59 learning model was called 'Online Problem Based Learning (OPBL).' There is no significant difference
60 between OPBL and conventional PBL, and the difference only lies in the use of media and technology used
61 during learning (Erickson et al., 2021). However, the research results by Dinata et al. (2020) show that
62 OPBL is more efficient than conventional PBL with the same learning outcome.

63 Previous research has been conducted by Bakri et al. (2019); Bogusevschi et al. (2020); Dimitrienko &
64 Gubareva, (2018); X. Liu et al. (2019); Pirker et al. (2019); Sannikov et al. (2015); Thees et al. (2020) have
65 implemented physics learning media based on 3D visualization in the form of augmented reality and
66 virtual reality. However, when implemented in online learning, the weakness of this media is expensive
67 and requires too many devices to display the visualization. In addition, this research also has not
68 integrated visualization media into specific learning models. There is still no research integrating the PBL
69 with a digital book with 3D animations or visualizations in physics learning.

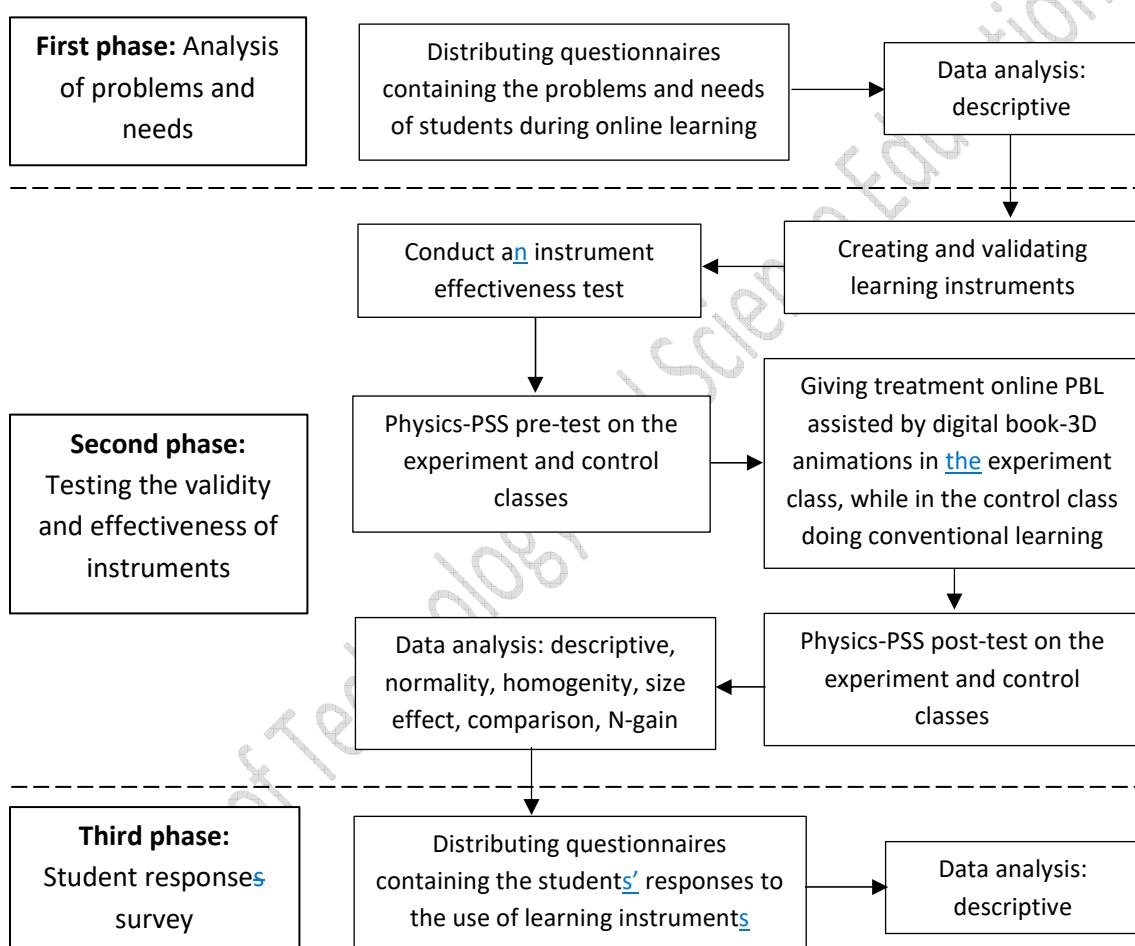
70 According to the A-preliminary research conducted on 61 research students, ~~showed that~~ 39 (63.9%)
71 students stated that the teacher's teaching method when learning online only gave assignments.
72 Furthermore, while using the-learning media for used during online learning, 40 (65.6%) students stated
73 that the contents were not understood, 23 (37.7%) students stated that they had difficulty accessing
74 learning media, 11 (18%) students stated that they lacked image visualization of regarding the material.
75 Based on the survey, it can be seen that students need more engaging, innovative teaching methods and
76 easy-to-understand learning media, that are easily accessible, and can provide exciting visualizations of
77 the subject being taught. Supported by a follow-up survey that 7 (11.5%) students strongly agreed, 40
78 (80.3%) students agreed that OPBL assisted by digital book with 3D animation media needs to be
79 implemented in physics learning.

80 Therefore, this research will create and implement an OPBL assisted by a digital book application assisted
81 with 3D animations so that it is more attractive and can provide learning material visualization to students.
82 This is done to optimize the achievement of students' PSS in physics learning, especially in the Magnetic
83 Field material. With this integrated learning model and media, it is hoped to improve students' physics-
84 PSS as one of the important skills in the 21st century. This study aims to analyze the validity, effectiveness,
85 and student responses to the use of OPBL assisted by digital books with 3D animations to improve the
86 ability to solve physics problems on magnetic field materials.

87 **2. Methodology**

88 The research was conducted at State Senior High School 24 Bangkalan (i.e. Indonesia) during September-
89 October 2021 with the learning system applied at the school being is-online learning. The research method
90 used is quantitative. The sample in this study was 65 students from an of 11th-grade class, consisting of
91 two classes from eight existing classes. However, when data collection has a different number of samples.
92 It is difficult to control the sample because all data collection is done online, and some samples are easily
93 lost. In this study, the sampling technique used was random cluster sampling because the school randomly
94 chose the two classes.

95 This research is divided into three phases of data collection, namely: 1) analysis of problems and needs;
96 2) testing the instrument's effectiveness; and 3) evaluation of student responses with the steps as in
97 Figure 1. Each phase is described as follows.



99 Figure 1. Stages of research diagram

100 2.1 First Phase: Analysis of Problems and Needs

101 This phase was carried out to determine know-the problems in learning physics experienced by students
102 during online learning. In addition, the need for relevant models and learning media can be seen so that
103 OPBL assisted by digital books with 3D animation can be an alternative solution to in solvingthe problems
104 faced. Data collection during this phase was carried out using a survey method by distributing
105 questionnaires containing the problems and needs of students during online learning. The sample
106 obtained in this research was 61 students (n = 61). The research data was werethen analyzed descriptively
107 to find out the problems and needs of students.

108

109

110 **2.2 Second Phase: Testing the Validity and Effectiveness of Instruments**

111 *Research Design*

112 The second phase uses a quasi-experimental type with a non-equivalent control group design (Creswell &
113 Creswell, 2018). The study was conducted in two classes with different treatments, namely the
114 experimental and control classes. At first, both classes were given a pre-test, and then they were given
115 different treatments between them as shown in Table 1. After that, a post-test was given at the end of
116 the lesson. The difference between the two classes only lies in the treatment. Other things, such as
117 materials, curriculum, number of meetings, class hours, and teachers, have the same design. The subject
118 used in this study is a magnetic field. In addition, schools implement the COVID-19 Pandemic Emergency
119 Curriculum with the same allocation of lesson hours but on different days. The number of meetings in
120 both classes have is also the same number of meetings per week, namely three meetings, and they have
121 has the same teacher.

Class	Pre-test	Treatment	Post-test
XI MIPA 3 (Experiment)	O_1	X	O_2
XI MIPA 5 (Control)	O_3	-	O_4

122 Note:

O_1 = Pre-test experimental class O_3 = Pre-test control class
 O_2 = Post-test experimental class O_4 = Post-test control class
X = treatment (OPBL assisted digital book)

123 Table 1. The difference in treatment between the experimental class and the control class

124

125 *Sample*

126 The research sample in the second phase only if students work on pre- and post-test questions, 59
127 students ($n = 59$) with details: in the experimental class there are 29 students, while in the control class
128 there are 30 students. So that the sample has almost the same number in the experimental class and the
129 control class.

130

131 *Instruments*

132 In this study, several instruments were used: learning implementation plans, digital books with 3D
133 animation, test instruments (pre- and post-test), and expert validation questionnaires.

134 1. Lesson Plans

135 The lesson plans consist of several components: the syllabus, lesson plans, and assessments. The learning
136 syllabus in both classes is adjusted to the current curriculum at school, but the lesson plans in both classes
137 have differences in their learning approaches. The experimental class uses OPBL with five syntaxes,
138 namely: 1) problem orientation; 2) organizing students; 3) guiding group investigations; 4) developing and
139 presenting works and exhibitions; and 5) analyzing and evaluating the problem-solving process; the
140 learning activities can be seen in Table 2 (Arends, 2011). The full syntax cannot be separated from the
141 assistance of digital books with 3D animation. In the control class, learning is conducted conventionally,
142 consisting of observing magnetic field phenomena, listening to written learning on theories, concepts,
143 and examples of phenomena, working on questions, and discussing them with class members. While the
144 assessment is carried out by focusing on students' PSS with the ACCES rubric, namely (A) Asses the
145 problem; (C) Create a drawing; (C) Conceptualize the strategy; (E) Execute the solution; (S) Scrutinize your
146 result (Teodorescu et al., 2013). Each rubric is assessed based on three categories: correct, logical, and
147 systematic. All learning activities are carried out online using WhatsApp media because the location of
148 students is constrained by the internet network, meaning so that there is no video conference for in-all
149 learning in both classes.

Syntax	Activity		PSS Indicator
	Teacher	Student	
Problem orientation	<ol style="list-style-type: none"> 1. Prepare <u>the</u> learning instruments, especially the digital book with 3D animation (DB3DA). 2. Introduce the magnetic field <u>topic subject</u> and its <u>significance</u> in <u>importance to learning</u>. 3. Orientation to magnetic field problems through contextual phenomena seen in DB3DA. 	<ol style="list-style-type: none"> 1. Download and install the DB3DA application. 2. Listen to the teacher's explanation of the magnetic field subject. 3. Observe and understand the problems to be solved. 	A
Organizing students	<ol style="list-style-type: none"> 1. Divide <u>the</u> students into <u>several</u> groups. 2. Ensure <u>that</u>—students <u>can</u> understand the problem <u>as well as</u> <u>and</u> the problem-solving process 	<ol style="list-style-type: none"> 1. Create groups based on the teacher's instruction. 2. Begin <u>to</u>—developing <u>problem solving with the help of in problem-solving</u>, <u>assisted</u> by DB3DA. 	A, C ₂
Guiding group investigations	Guides students in the problem-solving process through the student worksheet contained in the DB3DA	Conduct investigations, collect data, analyze ways of solving problems (more directed <u>at to</u> DB3DA).	C ₁ , C ₂ , E
Developing and presenting works and exhibitions	Monitor discussions and guide problem-solving reports as in the instructions in the DB3DA.	Conduct discussions to produce alternative problem-solving, make reports, and present their ideas	E, S
Analyzing and evaluating the problem-solving process	<ol style="list-style-type: none"> 1. Evaluation and reflection on the results of problem-solving that has been done by students. 2. Conclude the magnetic field learning subject based on BD3DA. 	<ol style="list-style-type: none"> 1. Evaluation of the extent of their acquired understanding. 2. Listen to the conclusion and ask if there are still confused 	S

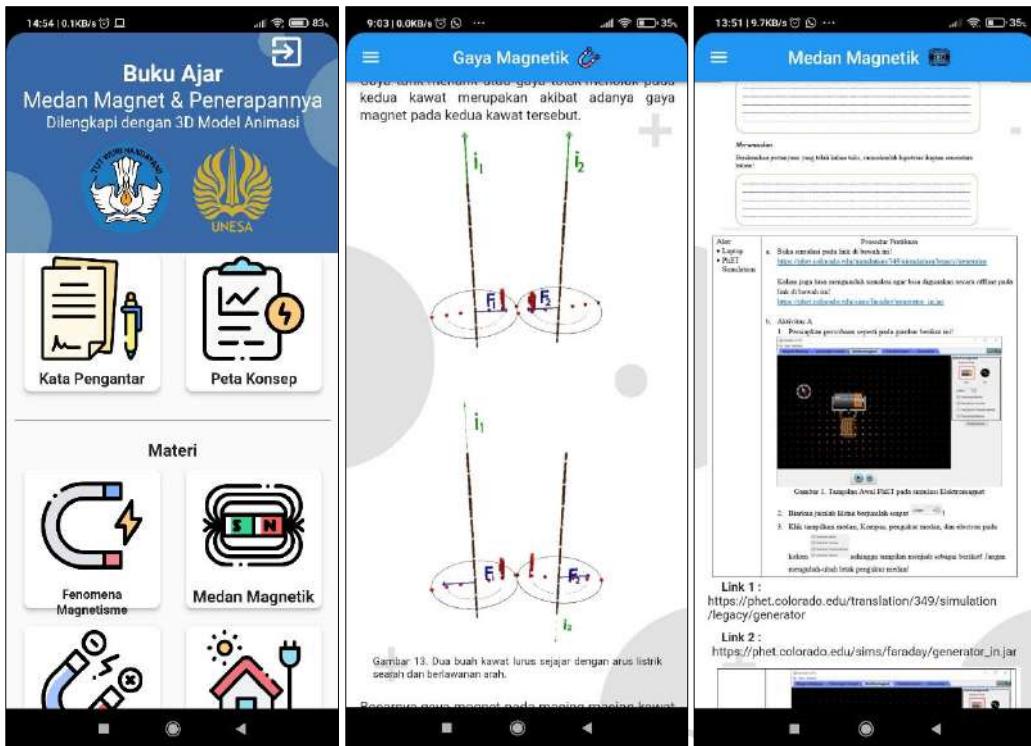
Note: A (Assen the problem); C₁ (Create a drawing); C₂ (Conceptualize the strategy); E (Execute the solution); S (Scrutinize your result)

Table 2. Learning activities in the experimental class (Adapted from Arends, 2011)

150
151
152

153 2. Digital book with 3D animation

154 This book has an extension.apk in the form of an application installed on via—mobile phones with a file size
155 of 67 MB. The application can be accessed offline to minimize network constraints during online learning.
156 However, this digital book also has weaknesses, such as being not yet integrated with practical simulations
157 and being less interactive. After the pre-test, this digital book set was used as a treatment for the
158 experimental class. Some pictures of digital books can be seen in Figure 2. To access this digital book
159 application, click [here](#).



(Source: Authors)

Figure 2. Some screenshots of digital book products with 3D animation.

3. Test instrument

The test instrument is divided into consists of two types, pre-test and post-test, but the tested questions are similar in both have similarities in the tested questions. This was done to determine the increase in the PSS of students in the experimental and control classes. Five questions are tested with the description questions with each ACCES rubric in each number. Each rubric will be assessed based on correct, logical, and systematic indicators. For example, if the student's answer represents the three indicators, the student gets a score of 3. If the student's answer only represents two indicators, then the student gets a score of 2, and so on until the student's answer does not meet all of the criteria, they will get a score of 0.

4. Expert validation questionnaire

The Expert validation questionnaire aims to determine the validity of the content and construct validity of the learning instruments used, namely the learning implementation plan and the application of digital books. Validation was carried out by three experts majoring in physics education.

Data Analysis

The validity of OPBL assisted by digital books with 3D animation models, is determined using the experts' average score of the assessment results. After that, the average assessment results will be adjusted according to the criteria in Table 3. In addition, the instrument's reliability is also assessed using the Cronbach's Alpha coefficient value, namely if the value is greater than >0.7 , the instrument can be said to be reliable (Taber, 2018).

The effectiveness of these learning instruments is analyzed based on the determined assessment before and after learning. The instruments can be said to be effective if they meet it meets the following criteria: 1) the average score of PSS is at least moderate; 2) there is a significant difference in the improvement of students' PSS abilities; 3) the effect size for the experimental class is at least medium effect; 4) the minimum n-gain value is middle for the experimental class; and 5) there is a significant difference between the experimental class and the control class. Determination of the value of the PSS score is determined done by using descriptive statistics on the pre-test and post-test scores. First, the PSS scores were adjusted

190 based on the criteria in Table 3. After that, the pre-, post-test, and n-gain data were analyzed using
 191 inferential statistics reviewed for normality using Shapiro-Wilk and homogeneity using Levene Statistic.
 192 Finally, to increase PSS, paired t-test/Mann-Whitney was performed for the pre-test, post-test, and n-gain
 193 values in the experimental and control classes were subjected to a paired t-test/Mann-Whitney test to
 194 increase PSS. The N-gain value was calculated by determined by: (post-test score – pre-test
 195 score)/(Maximum Score – pre-test score) and the results were adjusted using Hake's according to the
 196 criteria, according to Hake as shown in Table 3 (Hake, 1999). In addition, the size of the effect was
 197 determined using Cohen's d-effect size to see the impact of field operations as shown in Table 3 (Morgan
 198 et al., 2012).

Validity Criteria		PSS Criteria		Hake's N-gain		Cohen's d-effect size	
Average Score Validity	Criteria	Score	Criteria	N-gain	Category	D-effect	Category
3.25 < N ≤ 4.00	Very Valid	0 – 1,0	Low	g < 0.3	Low	≥1.00	Very Large
2.50 < N ≤ 3.25	Valid	1,01 – 2,0	Medium	0.3 ≤ g < 0.7	Middle	0.8	Large
1.75 < N ≤ 2.50	Less Valid	2,1 – 3,0	High	g ≥ 0.7	High	0.5	Medium
1.00 ≤ N ≤ 1.75	Invalid					0.2	Small

199 Table 3. The category of learning instrument validity criteria, PSS scoring, Hake's N-gain, and Cohen's d-
 200 effect size

201 **Third Phase: Students' Response Survey**

202 This phase was conducted to determine know student responses to OPBL, assisted by the digital book
 203 with 3D animation learning instruments that have been used during learning. Data was collected using
 204 the survey method by distributing questionnaires to the experimental class. This is because only the
 205 experimental class uses these learning instruments. The questionnaire contains ten questions that
 206 describe the use of the instrument to increase the ability of PSS in students. The research sample that
 207 filled out the questionnaire had was 32 students (n = 32), so there were differences with the second phase.
 208 However, according to attendance results, it turns out that all students in the experimental class always
 209 attend every learning meeting. The results of student responses were analyzed descriptively and
 210 quantitatively and adjusted to the following criteria: (1) Response of 75% (very positive); (2) 50% response
 211 < 75% (positive); (3) 25% response < 50% (less positive); and (4) response < 25% (not positive).

212 **3. Result and Discussion**

213 **3.1 Validity**

214 Three physics education experts assessed the validity of OPBL assisted by digital book-3D animations
 215 learning. The instruments assessed are the content and constructs of the lesson plan, the digital book
 216 application, test instruments, and the questionnaire of problems, needs, and responses to with the
 217 assessment results, as shown in Table 4. The validation results show that all aspects have valid criteria.
 218 The same as the reliability value, all aspects are reliable.

Component	Validity and reliability of OPBL assisted by digital book-3D animation			
	Score	Validity	α	Reliability
<i>Content Validity</i>				
1. Lesson plan	3.38	Very Valid	0.71	Reliable
2. Digital book	3.48	Very Valid	0.89	Reliable
3. Test Instruments	3.75	Very Valid	0.88	Reliable
4. Questionnaire of problems, needs, and responses	3.71	Very Valid	0.75	Reliable
<i>Construct Validity</i>				
1. Lesson plan	3.33	Very Valid	0.93	Reliable
2. Digital book	3.62	Very Valid	0.70	Reliable
3. Test Instruments	3.66	Very Valid	0.76	Reliable

4. Questionnaire of problems, needs, and responses	3.77	Very Valid	0.82	Reliable
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219 Note: α = Cronbach Alpha

220 Table 4. The results of the assessment of the validity of the instruments by the expert

221 This learning instrument has a novelty in OPBL implementation, assisted by digital books with 3D
 222 animation. Unlike PBL in general, which requires student worksheets and teaching materials, these two
 223 instruments are already integrated with a digital book, so this digital book application contains complete
 224 instruments. This application has also been integrated with simulation guidelines to assist in the problem-
 225 solving process. If all learning instruments could be integrated into one application, this could further
 226 optimize the learning process (Herayanti et al., 2017). The involvement of the digital book
 227 application can be seen from its occurrence in every process in the OPBL syntax. In addition, the test
 228 instruments and questionnaires were also declared valid by experts. According to the validator, this
 229 learning instrument is generally valid and feasible to assess the next aspect (effectiveness) after minor
 230 revisions have been made (Plomp, 2013). After corrections were made based on their recommendations,
 231 the OPBL assisted by digital books with 3D animations to improve physics-PSS could be implemented for
 232 SMAN 2 Bangkalan students.

233 **3.2 Effectiveness**

234 To determine the effectiveness of PBL online learning assisted by 3D digital-animated books, can be seen
 235 in Table 5, Table 6, Table 7, and Table 8 with the following explanation.

Group	N	Lowest Score			Highest Score		
		Pre-test	Post-test	Average	Pre test	Post test	Average
Experiment	29	0.51	1.35	0.82	1.20	2.64	2.32
Control	30	0.04	0.28	0.47	1.24	2.17	1.26

236 Table 5. Results of descriptive statistical calculations: lowest, highest, and average scores average in both
 237 classes

238 Based on Table 5, it can be seen that there are differences in the pre-test and post-test abilities in both
 239 the experimental and control classes. In the experimental class, the lowest pre-test PSS score was 0.51,
 240 and the highest was 1.20, while the lowest post-test PSS score was 1.35, and the highest was 2.64. There
 241 is also a difference in the pre-test. The average PSS score differs between the pre-test and is 0.82, while
 242 the post-test: the pre-test average is 0.82, while the post test average is 2.32. In the control class, the
 243 lowest PSS score on in the pre-test is 0.04, and the highest is 1.24, while the lowest PSS score on in the
 244 post-test is 0.28 and the highest is 2.17. In addition, there is also an average difference in the pre-test,
 245 which is 0.47, while in the post-test it is 1.26. The low pre-test score is caused by students who still do not
 246 understand the tested material and do not have PSS in solving physics problems. In line with the research
 247 results by Jua et al. (2018), Indonesian students' physics PSS is still relatively low. But when on post-test
 248 scores, there was an increase in PSS scores in both classes because students had learned about the subject
 249 being tested (magnetic field). When compared between the experimental class and the control class,
 250 there is a difference in values where the experimental class has a higher PSS value than the control class,
 251 especially in the post-test. This is due to the difference in treatment between the two classes, where the
 252 experimental class uses an OPBL assisted by digital books with 3D animation, while the control class uses
 253 conventional learning.

254 The normality test results revealed that showed that the data were not normally distributed in the
 255 experimental class, while the data were not normally distributed, whereas the data in the control class
 256 were normally distributed. This is due to the online treatment of PBL with the digital book with 3D
 257 animations, which causes the data to skew to the right, or most of the students' scores are high. In
 258 addition, the homogeneity test results indicate that the data is not homogeneous. Therefore, Mann-
 259 Whitney non-parametric statistical inferential analysis ($\alpha = 5\%$) was used to determine the difference
 260 between the two classes.

Shapiro-Wilk Normality Test

Group	Test	p (Sig.)	Distribution
Experiment Class	Pre-test	0.003	Not Normal
	Post-test	0.000	Not Normal
Control Class	Pre-test	0.025	Normal
	Post-test	0.317	Normal

Levene Statistic Homogeneity Test			
Test	Number of Sample	p (Sig.)	Homogeneity
Pre-test	59	0.002	Not Homogenous
Post-test		0.020	Homogenous

Mann-Whitney Test			
Group	p (sig.)	Hypothesis	
Experiment Class	0.000	There is a significant difference between the pre-test and post-test scores	
Control Class	0.000		

Cohen's d-effect size			
Group	d-effect size	Category	
Experiment Class	1.95	Very Large	
Control Class	1.63	Very Large	

261 Table 6. The test results of Shapiro-Wilk normality, Levene statistic homogeneity, Mann-Whitney, and
262 Cohen's d-effect size for both classes

263 Based on the results of the Mann-Whitney test as shown in Table 6, it can be seen that the significance
264 value is $p < 0.05$ which means so that the hypothesis is accepted. In both classes, it means there is a
265 significant difference between the pre- and post-test results in both classes. It is because there are
266 differences in students' understanding who initially had not learned about the magnetic field subject.
267 After being given treatment and learning about the subject, the students understood the material and
268 increased their learning outcomes. In line with several research results, using the PBL can improve their
269 learning outcomes (Amini et al., 2019; Kawuri et al., 2019; Qomariyah, 2019). If viewed from the effect
270 size, it can be seen that both classes have a very large effect category. But the experimental class has a
271 higher value than the control class. This is because in the experimental class, learning focuses more on
272 solving problems using the PBL, assisted by a digital book with 3D animations. While the control class only
273 uses conventional learning. In line with (Kapi et al., 2017) research, visual media can display more real
274 physical phenomena. The use of multimedia aims to facilitate learning physics and change the paradigm
275 of students who do not realize that many everyday events related to physics can encourage students to
276 be actively involved in the thinking process by linking learning to real-life situations (Jabaliah et al.,
277 2021; Liew & Tan, 2016; Warsono et al., 2020). The use of digital book media in the experimental class
278 can increase student learning activities so that students are more motivated than learning in
279 conventional classes (Iskandar et al., 2018).

Group	Indicators of PSS										
	A		C ₁		C ₂		E		S		
EC	O ₁	0.80	L	0.50	L	0.90	L	1.00	L	0.50s	L
	O ₂	2.60	H	2.00	M	1.60	M	2.60	H	1.90	M
	<g>	0.80	H	0.60	M	0.40	M	0.80	H	0.50	M
CC	O ₃	0.90	L	0.50	L	0.40	L	0.50	L	0.00	L
	O ₄	2.40	H	1.40	M	0.80	L	0.50	L	1.00	L
	<g>	0.60	M	0.30	M	0.10	L	0.00	L	0.30	M

280 Note:

281 EC (Experiment Class); CC (Control Class); O₁ (Pre-test experimental class); O₂ (Post-test experimental class); O₃ (Pre-test control
282 class); O₄ (Post-test control class); A (Assen the problem); C₁ (Create a drawing); C₂ (Conceptualize the strategy); E (Execute the
283 solution); S (Scrutinize your result); L (Low); M (Middle); H (High)

284 Table 7. The increase in PSS for each indicator in both classes.

285 In more detail, the increase in PSS for each indicator in both classes can be seen in Table 7. It can be seen
 286 that the results of the pre-test on all PSS indicators for both classes are in the a-low category. After
 287 applying the OPBL assisted by digital books in the experimental class, there was an increase in N-gain for
 288 all skills in the into-middle and high categories. Increased the smallest N-gain contained in the
 289 Conceptualize the Strategy (C₂) indicator. For this indicator, the students are still using strategies by
 290 applying the equation only to solve the problems as generally taught in the classroom. In line with the
 291 research results (Ceberio et al., 2016; Reddy & Panacharoensawad, 2017; Riantoni et al., 2017), students
 292 tend not to use physics concepts to solve problems and only use memorized equations. But they can
 293 answer correctly on the Execute the Solution (E) indicator because some of the students copy each other's
 294 answers, which is are-indicated by the similarity of their answers. As a result, on the Scrutinize your result
 295 (S) indicator has the smallest N-gain second after C₂. OnWhile online tests, students more easily cheat on
 296 each other, so they become less confident about their work results (Cindikia et al., 2020). In the control
 297 class, the increase in the N-gain value for each indicator is smaller than in the experimental class because
 298 this class uses conventional learning. The lowest increase in N-gain is found in the-Execute the Solution
 299 (E) indicator because students cannot apply problem-solving skills in executing solutions to the problems
 300 asked.

301 The comparison of the average N-gain results in the experimental class with the control class can be seen
 302 in Table 8. It can be seen that the average N-gain value between the experimental class is 0.688 including
 303 the middle criteria, while in the control class is 0.282 including in the low criteria. So, the N-gain value of
 304 the PSS students in the experimental class is greater than the control class. Furthermore, the results of
 305 the normality test on the N-gain data of both classes showed that the experimental class was not normally
 306 distributed, while the control class had a normal distribution. This is because the N-gain value in the
 307 experimental class is skewed to the right, which means more high-value data. Furthermore, the
 308 homogeneity test results showed that the data were homogeneously distributed. Thus, to determine the
 309 significance of the difference between the N-gain of the two classes, non-parametric inferential statistics
 310 were used, namely the Mann-Whitney test.

Group	Descriptive Statistic		Shapiro-Wilk Normality Test		Levene Statistic Homogeneity Test		Mann-Whitney Test
	Average N-Gain	Criteria	p (Sig.)	Distribution	p (Sig.)	Criteria	p (Sig.)
EC	0.688	Middle	0.000	Not Normal	0.091	Homo-geneous	0.000
	0.282	Low	0.601	Normal			

311 Note: EC (Experiment Class); CC (Control Class)

312 Table 7. The test result of descriptive statistic, Shapiro-Wilk normality, Levene statistic, and Mann-
 313 Whitney for increasing PSS in both classes

314 It can be seen that the *p*-value < 0.05, which means that there is a significant difference in the N-gain
 315 value between the experimental class and the control class statistically. This is because OPBL assisted by
 316 digital books with 3D animation can help students improve their PSS. The PBL that focuses on problem-
 317 solving makes students accustomed to solving problems and applying them to physics problems. In
 318 addition, in learning activities, students are given assignments in the form of physics questions that must
 319 be done in stages with problem-solving indicators. Students who receive OPBL-based learning also have
 320 PSS to easily answer physics problems compared to conventional learning models who are not trained in
 321 problem-solving. In line with some research results that PBL emphasizes more on PSS aspects such as
 322 analyzing in choosing the right concepts and principles needed in solving problems so that it is better than
 323 conventional classes (Docktor et al., 2015; Docktor & Mestre, 2014; Parno et al., 2019; Valdez & Bungihan,
 324 2019). This finding is consistent with research by (Sari et al., 2021; Sota & Peltzer, 2017), which reveals
 325 that problem-solving skills need a problem understanding process, whereas the OPBL syntax is found in
 326 the problem orientation process. Through this process, students can be guided to understand the
 327 problem, formulate a solution design, execute problem-solving according to plan, and re-examine the
 328 problem-solving process. Another study by (Septian et al., 2020; Syafii & Yasin, 2013) agrees with
 329 increasing PSS through PBL because this ability can be developed through practice. Students can have
 330 excellent thinking skills and justify with scientific evidence to find alternative problem-solving. With
 331 OPBL, students will practice problem-solving through student worksheets or structured assignments.

333 In terms of learning theory, this is findings also reinforced by the John Dewey's learning theory that the
334 class should be a laboratory in solving real-life problems (Arends, 2011). In addition, PBL is also based on
335 cognitive constructivism learning theory by Piaget. Through the PBL, students can actively construct their
336 own knowledge by interacting with their environment through the assimilation and the accommodation
337 process (Arends, 2011). PBL is also reinforced by Vygotsky, which reveals that the learning process will
338 occur when students work in the Zone of Proximal Development (Schunk, 2011). During problem-based
339 learning, students will be in a top-down process, where students start with complex problems to solve
340 and then solve or find (with the teacher's help) the basic skills needed (Slavin, 2011). The results of this
341 study are also supported by Bruner's discovery learning theory, where students are required to be active
342 in solving existing problems and are assisted by teachers to provide scaffolding (Moreno, 2010).

343 Digital books also support the OPBL with 3D animations that make it easier for students to understand
344 the concept because the animation can help students visualize abstract and complex magnetic field
345 subjects. In line with several studies showing that the use of 3D animation can improve visual
346 understanding, spatial abilities, cognitive understanding, and student learning outcomes (Bakar et al.,
347 2019; Benzer & Yildiz, 2019; Cai et al., 2013; Dori & Belcher, 2005; Kumar, 2016; Mystakidis & Berki, 2018;
348 Park et al., 2016). This finding is supported by (McKnight et al., 2016) research which explains that the use
349 of technology in learning (such as digital books) can replace the roles of teachers and students, where a
350 teacher's guide, ask questions, and facilitate students to find their own answers and construct their
351 knowledge. Meanwhile, students are more flexible, accessible, and active in seeking what knowledge is
352 relevant to learning to become deep learners. This certainly supports the implementation of student-
353 centered OPBL learning. The integration between this digital book and the OPBL model can support the
354 learning process and improve students' PSS. Supported by research by (Chao et al., 2017; Siregar et al.,
355 2021b) also agrees that the use of digital books and 3D animations can help students to solve problems,
356 so it is very relevant when combined with the OPBL model. This digital book can make physics learning
357 better because the learning media used is the right mix of verbal channels (in material text) and visuals
358 (3D animated images). This is reinforced by the dual coding theory by Paivio that information received by
359 a person is processed through one of two channels, namely verbal and visual channels that can function
360 either independently, parallel, or integrated (Paivio, 2013).

361 In general, the results of the analysis on the effectiveness of the learning instruments show that 1) the
362 average problem-solving score of students in the experimental class is 2.32, which means it is in the high
363 category; 2) the increase in the PSS ability of students has a *p*-value of < 0.05 so that there is a significant
364 difference; and 3) the effect size for the experimental class is 1.95, so it is included in the very large
365 category; 4) the value of n-gain for the experimental class is middle-; and 5) between the experimental
366 class and the control class has a *p*-value < 0.05 indicating so that there is a significant difference between
367 the two. Thus, PBL online learning assisted by digital books with 3D animation effectively increases
368 students' physics-PSS on magnetic field subjects.

369 **3.3 Students' Responses**

370 The results of a survey of a sample of 32 students (*n* = 32) to find out their response to PBL online learning
371 activities assisted by digital books with 3D animation can be seen in Table 9. The calculation results show
372 that the category's average score agrees and strongly agrees with by 80.60%, while disagreeing and
373 strongly disagree with by 19.40%. Thus, according to students, this learning activity is included in the very
374 positive criteria. The use of the OPBL is a more innovative and exciting learning model because so far, the
375 learning that has been carried out has only focused on working on tasks independently so that students
376 are easily bored. Especially for learning physics, which is considered complex and complicated by them.
377 In addition, the use of digital book applications with 3D animation is a new learning medium for them to
378 help create more enjoyable learning through the media provided. This finding is supported by research
379 by (Abdinejad et al., 2021; Sin & Al-Asmari, 2018) that the majority of students agree with the use of 3D
380 animation-based learning media to help their understanding through object visualization. This is because
381 conventional learning methods are limited in describing difficult visual concepts. So the use of 3D
382 animation can be used in magnetic field materials to facilitate the learning process by adding motion and
383 trajectories to describe spatial and visual information effectively (Rieber, 1991).

Average Responses	Responses (%)
-------------------	---------------

	Very Agree	Agree	Disagree	Very Disagree
	16,25	64,35	16,59	2,81

385 Table 9. Average student responses in the experimental class regarding learning activities that have been
 386 carried out.

387

388 **3.4 Limitations, Recommendations, and Implications**

389 This research still has limitations, such as: 1) It has still have-not been tested practically on the models
 390 and learning media used; 2) the sample used is only two classes; and 3) the validity assessment only
 391 focuses on lesson plans and digital book products. In addition, there are also limitations in the products
 392 made, such as: 1) the size of the application is still too big, so it requires a large enough storage space; 2)
 393 3D animation is still less interactive; 3) the application is not yet integrated with the practical simulation;
 394 4) it is not known whether it is compatible with for all types of operating systems; 4) The material available
 395 is only Magnetic Field.

396 So that there are recommendations, including 1) conducting a practical test of the models and learning
 397 media used; 2) increasing the number of research samples up to 4 classes; and 3) conducting validity
 398 assessments for other learning instruments, such as test instruments and survey questionnaires. There
 399 are also recommendations for digital book application products: 1) compressing the file size to become
 400 smaller; 2) making animations more interesting and interactive; 3) integrating applications with virtual
 401 practicums; and 4) performing compatibility tests for all kinds of operating systems.

402 This research implies that the results of the research product in the form of an OPBL assisted by the digital
 403 book with 3D animations can be applied by teachers in learning physics material during online learning. It
 404 is hoped that the application of these products can improve students' PSS while at the same time solving
 405 real-life problems that students will face related to the concept, especially in magnetic field subjects.

406 **4. Conclusions**

407 It can be concluded that the OPBL assisted with digital book applications with 3D animation learning
 408 instruments to improve students' PSS on Magnetic Field material. This learning instrument meets the
 409 validity aspect with very valid and reliable criteria both from the content component and the construct.
 410 This-These learning instruments are is also effective in improving students' PSS. The survey results to
 411 students showed that students responded very positively to this learning instruments. We recommend
 412 that further researchers conduct practicality tests, develop applications, or test their effects on other 21st
 413 century skills.

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691 **IMPLEMENTATION OF ONLINE PROBLEM-BASED LEARNING**
692 **ASSISTED BY DIGITAL BOOK WITH 3D ANIMATIONS TO**
693 **IMPROVE STUDENT'S PHYSICS PROBLEM-SOLVING SKILLS IN**
694 **MAGNETIC FIELD SUBJECT**

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699 **Abstract**

700 The magnetic field is a more complex and abstract physics subject than other physics subjects, causing
701 students' low ability to solve problems. So there is a need for learning instruments to overcome these
702 problems, especially when online learning during the COVID-19 pandemic. Research creates and
703 implements an online problem-based learning (OPBL) assisted by digital books with 3D animation to
704 improve students' physics problem-solving skills on magnetic field subjects. Research aimed to analyze
705 the validity, effectiveness, and student responses to the learning instruments used. The method used in
706 this research is quantitative by using quasi-experiment and survey methods. The results showed that this
707 learning instrument was valid and reliable to use in terms of contents and constructs. According to
708 statistical test results, this learning instrument is also effective in improving students' problem-solving
709 skills on magnetic field subjects. Furthermore, the student's response to this learning instrument was very
710 positive, making this learning activity more innovative and fun. Research implies that an OPBL assisted by
711 digital books with 3D animation instruments can be a solution to improve students' physics problem-
712 solving skills, especially during the online learning period.

713 Keywords: Digital book with 3D animations, Magnetic field, Online problem-based learning, Problem-
714 solving skills.

715 **1. Introduction**

716 Problem-Solving Skills (PSS) are important skills for students to have in order to the challenges and
717 demands of the 21st century (Ghafar, 2020; Mohd-Yusof et al., 2011; Nurdyansyah et al., 2021; Parno et
718 al., 2020; Ridhwan et al., 2020; Suhirman et al., 2020). PSS can train students in observation, reasoning,
719 analyzing, and creative thinking to help them solve everyday problems (Devanti et al., 2020). In addition,
720 PSS is essential in physics subjects to improve students' conceptual understanding because it prioritizes
721 contextual understanding (Hudha et al., 2017).

722 In reality, sometimes students have difficulty developing their knowledge when solving a problem (Umara,
723 2019). This is evidenced by the preliminary test results on 59 students, which showed that 52 (88.13%)
724 students had low PSS scores. One of the reasons is the difficulty of visualization, which can obstruct the
725 problem-solving process because there are some abstract and microscopic physics subjects (Cai et al.,
726 2021; İbili et al., 2020), such as magnetic field subjects. Because of the subject's high complexity and
727 abstraction, Students' PSS tend to be low and they have many misconceptions it (Bestiantono et al., 2019;
728 Turgut et al., 2016; Yilmaz & Ince, 2012). Furthermore, magnetic field subject is a prerequisite subject for
729 electromagnetic induction with many applications in everyday life, such as power plants, fans, dynamos,
730 and generators. Therefore, students' low understanding of concepts will affect their ability to solve a

731 problem (Gultepe et al., 2013). Consequently, it is necessary to have a learning media that can visualize
732 students on microscopic materials, one of which is a digital book with 3D animations.

733 Currently, the use of digital books as physics learning media has seen a rapid increase and is very much
734 needed when online learning during the COVID-19 pandemic (Abtokhi et al., 2021; Kholiq, 2020; Saraswati
735 et al., 2021). Digital books are electronic versions of printed books that can be read on a device with a
736 specific purpose (Siegenthaler et al., 2010), in this case, to improve the quality of physics learning. Digital
737 books have many advantages, including being practical, simple, interactive, and flexible, so they can be
738 integrated with other media such as 3D animation visualization (Siregar et al., 2021a). The 3D animation
739 will help students provide a clear picture and understanding of the process (Wu & Chiang, 2013). For
740 example, in the abstract magnetic field material, 3D animation can help students clearly visualize the
741 concept of a magnetic field. Therefore, the integration of 3D animation in digital books can be applied in
742 physics learning, especially in abstract and microscopic materials. However, using digital book media with
743 3D animations requires a supporting learning model that can simultaneously improve students' PSS, one
744 of which is the Problem Based Learning (PBL) model (Chamidy et al., 2020; Surur et al., 2020).

745 PBL is a relevant learning model within the Indonesian curriculum because it is a student-oriented learning
746 system (Anazifa & Djukri, 2017; Demirel & Dağyar, 2016). Furthermore, this learning model uses a real-
747 life problem as a basis to train students to solve the problems they face (L. Liu, 2017; Setyawan et al.,
748 2020). It supported by Simanjuntak et al. (2021); Suastra et al. (2019); Yetri et al. (2019); Yuberti et al.
749 (2019) research which shows that the PBL is effective in improving students' PSS in physics material.
750 However, during the COVID-19 pandemic, the learning system was done online; thus this learning model
751 was called 'Online Problem Based Learning (OPBL).' There is no significant difference between OPBL and
752 conventional PBL, and the difference only lies in the use of media and technology used during learning
753 (Erickson et al., 2021). However, the research results by Dinata et al. (2020) show that OPBL is more
754 efficient than conventional PBL with the same learning outcome.

755 Previous research has been conducted by Bakri et al. (2019); Bogusevski et al. (2020); Dimitrienko &
756 Gubareva, (2018); X. Liu et al. (2019); Pirker et al. (2019); Sannikov et al. (2015); Thees et al. (2020) have
757 implemented physics learning media based on 3D visualization in the form of augmented reality and
758 virtual reality. However, when implemented in online learning, the weakness of this media is expensive
759 and requires too many devices to display the visualization. In addition, this research also has not
760 integrated visualization media into specific learning models. There is still no research integrating the PBL
761 with a digital book with 3D animations or visualizations in physics learning.

762 According to the preliminary research conducted on 61 research students, 39 (63.9%) students stated that
763 the teacher's teaching method when learning online only gave assignments. Furthermore, while using
764 learning media for online learning, 40 (65.6%) students stated that the contents were not understood, 23
765 (37.7%) students stated that they had difficulty accessing learning media, 11 (18%) students stated that
766 they lacked image visualization of the material. Based on the survey, it can be seen that students need
767 more engaging, innovative teaching methods and easy-to-understand learning media that are easily
768 accessible and can provide exciting visualizations of the subject being taught. Supported by a follow-up
769 survey that 7 (11.5%) students strongly agreed, 40 (80.3%) students agreed that OPBL assisted by digital
770 book with 3D animation media needs to be implemented in physics learning.

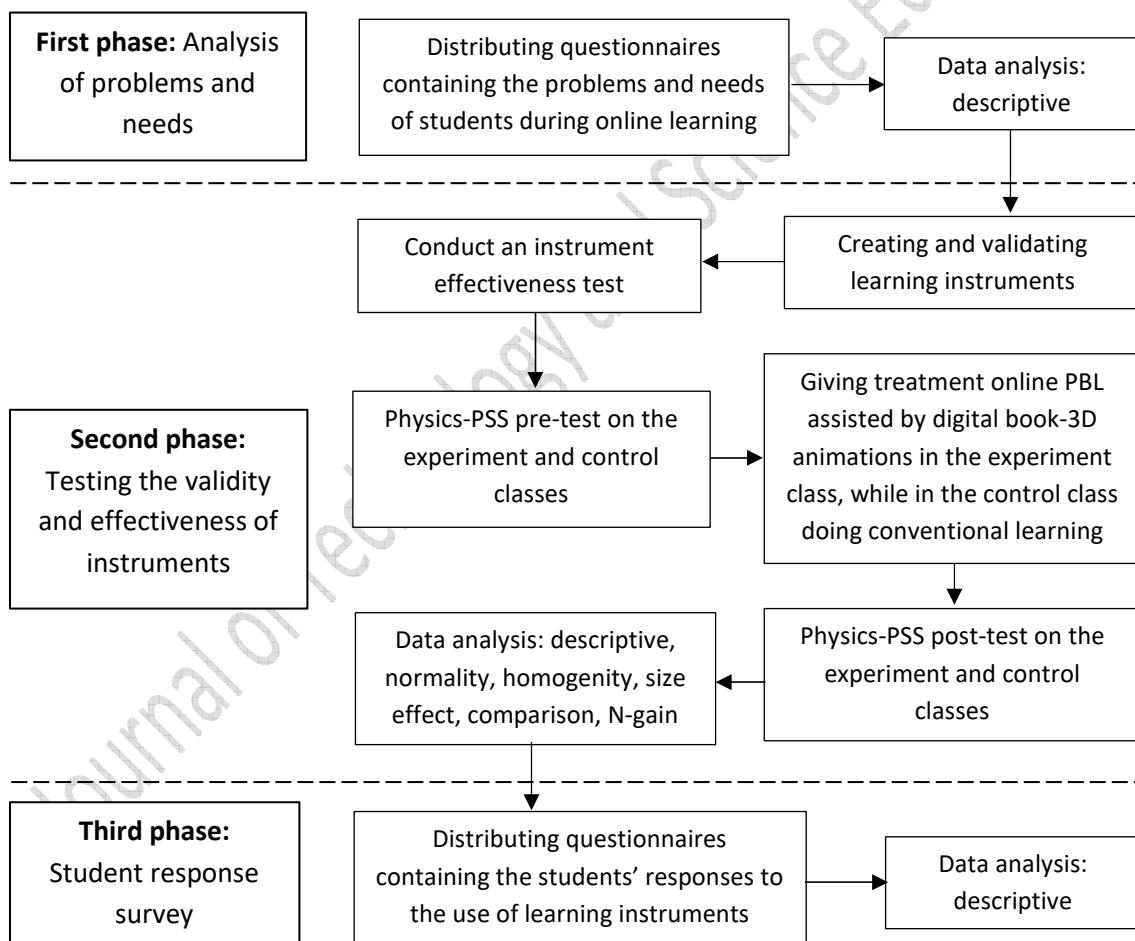
771 Therefore, this research will create and implement an OPBL assisted by a digital book application assisted
772 with 3D animations so that it is more attractive and can provide learning material visualization to students.
773 This is done to optimize the achievement of students' PSS in physics learning, especially in the Magnetic
774 Field material. With this integrated learning model and media, it is hoped to improve students' physics-
775 PSS as one of the important skills in the 21st century. This study aims to analyze the validity, effectiveness,

776 and student responses to the use of OPBL assisted by digital books with 3D animations to improve the
777 ability to solve physics problems on magnetic field materials.

778 **2. Methodology**

779 The research was conducted at State Senior High School 2 Bangkalan (i.e. Indonesia) during September-
780 October 2021 with the learning system applied at the school being online learning. The research method
781 used is quantitative. The sample in this study was 65 students from an 11th-grade class, consisting of two
782 classes from eight existing classes. However, when data collection has a different number of samples. It
783 is difficult to control the sample because all data collection is done online, and some samples are easily
784 lost. In this study, the sampling technique used was random cluster sampling because the school randomly
785 chose the two classes.

786 This research is divided into three phases of data collection, namely: 1) analysis of problems and needs;
787 2) testing the instrument's effectiveness; and 3) evaluation of student responses with the steps as in
788 Figure 1. Each phase is described as follows.



790 Figure 1. Stages of research diagram

791 **2.1 First Phase: Analysis of Problems and Needs**

792 This phase was carried out to determine the problems in learning physics experienced by students during
793 online learning. In addition, the need for relevant models and learning media can be seen so that OPBL
794 assisted by digital books with 3D animation can be an alternative solution to the problems faced. Data

795 collection during this phase was carried out using a survey method by distributing questionnaires
796 containing the problems and needs of students during online learning. The sample obtained in this
797 research was 61 students ($n = 61$). The research data was then analyzed descriptively to find out the
798 problems and needs of students.

799 **2.2 Second Phase: Testing the Validity and Effectiveness of Instruments**

800 *Research Design*

801 The second phase uses a quasi-experimental type with a non-equivalent control group design (Creswell &
802 Creswell, 2018). The study was conducted in two classes with different treatments, namely the
803 experimental and control classes. first, both classes were given a pre-test, and then they were given
804 different treatments between them as shown in Table 1. After that, a post-test was given at the end of
805 the lesson. The difference between the two classes only lies in the treatment. Other things, such as
806 materials, curriculum, number of meetings, class hours, and teachers, have the same design. The subject
807 used in this study is a magnetic field. In addition, schools implement the COVID-19 Pandemic Emergency
808 Curriculum with the same allocation of lesson hours but on different days. both classes have is also the
809 same number of meetings per week, namely three meetings, and they have the same teacher.

<i>Class</i>	<i>Pre-test</i>	<i>Treatment</i>	<i>Post-test</i>
<i>XI MIPA 3 (Experiment)</i>	O_1	X	O_2
<i>XI MIPA 5 (Control)</i>	O_3	-	O_4

810 Note:

O_1 = Pre-test experimental class O_3 = Pre-test control class
 O_2 = Post-test experimental class O_4 = Post-test control class
X = treatment (OPBL assisted digital book)

811 Table 1. The difference in treatment between the experimental class and the control class

812

813 *Sample*

814 The research sample in the second phase only if students work on pre- and post-test questions, 59
815 students ($n = 59$) with details: in the experimental class there are 29 students, while in the control class
816 there are 30 students. So that the sample has almost the same number in the experimental class and the
817 control class.

818

819 *Instruments*

820 In this study, several instruments were used: learning implementation plans, digital books with 3D
821 animation, test instruments (pre- and post-test), and expert validation questionnaires.

822 5. Lesson Plans

823 The lesson plans consist of several components: the syllabus, lesson plans, and assessments. The learning
824 syllabus in both classes is adjusted to the current curriculum at school, but the lesson plans in both classes
825 have differences in their learning approaches. The experimental class uses OPBL with five syntaxes,
826 namely: 1) problem orientation; 2) organizing students; 3) guiding group investigations; 4) developing and
827 presenting works and exhibitions; and 5) analyzing and evaluating the problem-solving process; the
828 learning activities can be seen in Table 2 (Arends, 2011). The full syntax cannot be separated from the
829 assistance of digital books with 3D animation. In the control class, learning is conducted conventionally,
830 consisting of observing magnetic field phenomena, listening to written learning on theories, concepts,
831 and examples of phenomena, working on questions, and discussing them with class members. the
832 assessment is carried out by focusing on students' PSS with the ACCES rubric, namely (A) Asses the
833 problem; (C) Create a drawing; (C) Conceptualize the strategy; (E) Execute the solution; (S) Scrutinize your
834 result (Teodorescu et al., 2013). Each rubric is assessed based on three categories: correct, logical, and
835 systematic. All learning activities are carried out online using WhatsApp media because the location of
836 students is constrained by the internet network, meaning there is no video conference for all learning in
837 both classes.

Syntax	Activity		PSS Indicator
	Teacher	Student	
Problem orientation	4. Prepare the learning instruments, especially the digital book with 3D animation (DB3DA). 5. Introduce the magnetic field topic and its significance in learning. 6. Orientation to magnetic field problems through contextual phenomena seen in DB3DA.	4. Download and install the DB3DA application. 5. Listen to the teacher's explanation of the magnetic field subject. 6. Observe and understand the problems to be solved.	A
Organizing students	3. Divide the students into groups. 4. Ensure that students understand the problem as well as the problem-solving process	3. Create groups based on the teacher's instruction. 4. Begin developing problem solving with the help of by BD3DA.	A, C ₂
Guiding group investigations	Guides students in the problem-solving process through the student worksheet contained in the DB3DA	Conduct investigations, collect data, analyze ways of solving problems (more directed at DB3DA).	C ₁ , C ₂ , E
Developing and presenting works and exhibitions	Monitor discussions and guide problem-solving reports as in the instructions in the DB3DA.	Conduct discussions to produce alternative problem-solving, make reports, and present their ideas	E, S
Analyzing and evaluating the problem-solving process	3. Evaluation and reflection on the results of problem-solving that has been done by students. 4. Conclude the magnetic field learning subject based on BD3DA.	3. Evaluation of the extent of their acquired understanding. 4. Listen to the conclusion and ask if there are still confused	S

Note: A (Assen the problem); C₁ (Create a drawing); C₂ (Conceptualize the strategy); E (Execute the solution); S (Scrutinize your result)

Table 2. Learning activities in the experimental class (Adapted from Arends, 2011)

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6. Digital book with 3D animation

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This book has an extension.apk in the form of an application installed on mobile phones with a file size of 67 MB. The application can be accessed offline to minimize network constraints during online learning. However, this digital book also has weaknesses, such as being not yet integrated with practical simulations and being less interactive. After the pre-test, this digital book set was used as a treatment for the experimental class. Some pictures of digital books can be seen in Figure 2. To access this digital book application, click [here](#).

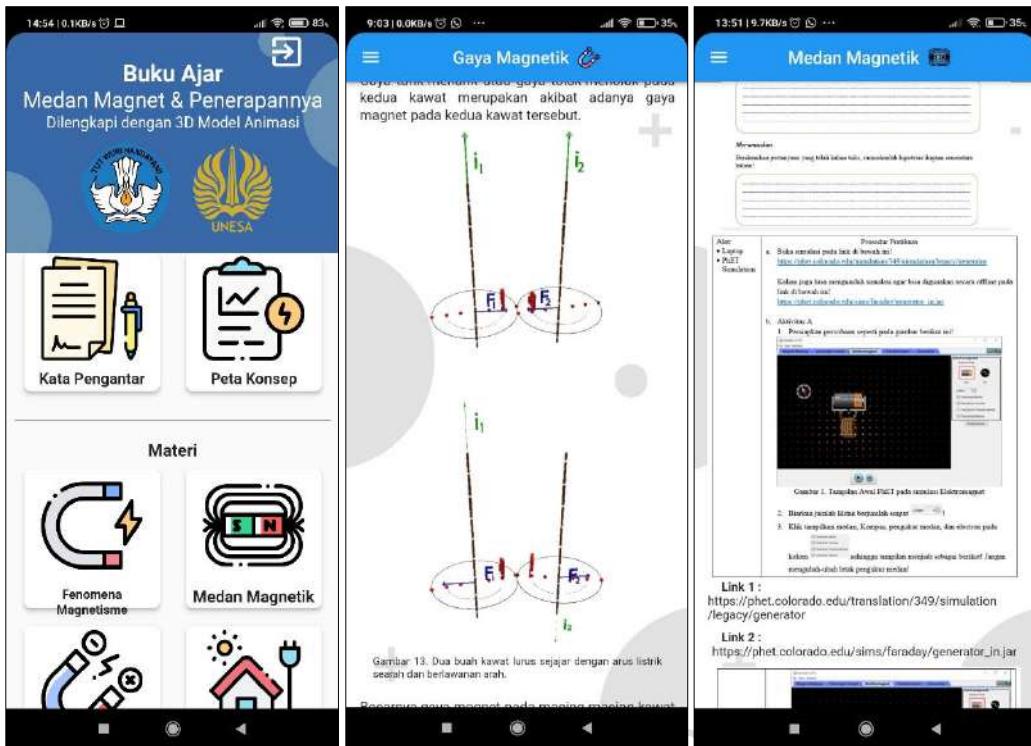
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7. Test instrument

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The test instrument is divided into two types, pre-test and post-test, but the tested questions are similar in both. This was done to determine the increase in the PSS of students in the experimental and control classes. Five questions are tested with the description questions with each ACCES rubric in each number. Each rubric will be assessed based on correct, logical, and systematic indicators. For example, if the student's answer represents the three indicators, the student gets a score of 3. If the student's answer only represents two indicators, then the student gets a score of 2, and so on until the student's answer does not meet all of the criteria, they will get a score of 0.

856



(Source: Authors)

Figure 2. Some screenshots of digital book products with 3D animation.

8. Expert validation questionnaire

The Expert validation questionnaire aims to determine the validity of the content and construct validity of the learning instruments used, namely the learning implementation plan and the application of digital books. Validation was carried out by three experts majoring in physics education.

5. Data Analysis

The validity of OPBL assisted by digital books with 3D animation models, is determined using the experts' average score of the assessment results. After that, the average assessment results will be adjusted according to the criteria in Table 3. In addition, the instrument's reliability is also assessed using the Cronbach's Alpha coefficient value, namely if the value is greater than 0.7, the instrument can be said to be reliable (Taber, 2018).

The effectiveness of these learning instruments is analyzed based on the determined assessment before and after learning. The instruments can be said to be effective if they meet the following criteria: 1) the average score of PSS is at least moderate; 2) there is a significant difference in the improvement of students' PSS abilities; 3) the effect size for the experimental class is at least medium effect; 4) the minimum n-gain value is middle for the experimental class; and 5) there is a significant difference between the experimental class and the control class. the value of the PSS score is determined by using descriptive statistics on the pre-test and post-test scores. First, the PSS scores were adjusted based on the criteria in Table 3. After that, the pre-, post-test, and n-gain data were analyzed using inferential statistics reviewed for normality using Shapiro-Wilk and homogeneity using Levene Statistic. Finally, to increase PSS, the pre-test, post-test, and n-gain values in the experimental and control classes were subjected to a paired t-test/Mann-Whitney test. The N-gain value was calculated by: $(\text{post-test score} - \text{pre-test score}) / (\text{Maximum Score} - \text{pre-test score})$ and the results were adjusted using Hake's criteria, as shown in Table 3 (Hake, 1999). In addition, the size of the effect was determined using Cohen's d-effect size to see the impact of field operations as shown in Table 3 (Morgan et al., 2012).

Validity Criteria		PSS Criteria		Hake's N-gain		Cohen's d-effect size	
Average Score Validity	Criteria	Score	Criteria	N-gain	Category	D-effect	Category
$3.25 < N \leq 4.00$	Very Valid	0 – 1,0	Low	$g < 0.3$	Low	≥ 1.00	Very Large
$2.50 < N \leq 3.25$	Valid	1,01 – 2,0	Medium	$0.3 \leq g < 0.7$	Middle	0.8	Large
$1.75 < N \leq 2.50$	Less Valid	2,1 – 3,0	High	$g \geq 0.7$	High	0.5	Medium
$1.00 \leq N \leq 1.75$	Invalid					0.2	Small

886 Table 3. The category of learning instrument validity criteria, PSS scoring, Hake's N-gain, and Cohen's d-
 887 effect size

888 **Third Phase: Students' Response Survey**

889 This phase was conducted to determine student responses to OPBL, assisted by the digital book with 3D
 890 animation learning instruments that have been used during learning. Data was collected using the survey
 891 method by distributing questionnaires to the experimental class. This is because only the experimental
 892 class uses these learning instruments. The questionnaire contains ten questions that describe the use of
 893 the instrument to increase the ability of PSS in students. The research sample that filled out the
 894 questionnaire had 32 students ($n = 32$), so there were differences with the second phase. However,
 895 according to attendance results, it turns out that all students in the experimental class always attend every
 896 learning meeting. The results of student responses were analyzed descriptively and quantitatively and
 897 adjusted to the following criteria: (1) Response of 75% (very positive); (2) 50% response $< 75\%$ (positive);
 898 (3) 25% response $< 50\%$ (less positive); and (4) response $< 25\%$ (not positive).

899 **3. Result and Discussion**

900 **3.1 Validity**

901 Three physics education experts assessed the validity of OPBL assisted by digital book-3D animation
 902 learning. The instruments assessed are the content and constructs of the lesson plan, the digital book
 903 application, test instruments, and the questionnaire of problems, needs, and responses to the assessment
 904 results, as shown in Table 4. The validation results show that all aspects have valid criteria. The same as
 905 the reliability value, all aspects are reliable.

Component	Validity and reliability of OPBL assisted by digital book-3D animation			
	Score	Validity	A	Reliability
<i>Content Validity</i>				
1. Lesson plan	3.38	Very Valid	0.71	Reliable
2. Digital book	3.48	Very Valid	0.89	Reliable
3. Test Instruments	3.75	Very Valid	0.88	Reliable
4. Questionnaire of problems, needs, and responses	3.71	Very Valid	0.75	Reliable
<i>Construct Validity</i>				
1. Lesson plan	3.33	Very Valid	0.93	Reliable
2. Digital book	3.62	Very Valid	0.70	Reliable
3. Test Instruments	3.66	Very Valid	0.76	Reliable
4. Questionnaire of problems, needs, and responses	3.77	Very Valid	0.82	Reliable

906 Note: $\alpha = \text{Cronbach Alpha}$

907 Table 4. The results of the assessment of the validity of the instruments by the expert

908 This learning instrument has a novelty in OPBL implementation, assisted by digital books with 3D
 909 animation. Unlike PBL in general, which requires student worksheets and teaching materials, these two
 910 instruments are already integrated with a digital book, so this digital book application contains complete
 911 instruments. This application has also been integrated with simulation guidelines to assist in the problem-
 912 solving process. If all learning instruments could be integrated into one application, this could further
 913 optimize the learning process (Herayanti et al., 2017). The involvement of the digital book application can

914 be seen from its occurrence in every process in the OPBL syntax. In addition, the test instruments and
 915 questionnaires were also declared valid by experts. According to the validator, this learning instrument is
 916 generally valid and feasible to assess the next aspect (effectiveness) after minor revisions have been made
 917 (Plomp, 2013). After corrections were made based on their recommendations, the OPBL, assisted by
 918 digital books with 3D animations to improve physics-PSS, could be implemented for SMAN 2 Bangkalan
 919 students.

920 **3.2 Effectiveness**

921 To determine the effectiveness of PBL online learning assisted by 3D digital-animated books, see Table 5,
 922 Table 6, Table 7, and Table 8 with the following explanation.

Group	N	Lowest Score			Highest Score		
		<i>Pre-test</i>	<i>Post-test</i>	<i>Average</i>	<i>Pre test</i>	<i>Post test</i>	<i>Average</i>
<i>Experiment</i>	29	0.51	1.35	0.82	1.20	2.64	2.32
<i>Control</i>	30	0.04	0.28	0.47	1.24	2.17	1.26

923 Table 5. Results of descriptive statistical calculations: lowest, highest, and average scores average in both
 924 classes

925 Based on Table 5, it can be seen that there are differences in the pre-test and post-test abilities in both
 926 the experimental and control classes. In the experimental class, the lowest pre-test PSS score was 0.51,
 927 and the highest was 1.20, while the lowest post-test PSS score was 1.35, and the highest was 2.64. The
 928 average PSS score differs between the pre-test and the post-test: the pre-test average is 0.82, while the
 929 post-test average is 2.32. In the control class, the lowest PSS score on the pre-test is 0.04, and the highest
 930 is 1.24, while the lowest PSS score on the post-test is 0.28 and the highest is 2.17. In addition, there is also
 931 an average difference in the pre-test, which is 0.47, while in the post-test it is 1.26. The low pre-test score
 932 is caused by students who still do not understand the tested material and do not have PSS in solving
 933 physics problems. In line with the research results by Jua et al. (2018), Indonesian students' physics PSS is
 934 still relatively low. But when on post-test scores, there was an increase in PSS scores in both classes
 935 because students had learned about the subject being tested (magnetic field). When compared between
 936 the experimental class and the control class, there is a difference in values where the experimental class
 937 has a higher PSS value than the control class, especially in the post-test. This is due to the difference in
 938 treatment between the two classes, where the experimental class uses an OPBL assisted by digital books
 939 with 3D animation, while the control class uses conventional learning.

Shapiro-Wilk Normality Test			
Group	Test	p (Sig.)	Distribution
<i>Experiment Class</i>	<i>Pre-test</i>	0.003	<i>Not Normal</i>
	<i>Post-test</i>	0.000	<i>Not Normal</i>
<i>Control Class</i>	<i>Pre-test</i>	0.025	<i>Normal</i>
	<i>Post-test</i>	0.317	<i>Normal</i>
Levene Statistic Homogeneity Test			
Test	Number of Sample	p (Sig.)	Homogeneity
<i>Pre-test</i>	59	0.002	<i>Not Homogenous</i>
<i>Post-test</i>		0.020	<i>Homogenous</i>
Mann-Whitney Test			
Group	p (sig.)	Hypothesis	
<i>Experiment Class</i>	0.000	<i>There is a significant difference between the pre-test and post-test scores</i>	
<i>Control Class</i>	0.000		
Cohen's d-effect size			
Group	d-effect size	Category	
<i>Experiment Class</i>	1.95	<i>Very Large</i>	
<i>Control Class</i>	1.63	<i>Very Large</i>	

940 Table 6. The test results of Shapiro-Wilk normality, Levene statistic homogeneity, Mann-Whitney, and
 941 Cohen's d-effect size for both classes

942 The normality test results revealed that the data in the experimental class were not normally distributed,
 943 whereas the data in the control class were normally distributed. This is due to the online treatment of PBL
 944 with the digital book with 3D animations, which causes the data to skew to the right, or most of the
 945 students' scores are high. In addition, the homogeneity test results indicate that the data is not
 946 homogeneous. Therefore, Mann-Whitney non-parametric statistical inferential analysis ($\alpha = 5\%$) was used
 947 to determine the difference between the two classes.

948 Based on the results of the Mann-Whitney test as shown in Table 6, it can be seen that the significance
 949 value is $p < 0.05$ which means that the hypothesis is accepted. In both classes, there is a significant
 950 difference between the pre- and post-test results. It is because there are differences in students'
 951 understanding who initially had not learned about the magnetic field subject. After being given treatment
 952 and learning about the subject, the students understood the material and increased their learning
 953 outcomes. In line with several research results, using the PBL can improve their learning outcomes (Amini
 954 et al., 2019; Kawuri et al., 2019; Qomariyah, 2019). If viewed from the effect size, it can be seen that both
 955 classes have a very large effect category. But the experimental class has a higher value than the control
 956 class. This is because in the experimental class, learning focuses more on solving problems using the PBL,
 957 assisted by a digital book with 3D animations. While the control class only uses conventional learning. In
 958 line with (Kapi et al., 2017) research, visual media can display more real physical phenomena. The use of
 959 multimedia aims to facilitate learning physics and change the paradigm of students who do not realize
 960 that many everyday events related to physics can encourage students to be actively involved in the
 961 thinking process by linking learning to real-life situations (Jabaliah et al., 2021; Liew & Tan, 2016; Warsono
 962 et al., 2020). The use of digital book media in the experimental class can increase student learning
 963 activities so that students are more motivated than learners in conventional classes (Iskandar et al., 2018).

Group		Indicators of PSS									
		A		C ₁		C ₂		E		S	
EC	O ₁	0.80	L	0.50	L	0.90	L	1.00	L	0.50s	L
	O ₂	2.60	H	2.00	M	1.60	M	2.60	H	1.90	M
	<g>	0.80	H	0.60	M	0.40	M	0.80	H	0.50	M
CC	O ₃	0.90	L	0.50	L	0.40	L	0.50	L	0.00	L
	O ₄	2.40	H	1.40	M	0.80	L	0.50	L	1.00	L
	<g>	0.60	M	0.30	M	0.10	L	0.00	L	0.30	M

964 Note:

965 EC (Experiment Class); CC (Control Class); O₁ (Pre-test experimental class); O₂ (Post-test experimental class); O₃ (Pre-test control
 966 class); O₄ (Post-test control class); A (Assen the problem); C₁ (Create a drawing); C₂ (Conceptualize the strategy); E (Execute the
 967 solution); S (Scrutinize your result); L (Low); M (Middle); H (High)

968 Table 7. The increase in PSS for each indicator in both classes.

969 In more detail, the increase in PSS for each indicator in both classes can be seen in Table 7. It can be seen
 970 that the results of the pre-test on all PSS indicators for both classes are in the low category. After applying
 971 the OPBL, assisted by digital books in the experimental class, there was an increase in N-gain for all skills
 972 in the middle and high categories. Increased the smallest N-gain contained in the Conceptualize the
 973 Strategy (C₂) indicator. For this indicator, the students are still using strategies by applying the equation
 974 only to solve the problems as generally taught in the classroom. In line with the research results (Ceberio
 975 et al., 2016; Reddy & Panacharoensawad, 2017; Riantoni et al., 2017), students tend not to use physics
 976 concepts to solve problems and only use memorized equations. But they can answer correctly on the
 977 Execute the Solution (E) indicator because some of the students copy each other's answers, which is
 978 indicated by the similarity of their answers. As a result, on the Scrutinize your result (S) indicator has the
 979 smallest N-gain second after C₂. On online tests, students more easily cheat on each other, so they become
 980 less confident about their work results (Cindikia et al., 2020). In the control class, the increase in the N-
 981 gain value for each indicator is smaller than in the experimental class because this class uses conventional
 982 learning. The lowest increase in N-gain is found in Execute the Solution (E) indicator because students
 983 cannot apply problem-solving skills in executing solutions to the problems asked.

984 The comparison of the average N-gain results in the experimental class with the control class can be seen
 985 in Table 8. It can be seen that the average N-gain value between the experimental class is 0.688 including
 986 the middle criteria, while in the control class is 0.282 including in the low criteria. So, the N-gain value of
 987 the PSS students in the experimental class is greater than the control class. Furthermore, the results of
 988 the normality test on the N-gain data of both classes showed that the experimental class was not normally
 989 distributed, while the control class had a normal distribution. This is because the N-gain value in the
 990 experimental class is skewed to the right, which means more high-value data. Furthermore, the
 991 homogeneity test results showed that the data were homogeneously distributed. Thus, to determine the
 992 significance of the difference between the N-gain of the two classes, non-parametric inferential statistics
 993 were used, namely the Mann-Whitney test.

Group	Descriptive Statistic		Shapiro-Wilk Normality Test		Levene Statistic Homogeneity Test		Mann-Whitney Test
	Average N-Gain	Criteria	p (Sig.)	Distribution	p (Sig.)	Criteria	p (Sig.)
EC	0.688	Middle	0.000	Not Normal	0.091	Homogeneous	0.000
CC	0.282	Low	0.601	Normal			

994 Note: EC (Experiment Class); CC (Control Class)

995 Table 7. The test result of descriptive statistic, Shapiro-Wilk normality, Levene statistic, and Mann-
 996 Whitney for increasing PSS in both classes

997 It can be seen that the *p*-value < 0.05, which means that there is a significant difference in the N-gain
 998 value between the experimental class and the control class statistically. This is because OPBL assisted by
 1000 digital books with 3D animation can help students improve their PSS. The PBL that focuses on problem-
 1001 solving makes students accustomed to solving problems and applying them to physics problems. In
 1002 addition, in learning activities, students are given assignments in the form of physics questions that must
 1003 be done in stages with problem-solving indicators. Students who receive OPBL-based learning also have
 1004 PSS to easily answer physics problems compared to conventional learning models who are not trained in
 1005 problem-solving. In line with some research results that PBL emphasizes more on PSS aspects such as
 1006 analyzing in choosing the right concepts and principles needed in solving problems so that it is better than
 1007 conventional classes (Docktor et al., 2015; Docktor & Mestre, 2014; Parno et al., 2019; Valdez & Bungihan,
 1008 2019). This finding is consistent with research by (Sari et al., 2021; Sota & Peltzer, 2017), which reveals
 1009 that problem-solving skills need a problem understanding process, whereas the OPBL syntax is found in
 1010 the problem orientation process. Through this process, students can be guided to understand the
 1011 problem, formulate a solution design, execute problem-solving according to plan, and re-examine the
 1012 problem-solving process. Another study by (Septian et al., 2020; Syafii & Yasin, 2013) agrees with
 1013 increasing PSS through PBL because this ability can be developed through practice. Students can have
 1014 excellent thinking skills and justify with scientific evidence to find alternative problem-solving. With OPBL,
 1015 students will practice problem-solving through student worksheets or structured assignments.

1016 In terms of learning theory, this findings also reinforced by the John Dewey's learning theory that the class
 1017 should be a laboratory in solving real-life problems (Arends, 2011). In addition, PBL is also based on
 1018 cognitive constructivism learning theory by Piaget. Through the PBL, students can actively construct their
 1019 own knowledge by interacting with their environment through the assimilation and the accommodation
 1020 process (Arends, 2011). PBL is also reinforced by Vygotsky, which reveals that the learning process will
 1021 occur when students work in the Zone of Proximal Development (Schunk, 2011). During problem-based
 1022 learning, students will be in a top-down process, where students start with complex problems to solve
 1023 and then solve or find (with the teacher's help) the basic skills needed (Slavin, 2011). The results of this
 1024 study are also supported by Bruner's discovery learning theory, where students are required to be active
 1025 in solving existing problems and are assisted by teachers to provide scaffolding (Moreno, 2010).

1026 Digital books also support the OPBL with 3D animation that make it easier for students to understand the
 1027 concept because the animation can help students visualize abstract and complex magnetic field subjects.
 1028 In line with several studies showing that the use of 3D animation can improve visual understanding, spatial
 1029 abilities, cognitive understanding, and student learning outcomes (Bakar et al., 2019; Benzer & Yildiz,
 1030 2019; Cai et al., 2013; Dori & Belcher, 2005; Kumar, 2016; Mystakidis & Berki, 2018; Park et al., 2016). This
 1031 finding is supported by (McKnight et al., 2016) research which explains that the use of technology in

learning (such as digital books) can replace the roles of teachers and students, where a teacher's guide, ask questions, and facilitate students to find their own answers and construct their knowledge. Meanwhile, students are more flexible, accessible, and active in seeking what knowledge is relevant to learning to become deep learners. This certainly supports the implementation of student-centered OPBL learning. The integration between this digital book and the OPBL model can support the learning process and improve students' PSS. Supported by research by (Chao et al., 2017; Siregar et al., 2021b) also agrees that the use of digital books and 3D animation can help students to solve problems, so it is very relevant when combined with the OPBL model. This digital book can make physics learning better because the learning media used is the right mix of verbal channels (in material text) and visuals (3D animated images). This is reinforced by the dual coding theory by Paivio that information received by a person is processed through one of two channels, namely verbal and visual channels that can function either independently, parallel, or integrated (Paivio, 2013).

In general, the results of the analysis on the effectiveness of the learning instruments show that 1) the average problem-solving score of students in the experimental class is 2.32, which means it is in the high category; 2) the increase in the PSS ability of students has a *p*-value of < 0.05 so that there is a significant difference; and 3) the effect size for the experimental class is 1.95, so it is included in the very large category; 4) the value of n-gain for the experimental class is middle; and 5) between the experimental class and the control class has a *p*-value < 0.05 indicating that there is a significant difference between the two. Thus, PBL online learning assisted by digital books with 3D animation effectively increases students' physics-PSS on magnetic field subjects.

3.3 Students' Responses

The results of a survey of a sample of 32 students (*n* = 32) to find out their response to PBL online learning activities assisted by digital books with 3D animation can be seen in Table 9. The calculation results show that the category's average score agrees and strongly agrees with 80.60%, while disagreeing and strongly disagree with 19.40%. Thus, according to students, this learning activity is included in the very positive criteria. The use of the OPBL is a more innovative and exciting learning model because so far, the learning that has been carried out has only focused on working on tasks independently so that students are easily bored. Especially for learning physics, which is considered complex and complicated by them. In addition, the use of digital book applications with 3D animation is a new learning medium for them to help create more enjoyable learning through the media provided. This finding is supported by research by (Abdinejad et al., 2021; Sin & Al-Asmari, 2018) that the majority of students agree with the use of 3D animation-based learning media to help their understanding through object visualization. This is because conventional learning methods are limited in describing difficult visual concepts. So the use of 3D animation can be used in magnetic field materials to facilitate the learning process by adding motion and trajectories to describe spatial and visual information effectively (Rieber, 1991).

Average Responses	Responses (%)			
	Very Agree	Agree	Disagree	Very Disagree
	16,25	64,35	16,59	2,81

Table 9. Average student responses in the experimental class regarding learning activities that have been carried out.

3.4 Limitations, Recommendations, and Implications

This research still has limitations, such as: 1) It has not been tested practically on the models and learning media used; 2) the sample used is only two classes; and 3) the validity assessment only focuses on lesson plans and digital book products. In addition, there are also limitations in the products made, such as: 1) the size of the application is still too big, so it requires a large enough storage space; 2) 3D animation is still less interactive; 3) the application is not yet integrated with the practical simulation; 4) it is not known whether it is compatible with for all types of operating systems; 4) The material available is only Magnetic Field.

there are recommendations, including 1) conducting a practical test of the models and learning media used; 2) increasing the number of research samples up to 4 classes; and 3) conducting validity assessments

1081 for other learning instruments, such as test instruments and survey questionnaires. There are also
1082 recommendations for digital book application products: 1) compressing the file size to become smaller;
1083 2) making animations more interesting and interactive; 3) integrating applications with virtual practicums;
1084 and 4) performing compatibility tests for all kinds of operating systems.

1085 This research implies that the results of the research product in the form of an OPBL assisted by the digital
1086 book with 3D animations can be applied by teachers in learning physics material during online learning. It
1087 is hoped that the application of these products can improve students' PSS while at the same time solving
1088 real-life problems that students will face related to the concept, especially in magnetic field subjects.

1089 **4. Conclusions**

1090 It can be concluded that the OPBL assisted with digital book applications with 3D animation learning
1091 instruments to improve students' PSS on Magnetic Field material. This learning instrument meets the
1092 validity aspect with very valid and reliable criteria both from the content component and the construct.
1093 These learning instruments are also effective in improving students' PSS. The survey results to students
1094 showed that students responded very positively to this learning instrument. We recommend that further
1095 researchers conduct practicality tests, develop applications, or test their effects on other 21st century
1096 skills.

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IMPLEMENTATION OF ONLINE PROBLEM-BASED LEARNING ASSISTED BY DIGITAL BOOK WITH 3D ANIMATIONS TO IMPROVE STUDENT'S PHYSICS PROBLEM-SOLVING SKILLS IN MAGNETIC FIELD SUBJECT

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Abstract

The magnetic field is a more complex and abstract physics subject than other physics subjects, causing students' low ability to solve problems. So there is a need for learning instruments to overcome these problems, especially when online learning during the COVID-19 pandemic. Research creates and implements an online problem-based learning (OPBL) assisted by digital books with 3D animation to improve students' physics problem-solving skills on magnetic field subjects. Research aimed to analyze the validity, effectiveness, and student responses to the learning instruments used. The method used in this research is quantitative by using quasi-experiment and survey methods. The results showed that this learning instrument was valid and reliable to use in terms of contents and constructs. According to statistical test results, this learning instrument is also effective in improving students' problem-solving skills on magnetic field subjects. Furthermore, the student's response to this learning instrument was very positive, making this learning activity more innovative and fun. Research implies that an OPBL assisted by digital books with 3D animation instruments can be a solution to improve students' physics problem-solving skills, especially during the online learning period.

Keywords – Digital book with 3D animations, Magnetic field, Online problem-based learning, Problem-solving skills.

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1. Introduction

Problem-Solving Skills (PSS) are important skills for students to have in order to the challenges and demands of the 21st century (Ghafar, 2020; Mohd-Yusof, Helmi, Jamaludin & Harun, 2011; Nurdyansyah, Teh, Fahyuni, Rudyanto & Daud, 2021; Parno, Yuliati, Munfaridah, Ali, Rosyidah & Indrasari, 2020; Ridhwan, Sumarmi, Ruja, Utomo & Sari, 2020; Suhirman, Muliadi & Prayogi, 2020). PSS can train students in observation, reasoning, analyzing, and creative thinking to help them solve everyday problems (Devanti, Achmadi & Prahani, 2020). In addition, PSS is essential in physics subjects to improve students' conceptual understanding because it prioritizes contextual understanding (Hudha, Aji & Rismawati, 2017).

In reality, sometimes students have difficulty developing their knowledge when solving a problem (Umara, 2019). This is evidenced by the preliminary test results on 59 students, which showed that 52 (88.13%) students had low PSS scores. One of the reasons is the difficulty of visualization, which can obstruct the problem-solving process because there are some abstract and microscopic physics subjects (Cai, Liu, Wang, Liu & Liang, 2021; İbili, Çat, Resnyansky, Şahin & Billinghurst, 2020), such as magnetic field subjects. Because of the subject's high complexity and abstraction, students' PSS tend to be low and they have many misconceptions it (Bestiantono et al., 2019; Turgut et al., 2016; Yilmaz & Ince, 2012). Furthermore, magnetic field subject is a prerequisite subject for electromagnetic induction with many applications in everyday life, such as power plants, fans, dynamos, and generators. Therefore, students' low understanding of concepts will affect their ability to solve a problem (Gultepe, Celik & Kilic, 2013). Consequently, it is necessary to have a learning media that can visualize students on microscopic materials, one of which is a digital book with 3D animations.

Currently, the use of digital books as physics learning media has seen a rapid increase and is very much needed when online learning during the COVID-19 pandemic (Abtokhi, Jatmiko & Wasis, 2021; Kholid, 2020; Saraswati, Mulyaningsih, Asih, Ardy & Dasmo, 2021). Digital books are electronic versions of printed books that can be read on a device with a specific purpose (Siegenthaler, Wurtz & Groner, 2010), in this case, to improve the quality of physics learning. Digital books have many advantages, including being practical, simple, interactive, and flexible, so they can be integrated with other media such as 3D animation visualization (Siregar, Kairuddin, Mansyur & Siregar, 2021a). The 3D animation will help students provide a clear picture and understanding of the process (Wu & Chiang, 2013). For example, in the abstract magnetic field material, 3D animation can help students clearly visualize the concept of a magnetic field. Therefore, the integration of 3D animation in digital books can be applied in physics learning, especially in abstract and microscopic materials. However, using digital book media with 3D animations requires a supporting learning model that can simultaneously improve students' PSS, one of which is the Problem Based Learning (PBL) model (Chamidy, Degeng & Ulfa, 2020; Surur, Degeng, Setyosari & Kuswandi, 2020).

PBL is a relevant learning model within the Indonesian curriculum because it is a student-oriented learning system (Anazifa & Djukri, 2017; Demirel & Dağyar, 2016). Furthermore, this learning model uses a real-life problem as a basis to train students to solve the problems they face (Liu, 2017; Setyawan, Aznam, Paidi & Citrawati, 2020). It supported by Simanjuntak, Hutahaean, Marpaung and Ramadhani (2021), Suastra, Ristiati, Adnyana and Kanca (2019), Yetri, Koderi, Amirudin, Latifah and Apriliana (2019) and Yuberti, Latifah, Anugrah, Saregar, Misbah and Jermitsiparsert (2019) research which shows that the PBL is effective in improving students' PSS in physics material. However, during the COVID-19 pandemic, the learning system was done online; thus this learning model was called 'Online Problem Based Learning (OPBL).' There is no significant difference between OPBL and conventional PBL, and the difference only lies in the use of media and technology used during learning (Erickson, Neilson, O'Halloran, Bruce & McLaughlin, 2021). However, the research results by Dinata, Suparwoto and Sari (2020) show that OPBL is more efficient than conventional PBL with the same learning outcome.

Previous research has been conducted by Bakri, Sumardani and Mulyati (2019), Bogusevschi, Muntean and Muntean (2020), Dimitrienko and Gubareva (2018), Liu, Liu and Wang (2019), Pirker, Holly, Lesjak, Kopf and Gütl (2019), Sannikov, Zhdanov, Chebotarev and Rabinovich (2015) and Thees, Kapp, Strzys, Beil, Lukowicz and Kuhn (2020) have implemented physics learning media based on 3D visualization in the form

of augmented reality and virtual reality. However, when implemented in online learning, the weakness of this media is expensive and requires too many devices to display the visualization. In addition, this research also has not integrated visualization media into specific learning models. There is still no research integrating the PBL with a digital book with 3D animations or visualizations in physics learning.

According to the preliminary research conducted on 61 research students, 39 (63.9%) students stated that the teacher's teaching method when learning online only gave assignments. Furthermore, while using learning media for online learning, 40 (65.6%) students stated that the contents were not understood, 23 (37.7%) students stated that they had difficulty accessing learning media, 11 (18%) students stated that they lacked image visualization of the material. Based on the survey, it can be seen that students need more engaging, innovative teaching methods and easy-to-understand learning media that are easily accessible and can provide exciting visualizations of the subject being taught. Supported by a follow-up survey that 7 (11.5%) students strongly agreed, 40 (80.3%) students agreed that OPBL assisted by digital book with 3D animation media needs to be implemented in physics learning.

Therefore, this research will create and implement an OPBL assisted by a digital book application assisted with 3D animations so that it is more attractive and can provide learning material visualization to students. This is done to optimize the achievement of students' PSS in physics learning, especially in the Magnetic Field material. With this integrated learning model and media, it is hoped to improve students' physics-PSS as one of the important skills in the 21st century. This study aims to analyze the validity, effectiveness, and student responses to the use of OPBL assisted by digital books with 3D animations to improve the ability to solve physics problems on magnetic field materials.

2. Methodology

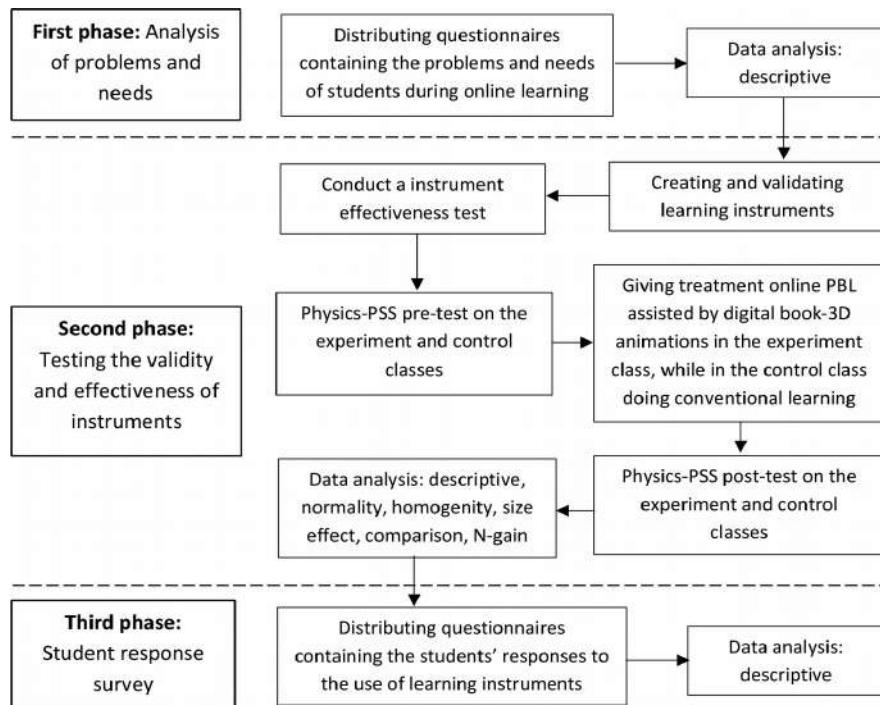


Figure 1. Stages of research diagram

The research was conducted at State Senior High School 2 Bangkalan (i.e. Indonesia) during September-October 2021 with the learning system applied at the school being online learning. The research method used is quantitative. The sample in this study was 65 students from an 11th-grade class, consisting of two classes from eight existing classes. However, when data collection has a different number of samples. It is difficult to control the sample because all data collection is done online, and

some samples are easily lost. In this study, the sampling technique used was random cluster sampling because the school randomly chose the two classes.

This research is divided into three phases of data collection, namely: 1) analysis of problems and needs; 2) testing the instrument's effectiveness; and 3) evaluation of student responses with the steps as in Figure 1. Each phase is described as follows.

2.1. First Phase: Analysis of Problems and Needs

This phase was carried out to determine the problems in learning physics experienced by students during online learning. In addition, the need for relevant models and learning media can be seen so that OPBL assisted by digital books with 3D animation can be an alternative solution to the problems faced. Data collection during this phase was carried out using a survey method by distributing questionnaires containing the problems and needs of students during online learning. The sample obtained in this research was 61 students ($n = 61$). The research data was then analyzed descriptively to find out the problems and needs of students.

2.2. Second Phase: Testing the Validity and Effectiveness of Instruments

2.2.1. Research Design

The second phase uses a quasi-experimental type with a non-equivalent control group design (Creswell & Creswell, 2018). The study was conducted in two classes with different treatments, namely the experimental and control classes. First, both classes were given a pre-test, and then they were given different treatments between them as shown in Table 1. After that, a post-test was given at the end of the lesson. The difference between the two classes only lies in the treatment. Other things, such as materials, curriculum, number of meetings, class hours, and teachers, have the same design. The subject used in this study is a magnetic field. In addition, schools implement the COVID-19 Pandemic Emergency Curriculum with the same allocation of lesson hours but on different days. both classes have is also the same number of meetings per week, namely three meetings, and they have the same teacher.

Class	Pre-test	Treatment	Post-test
XI MIPA 3 (Experiment)	O_1	X	O_2
XI MIPA 5 (Control)	O_3	-	O_4

Note: O_1 = Pre-test experimental class; O_3 = Pre-test control class; O_2 = Post-test experimental class; O_4 = Post-test control class; X = treatment (OPBL assisted digital book)

Table 1. The difference in treatment between the experimental class and the control class

2.2.2. Sample

The research sample in the second phase only if students work on pre- and post-test questions, 59 students ($n = 59$) with details: in the experimental class there are 29 students, while in the control class there are 30 students. So that the sample has almost the same number in the experimental class and the control class.

2.2.3. Instruments

In this study, several instruments were used: learning implementation plans, digital books with 3D animation, test instruments (pre- and post-test), and expert validation questionnaires.

1. Lesson Plans

The lesson plans consist of several components: the syllabus, lesson plans, and assessments. The learning syllabus in both classes is adjusted to the current curriculum at school, but the lesson plans in both classes have differences in their learning approaches. The experimental class uses OPBL with five syntaxes, namely: 1) problem orientation; 2) organizing students; 3) guiding group investigations; 4) developing and

presenting works and exhibitions; and 5) analyzing and evaluating the problem-solving process; the learning activities can be seen in Table 2 (Arends, 2011). The full syntax cannot be separated from the assistance of digital books with 3D animation. In the control class, learning is conducted conventionally, consisting of observing magnetic field phenomena, listening to written learning on theories, concepts, and examples of phenomena, working on questions, and discussing them with class members. The assessment is carried out by focusing on students' PSS with the ACCES rubric, namely (A) Asses the problem; (C) Create a drawing; (C) Conceptualize the strategy; (E) Execute the solution; (S) Scrutinize your result (Teodorescu, Bennhold, Feldman & Medsker, 2013). Each rubric is assessed based on three categories: correct, logical, and systematic. All learning activities are carried out online using WhatsApp media because the location of students is constrained by the internet network, meaning there is no video conference for all learning in both classes.

Syntax	Activity		PSS Indicator
	Teacher	Student	
Problem orientation	<ol style="list-style-type: none"> 1. Prepare the learning instruments, especially the digital book with 3D animation (DB3DA). 2. Introduce the magnetic field topic and its significance in learning. 3. Orientation to magnetic field problems through contextual phenomena seen in DB3DA. 	<ol style="list-style-type: none"> 1. Download and install the DB3DA application. 2. Listen to the teacher's explanation of the magnetic field subject. 3. Observe and understand the problems to be solved. 	A
Organizing students	<ol style="list-style-type: none"> 1. Divide the students into groups. 2. Ensure that students understand the problem as well as the problem-solving process 	<ol style="list-style-type: none"> 1. Create groups based on the teacher's instruction. 2. Begin developing problem solving with the help of by BD3DA. 	A, C ₂
Guiding group investigations	Guides students in the problem-solving process through the student worksheet contained in the DB3DA	Conduct investigations, collect data, analyze ways of solving problems (more directed at DB3DA).	C ₁ , C ₂ , E
Developing and presenting works and exhibitions	Monitor discussions and guide problem-solving reports as in the instructions in the DB3DA.	Conduct discussions to produce alternative problem-solving, make reports, and present their ideas	E, S
Analyzing and evaluating the problem-solving process	<ol style="list-style-type: none"> 1. Evaluation and reflection on the results of problem-solving that has been done by students. 2. Conclude the magnetic field learning subject based on BD3DA. 	<ol style="list-style-type: none"> 1. Evaluation of the extent of their acquired understanding. 2. Listen to the conclusion and ask if there are still confused 	S

Note: A (Assen the problem); C₁ (Create a drawing); C₂ (Conceptualize the strategy); E (Execute the solution); S (Scrutinize your result)

Table 2. Learning activities in the experimental class (Arends, 2011)

2. Digital Book with 3D Animation

This book has an extension.*apk* in the form of an application installed on mobile phones with a file size of 67 MB. The application can be accessed offline to minimize network constraints during online learning. However, this digital book also has weaknesses, such as being not yet integrated with practical simulations and being less interactive. After the pre-test, this digital book set was used as a treatment for the experimental class. Some pictures of digital books can be seen in Figure 2. To access this digital book application, [click here](#).

3. Test Instrument

The test instrument is divided into two types, pre-test and post-test, but the tested questions are similar in both. This was done to determine the increase in the PSS of students in the experimental and control classes. Five questions are tested with the description questions with each ACCES rubric in each number.

Each rubric will be assessed based on correct, logical, and systematic indicators. For example, if the student's answer represents the three indicators, the student gets a score of 3. If the student's answer only represents two indicators, then the student gets a score of 2, and so on until the student's answer does not meet all of the criteria, they will get a score of 0.

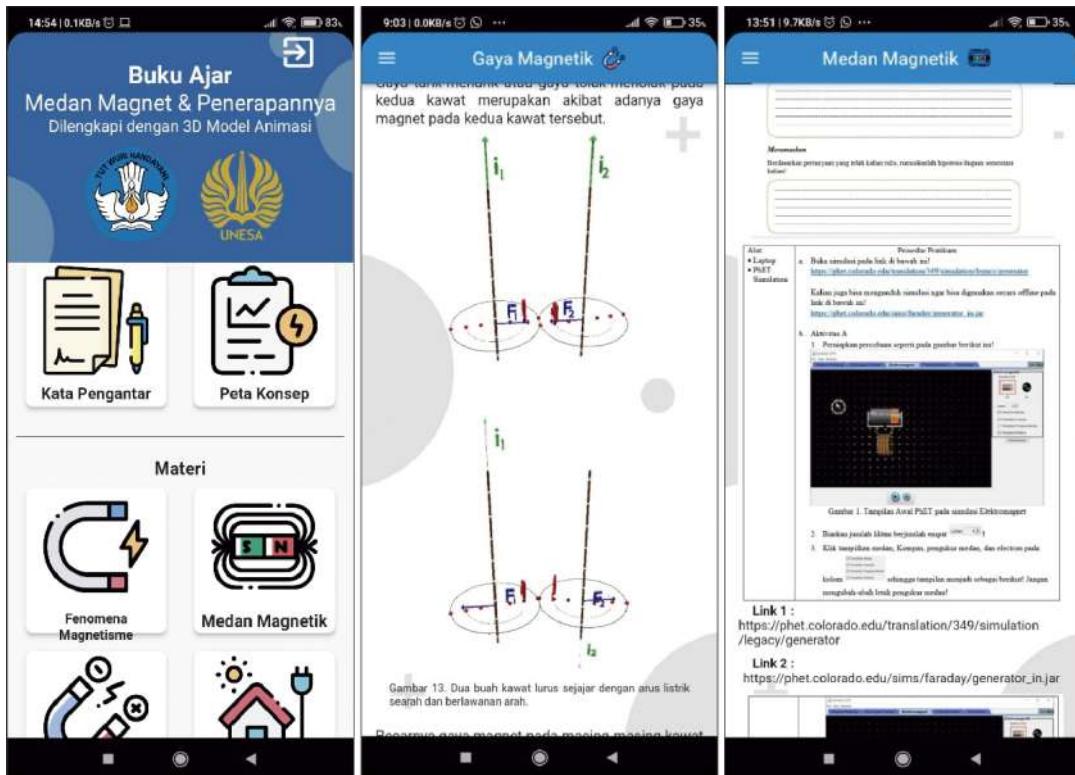


Figure 2. Some screenshots of digital book products with 3D animation (Source: Authors)

4. Expert Validation Questionnaire

The Expert validation questionnaire aims to determine the validity of the content and construct validity of the learning instruments used, namely the learning implementation plan and the application of digital books. Validation was carried out by three experts majoring in physics education.

2.2.4. Data Analysis

The validity of OPBL assisted by digital books with 3D animation models, is determined using the experts' average score of the assessment results. After that, the average assessment results will be adjusted according to the criteria in Table 3. In addition, the instrument's reliability is also assessed using the Cronbach's Alpha coefficient value, namely if the value is greater than 0.7, the instrument can be said to be reliable (Taber, 2018).

The effectiveness of these learning instruments is analyzed based on the determined assessment before and after learning. The instruments can be said to be effective if they meet the following criteria: 1) the average score of PSS is at least moderate; 2) there is a significant difference in the improvement of students' PSS abilities; 3) the effect size for the experimental class is at least medium effect; 4) the minimum n-gain value is middle for the experimental class; and 5) there is a significant difference between the experimental class and the control class. The value of the PSS score is determined by using descriptive statistics on the pre-test and post-test scores. First, the PSS scores were adjusted based on the criteria in Table 3. After that, the pre-, post-test, and n-gain data were analyzed using inferential statistics reviewed for normality using Shapiro-Wilk and homogeneity using Levene Statistic. Finally, to increase PSS, the pre-test, post-test, and n-gain values in the experimental and control classes were subjected to a paired

t-test/Mann-Whitney test. The N-gain value was calculated by: (post-test score – pre-test score)/(Maximum Score – pre-test score) and the results were adjusted using Hake's criteria, as shown in Table 3 (Hake, 1999). In addition, the size of the effect was determined using Cohen's d-effect size to see the impact of field operations as shown in Table 3 (Morgan, Leech, Gloeckner & Barrett, 2012).

Validity Criteria		PSS Criteria		Hake's N-gain		Cohen's d-effect size	
Average Score Validity	Criteria	Score	Criteria	N-gain	Category	D-effect	Category
3.25 < N ≤ 4.00	Very Valid	0 – 1.0	Low	$g < 0.3$	Low	≥1.00	Very Large
2.50 < N ≤ 3.25	Valid	1.01 – 2.0	Medium	$0.3 \leq g < 0.7$	Middle	0.8	Large
1.75 < N ≤ 2.50	Less Valid	2.1 – 3.0	High	$g \geq 0.7$	High	0.5	Medium
1.00 ≤ N ≤ 1.75	Invalid					0.2	Small

Table 3. The category of learning instrument validity criteria, PSS scoring, Hake's N-gain, and Cohen's d-effect size

2.3. Third Phase: Students' Response Survey

This phase was conducted to determine student responses to OPBL, assisted by the digital book with 3D animation learning instruments that have been used during learning. Data was collected using the survey method by distributing questionnaires to the experimental class. This is because only the experimental class uses these learning instruments. The questionnaire contains ten questions that describe the use of the instrument to increase the ability of PSS in students. The research sample that filled out the questionnaire had 32 students ($n = 32$), so there were differences with the second phase. However, according to attendance results, it turns out that all students in the experimental class always attend every learning meeting. The results of student responses were analyzed descriptively and quantitatively and adjusted to the following criteria: (1) Response of 75% (very positive); (2) 50% response < 75% (positive); (3) 25% response < 50% (less positive); and (4) response < 25% (not positive).

3. Result and Discussion

3.1. Validity

Three physics education experts assessed the validity of OPBL assisted by digital book-3D animation learning. The instruments assessed are the content and constructs of the lesson plan, the digital book application, test instruments, and the questionnaire of problems, needs, and responses to the assessment results, as shown in Table 4. The validation results show that all aspects have valid criteria. The same as the reliability value, all aspects are reliable.

Component	Validity and reliability of OPBL assisted by digital book-3D animation			
	Score	Validity	α	Reliability
<i>Content Validity</i>				
1. Lesson plan	3.38	Very Valid	0.71	Reliable
2. Digital book	3.48	Very Valid	0.89	Reliable
3. Test Instruments	3.75	Very Valid	0.88	Reliable
4. Questionnaire of problems, needs, and responses	3.71	Very Valid	0.75	Reliable
<i>Construct Validity</i>				
1. Lesson plan	3.33	Very Valid	0.93	Reliable
2. Digital book	3.62	Very Valid	0.70	Reliable
3. Test Instruments	3.66	Very Valid	0.76	Reliable
4. Questionnaire of problems, needs, and responses	3.77	Very Valid	0.82	Reliable

Note: α = Cronbach Alpha

Table 4. The results of the assessment of the validity of the instruments by the expert

This learning instrument has a novelty in OPBL implementation, assisted by digital books with 3D animation. Unlike PBL in general, which requires student worksheets and teaching materials, these two instruments are already integrated with a digital book, so this digital book application contains complete instruments. This application has also been integrated with simulation guidelines to assist in the problem-solving process. If all learning instruments could be integrated into one application, this could further optimize the learning process (Herayanti, Fuaddunnazmi & Habibi, 2017). The involvement of the digital book application can be seen from its occurrence in every process in the OPBL syntax. In addition, the test instruments and questionnaires were also declared valid by experts. According to the validator, this learning instrument is generally valid and feasible to assess the next aspect (effectiveness) after minor revisions have been made (Plomp, 2013). After corrections were made based on their recommendations, the OPBL, assisted by digital books with 3D animations to improve physics-PSS, could be implemented for SMAN 2 Bangkalan students.

3.2. Effectiveness

To determine the effectiveness of PBL online learning assisted by 3D digital-animated books, see Table 5, Table 6, Table 7, and Table 8 with the following explanation.

Group	N	Lowest Score			Highest Score		
		Pre-test	Post-test	Average	Pre test	Post test	Average
Experiment	29	0.51	1.35	0.82	1.20	2.64	2.32
Control	30	0.04	0.28	0.47	1.24	2.17	1.26

Table 5. Results of descriptive statistical calculations: lowest, highest, and average scores average in both classes

Based on Table 5, it can be seen that there are differences in the pre-test and post-test abilities in both the experimental and control classes. In the experimental class, the lowest pre-test PSS score was 0.51, and the highest was 1.20, while the lowest post-test PSS score was 1.35, and the highest was 2.64. The average PSS score differs between the pre-test and the post-test: the pre-test average is 0.82, while the posttest average is 2.32. In the control class, the lowest PSS score on the pre-test is 0.04, and the highest is 1.24, while the lowest PSS score on in the post-test is 0.28 and the highest is 2.17. In addition, there is also an average difference in the pre-test, which is 0.47, while in the post-test it is 1.26. The low pre-test score is caused by students who still do not understand the tested material and do not have PSS in solving physics problems. In line with the research results by Jua, Sarwanto and Sukarmin (2018), Indonesian students' physics PSS is still relatively low. But when on post-test scores, there was an increase in PSS scores in both classes because students had learned about the subject being tested (magnetic field). When compared between the experimental class and the control class, there is a difference in values where the experimental class has a higher PSS value than the control class, especially in the post-test. This is due to the difference in treatment between the two classes, where the experimental class uses an OPBL assisted by digital books with 3D animation, while the control class uses conventional learning.

The normality test results revealed that the data in the experimental class were not normally distributed, whereas the data in the control class were normally distributed. This is due to the online treatment of PBL with the digital book with 3D animations, which causes the data to skew to the right, or most of the students' scores are high. In addition, the homogeneity test results indicate that the data is not homogeneous. Therefore, Mann-Whitney non-parametric statistical inferential analysis ($\alpha = 5\%$) was used to determine the difference between the two classes.

Based on the results of the Mann-Whitney test as shown in Table 6, it can be seen that the significance value is $p < 0.05$ which means that the hypothesis is accepted. In both classes, there is a significant difference between the pre- and post-test results. It is because there are differences in students' understanding who initially had not learned about the magnetic field subject. After being given treatment

and learning about the subject, the students understood the material and increased their learning outcomes. In line with several research results, using the PBL can improve their learning outcomes (Amini, Setiawan, Fitria & Ningsih, 2019; Kawuri, Ishafit & Fayanto, 2019; Qomariyah, 2019). If viewed from the effect size, it can be seen that both classes have a very large effect category. But the experimental class has a higher value than the control class. This is because in the experimental class, learning focuses more on solving problems using the PBL, assisted by a digital book with 3D animations. While the control class only uses conventional learning. In line with (Kapi, Osman, Ramli & Taib, 2017) research, visual media can display more real physical phenomena. The use of multimedia aims to facilitate learning physics and change the paradigm of students who do not realize that many everyday events related to physics can encourage students to be actively involved in the thinking process by linking learning to real-life situations (Jabaliah, Adlim, Syukri & Evendi, 2021; Liew & Tan, 2016; Warsono, Nursuhud, Darma, Supahar & Oktavia, 2020). The use of digital book media in the experimental class can increase student learning activities so that students are more motivated than learners in conventional classes (Iskandar, Rizal, Kurniasih, Sutiksno & Purnomo, 2018).

Shapiro-Wilk Normality Test			
Group	Test	p (Sig.)	Distribution
Experiment Class	Pre-test	0.003	Not Normal
	Post-test	0.000	Not Normal
Control Class	Pre-test	0.025	Normal
	Post-test	0.317	Normal
Levene Statistic Homogeneity Test			
Test	Number of Sample	p (Sig.)	Homogeneity
Pre-test	59	0.002	Not Homogenous
Post-test		0.020	Homogenous
Mann-Whitney Test			
Group	p (sig.)	Hypothesis	
Experiment Class	0.000	There is a significant difference between the pre-test and post-test scores	
Control Class	0.000		
Cohen's d-effect size			
Group	d-effect size	Category	
Experiment Class	1.95	Very Large	
Control Class	1.63	Very Large	

Table 6. The test results of Shapiro-Wilk normality, Levene statistic homogeneity, Mann-Whitney, and Cohen's d-effect size for both classes

In more detail, the increase in PSS for each indicator in both classes can be seen in Table 7. It can be seen that the results of the pre-test on all PSS indicators for both classes are in the low category. After applying the OPBL, assisted by digital books in the experimental class, there was an increase in N-gain for all skills in the middle and high categories. Increased the smallest N-gain contained in the Conceptualize the Strategy (C₂) indicator. For this indicator, the students are still using strategies by applying the equation only to solve the problems as generally taught in the classroom. In line with the research results (Ceberio, Almudí & Franco, 2016; Reddy & Panacharoenawad, 2017; Riantoni, Yuliati, Mufti & Nehru, 2017), students tend not to use physics concepts to solve problems and only use memorized equations. But they can answer correctly on the Execute the Solution (E) indicator because some of the students copy each other's answers, which is indicated by the similarity of their answers. As a result, on the Scrutinize your result (S) indicator has the smallest N-gain second after C₂. On online tests, students more easily cheat on each other, so they become less confident about their work results (Cindikia, Achmadi, Prahani & Mahtari, 2020). In the control class, the increase in the N-gain value for each indicator is smaller than in the experimental class because this class uses conventional learning. The lowest increase in N-gain is found in

Execute the Solution (E) indicator because students cannot apply problem-solving skills in executing solutions to the problems asked.

Group		Indicators of PSS							
		A		C ₁		C ₂		E	
EC	O ₁	0.80	L	0.50	L	0.90	L	1.00	L
	O ₂	2.60	H	2.00	M	1.60	M	2.60	H
	<g>	0.80	H	0.60	M	0.40	M	0.80	H
CC	O ₃	0.90	L	0.50	L	0.40	L	0.50	L
	O ₄	2.40	H	1.40	M	0.80	L	0.50	L
	<g>	0.60	M	0.30	M	0.10	L	0.00	L

Note: EC (Experiment Class); CC (Control Class); O₁ (Pre-test experimental class); O₂ (Post-test experimental class); O₃ (Pre-test control class); O₄ (Post-test control class); A (Assen the problem); C₁ (Create a drawing); C₂ (Conceptualize the strategy); E (Execute the solution); S (Scrutinize your result); L (Low); M (Middle); H (High)

Table 7. The increase in PSS for each indicator in both classes

The comparison of the average N-gain results in the experimental class with the control class can be seen in Table 8. It can be seen that the average N-gain value between the experimental class is 0.688 including the middle criteria, while in the control class is 0.282 including in the low criteria. So, the N-gain value of the PSS students in the experimental class is greater than the control class. Furthermore, the results of the normality test on the N-gain data of both classes showed that the experimental class was not normally distributed, while the control class had a normal distribution. This is because the N-gain value in the experimental class is skewed to the right, which means more high-value data. Furthermore, the homogeneity test results showed that the data were homogeneously distributed. Thus, to determine the significance of the difference between the N-gain of the two classes, non-parametric inferential statistics were used, namely the Mann-Whitney test.

Group	Descriptive Statistic		Shapiro-Wilk Normality Test		Levene Statistic Homogeneity Test		Mann-Whitney Test
	Average N-Gain	Criteria	p (Sig.)	Distribution	p (Sig.)	Criteria	p (Sig.)
EC	0.688	Middle	0.000	Not Normal	0.091	Homo-geneous	0.000
CC	0.282	Low	0.601	Normal			

Note: EC (Experiment Class); CC (Control Class)

Table 8. The test result of descriptive statistic, Shapiro = Wilk normality, Levene statistic, and Mann-Whitney for increasing PSS in both classes

It can be seen that the *p*-value < 0.05, which means that there is a significant difference in the N-gain value between the experimental class and the control class statistically. This is because OPBL assisted by digital books with 3D animation can help students improve their PSS. The PBL that focuses on problem-solving makes students accustomed to solving problems and applying them to physics problems. In addition, in learning activities, students are given assignments in the form of physics questions that must be done in stages with problem-solving indicators. Students who receive OPBL-based learning also have PSS to easily answer physics problems compared to conventional learning models who are not trained in problem-solving. In line with some research results that PBL emphasizes more on PSS aspects such as analyzing in choosing the right concepts and principles needed in solving problems so that it is better than conventional classes (Docktor, Strand, Mestre & Ross, 2015; Docktor & Mestre, 2014; Parno, Yuliati & Ni'Mah, 2019; Valdez & Bungihan, 2019). This finding is consistent with research by (Sari, Sumarmi, Utomo & Astina, 2021; Sota & Peltzer, 2017), which reveals that problem-solving skills need a problem understanding process, whereas the OPBL syntax is found in the problem orientation process.

Through this process, students can be guided to understand the problem, formulate a solution design, execute problem-solving according to plan, and re-examine the problem-solving process. Another study by (Septian, Inayah, Suwarman & Nugraha, 2020; Syafii & Yasin, 2013) agrees with increasing PSS through PBL because this ability can be developed through practice. Students can have excellent thinking skills and justify with scientific evidence to find alternative problem-solving. With OPBL, students will practice problem-solving through student worksheets or structured assignments.

In terms of learning theory, this findings also reinforced by the John Dewey's learning theory that the class should be a laboratory in solving real-life problems (Arends, 2011). In addition, PBL is also based on cognitive constructivism learning theory by Piaget. Through the PBL, students can actively construct their own knowledge by interacting with their environment through the assimilation and the accommodation process (Arends, 2011). PBL is also reinforced by Vygotsky, which reveals that the learning process will occur when students work in the Zone of Proximal Development (Schunk, 2011). During problem-based learning, students will be in a top-down process, where students start with complex problems to solve and then solve or find (with the teacher's help) the basic skills needed (Slavin, 2011). The results of this study are also supported by Bruner's discovery learning theory, where students are required to be active in solving existing problems and are assisted by teachers to provide scaffolding (Moreno, 2010).

Digital books also support the OPBL with 3D animation that make it easier for students to understand the concept because the animation can help students visualize abstract and complex magnetic field subjects. In line with several studies showing that the use of 3D animation can improve visual understanding, spatial abilities, cognitive understanding, and student learning outcomes (Bakar, Sugiyarto & Ikhsan, 2019; Benzer & Yildiz, 2019; Cai, Chiang & Wang, 2013; Dori & Belcher, 2005; Kumar, 2016; Mystakidis & Berki, 2018; Park, Lee & Han, 2016). This finding is supported by (McKnight, O'Malley, Ruzic, Horsley, Franey & Bassett, 2016) research which explains that the use of technology in learning (such as digital books) can replace the roles of teachers and students, where a teacher's guide, ask questions, and facilitate students to find their own answers and construct their knowledge. Meanwhile, students are more flexible, accessible, and active in seeking what knowledge is relevant to learning to become deep learners. This certainly supports the implementation of student-centered OPBL learning. The integration between this digital book and the OPBL model can support the learning process and improve students' PSS. Supported by research by (Chao, Tzeng & Po, 2017; Siregar, Kairuddin, Mansyur & Siregar, 2021b) also agrees that the use of digital books and 3D animation can help students to solve problems, so it is very relevant when combined with the OPBL model. This digital book can make physics learning better because the learning media used is the right mix of verbal channels (in material text) and visuals (3D animated images). This is reinforced by the dual coding theory by Paivio that information received by a person is processed through one of two channels, namely verbal and visual channels that can function either independently, parallel, or integrated (Paivio, 2013).

In general, the results of the analysis on the effectiveness of the learning instruments show that 1) the average problem-solving score of students in the experimental class is 2.32, which means it is in the high category; 2) the increase in the PSS ability of students has a *p*-value of < 0.05 so that there is a significant difference; and 3) the effect size for the experimental class is 1.95, so it is included in the very large category; 4) the value of n-gain for the experimental class is middle; and 5) between the experimental class and the control class has a *p*-value < 0.05 indicating that there is a significant difference between the two. Thus, PBL online learning assisted by digital books with 3D animation effectively increases students' physics-PSS on magnetic field subjects.

3.3. Students' Responses

The results of a survey of a sample of 32 students ($n = 32$) to find out their response to PBL online learning activities assisted by digital books with 3D animation can be seen in Table 9. The calculation results show that the category's average score agrees and strongly agrees with 80.60%, while disagreeing and strongly disagree with 19.40%. Thus, according to students, this learning activity is included in the very positive criteria. The use of the OPBL is a more innovative and exciting learning model because so

far, the learning that has been carried out has only focused on working on tasks independently so that students are easily bored. Especially for learning physics, which is considered complex and complicated by them. In addition, the use of digital book applications with 3D animation is a new learning medium for them to help create more enjoyable learning through the media provided. This finding is supported by research by (Abdinejad, Talaie, Qorbani & Dalili, 2021; Sin & Al-Asmari, 2018) that the majority of students agree with the use of 3D animation-based learning media to help their understanding through object visualization. This is because conventional learning methods are limited in describing difficult visual concepts. So the use of 3D animation can be used in magnetic field materials to facilitate the learning process by adding motion and trajectories to describe spatial and visual information effectively (Rieber, 1991).

Average Responses	Responses (%)			
	Very Agree	Agree	Disagree	Very Disagree
	16.25	64.35	16.59	2.81

Table 9. Average student responses in the experimental class regarding learning activities that have been carried out.

3.4. Limitations, Recommendations and Implications

This research still has limitations, such as: 1) It has not been tested practically on the models and learning media used; 2) the sample used is only two classes; and 3) the validity assessment only focuses on lesson plans and digital book products. In addition, there are also limitations in the products made, such as: 1) the size of the application is still too big, so it requires a large enough storage space; 2) 3D animation is still less interactive; 3) the application is not yet integrated with the practical simulation; 4) it is not known whether it is compatible with for all types of operating systems; 4) The material available is only Magnetic Field.

There are recommendations, including 1) conducting a practical test of the models and learning media used; 2) increasing the number of research samples up to 4 classes; and 3) conducting validity assessments for other learning instruments, such as test instruments and survey questionnaires. There are also recommendations for digital book application products: 1) compressing the file size to become smaller; 2) making animations more interesting and interactive; 3) integrating applications with virtual practicums; and 4) performing compatibility tests for all kinds of operating systems.

This research implies that the results of the research product in the form of an OPBL assisted by the digital book with 3D animations can be applied by teachers in learning physics material during online learning. It is hoped that the application of these products can improve students' PSS while at the same time solving real-life problems that students will face related to the concept, especially in magnetic field subjects.

4. Conclusions

It can be concluded that the OPBL assisted with digital book applications with 3D animation learning instruments to improve students' PSS on Magnetic Field material. This learning instrument meets the validity aspect with very valid and reliable criteria both from the content component and the construct. These learning instruments are also effective in improving students' PSS. The survey results to students showed that students responded very positively to this learning instrument. We recommend that further researchers conduct practicality tests, develop applications, or test their effects on other 21st century skills.

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