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Digital comic learning media based on character values on students' critical thinking in solving mathematical problems in terms of learning styles

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Abstract
In preparing students to compete in 21st-century skills, the Ministry of Education and Culture of the Republic of Indonesia integrates character education into school subjects. However, as a medium, comics do not contain the level of character values, exploration, and critical thinking skills in problem-solving on geometry material. Therefore, aim of this study is to produces digital media based on character values on mathematical critical thinking skills in solving problems related to learning styles for eighth-grade students. This development research employed the 4-D method (Define, Design, Develop, and Disseminate). The study indicates that the digital comic learning media is valid with a total average score of 3.60 based on the material expert's validation and 3.50 based on the media expert's validation. The eight-grade students' responses were positive (92%) based on the trials. The learning outcomes in terms of kinesthetic, auditory, and visual learning styles used in this study can all meet all indicators of mathematical problem-solving.

INTRODUCTION

The current learning process adopts the student-centered approach of the 2013 curriculum; however, all teaching methods are centered on teachers (Safitri et al., 2020; Yulianti & Wulandari, 2021). The teacher is expected to be more than just a facilitator (Naufal, 2021). They must prepare various learning resources for their students before entering the classroom. The resources can be lesson plans, assessment tools, teaching materials, and devices needed (Setyani et al., 2020). One factor that encourages students' success in mastering a lesson is how well the teacher can convey the lesson. Students and teachers also play an important role in improving the quality of learning (Lewis et al., 2012; Sunzuma & Maharaj, 2019). If the material provided is interesting and easy to understand, students will easily master the material. Learning media can be an alternative to providing attractive teaching materials and is easy for students to understand (Nurseto, 2012). Learning materials that can describe mathematical material tend to be abstract (Rachmavita, 2020; Widodo, 2018). Therefore, learning media helps students master the material provided, thereby increasing students' learning outcomes.

When learning geometry, students need to master the concepts to apply their geometric skills, such as visualizing and recognizing various types of shapes and spaces, describing images, making sketches, labeling certain points, and recognizing the differences and similarities between geometrical shapes (Ayuningrum, 2017; Kamps et al., 2018; Fauzi & Arisetyawan, 2020). However, students' can hardly master and implement the material because the teacher uses

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teaching methods and asks questions when delivering material (Ramadhan et al., 2021; Utami et al., 2019). It will affect the next subject if students do not master the geometrical shapes.

Based on the observations at the Assyfa Learning Center (YALC) of the Pasuruan Foundation, some students show small interest in their work and reading. The students do not like to read and do not understand the concepts. The interviews with one of the mathematics teachers at YALC Pasuruan stated that the learning method often applied in learning solid geometry materials were groups or individual works. Learning media used to support the learning was only student worksheets or modules. Conversely, teachers can use mathematical comics as teaching media (Pardimin & Widodo, 2017; Syukri et al., 2018).

As a tool to convey information, comics are visual media regularly arranged in panels (Fadella et al., 2018). Introducing comics into class has been proven to increase student interest and understanding of content (Wolski, 2020). The teacher can help students become more active and communicative by presenting comics (Wicaksono et al., 2020). Things like this deviate from students' desires because they want to use interesting learning media (Nurrita, 2018). One of them is by utilizing technology that can be designed as various media so that it can be used to convey the contents of the material as needed (Huda, 2020). Besides, students will be more fluent in recognizing and exploring content in learning (Taufiqulloh et al., 2018). Through technological media, character values will form in students (Rakim et al., 2017).

Efforts to prepare students' competitiveness in 21st-century competencies of the Indonesian Ministry of Education and Culture emphasize integrated character education in school subjects (Kemdikbud, 2021). Five main character values are interrelated in forming a value network that needs to be developed as a priority: religious values, nationalism, independence, cooperation, and integrity. Character education will develop the character values of elementary school to high school students to become the model citizens for the nation (Sakti, 2017). Character values in education form a generation of competent students with high intellect and good personalities (Kurniyati & Arwen, 2020; Pujiastuti & Suyitno, 2016; Suparno et al., 2020). Therefore, these character values can be integrated into 21st-century competencies or 4C abilities, namely critical thinking, creativity, communication, and collaboration.

Critical thinking is one of the competencies that students in Indonesia must possess. Critical thinking skills emphasize coordinating, adjusting, changing, or improving their thoughts to make decisions to act more appropriately (Afgani & Paradesa, 2019; Zakaria, 2021). Mathematics teachers need to equip students with critical thinking skills. Without this skill, mathematics learners will face difficulty when working on the activity of finding and analyzing information. Patonah (2014) claims that critical thinking can bring up a person's mentality in using his intelligence to solve the problems at hand. The problem-solving process with Polya (1973) suggests the detailed steps in problem-solving, which include understanding the problem, planning problem-solving, implementing problem-solving, and reviewing (Badawi, 2015).

In solving mathematical problems, students have their way of learning (Cronin et al., 2016; Knisley, 2002; Amah, et al., 2001). Rochmah (2017) shows that students with high mathematical ability based on Polya's problem-solving were reported to complete the four-step activities. Rahman (2018) states that a learning style is an approach that explains how a person focuses on the process and masters difficult and new information through different perceptions. DePorter & Hernacki (1992) suggest three types of learning styles using three learning modes, namely visual

learning (learning by seeing), auditory learning (learning by listening), and kinesthetic learning (learning by moving and trying).

Integrating character values in a learning process can be done through learning media (Kintu et al., 2017; Lonto et al., 2018). One of the learning media that can contain character values is comics. The comic can be entertainment for readers because the cartoon can increase students' interest in learning (Putra & Milenia, 2021). Digital comic media developed contains characters with character values (religious, nationalist, independence, cooperation, and integrity) to become an inspiration for students (Rakasiwi, 2019).

A previous study that developed digital comic media was carried out by Fitriani (2012). Using a linear equation system with a comic, she developed story-based questions using a comic on three assessments (content, design, and language). Furthermore, Novianti & Syaichudin (2010) produced comic learning tools in mathematics learning to increase knowledge of fractional material for elementary school students. Then, Witanta et al. (2019) developed comic media for comparative learning methods.

Research on comic development that aims to improve critical thinking skills has been carried out by Andayani et al. (2020) to increase the critical thinking competence of elementary school students. The research conducted was not on mathematics subjects. The subjects were not described or through what criteria so that the subjects could be used. Digital comics developed were only limited to Digital Convergence. This type of comic is only developed with other comics linked to other digital-based media, such as games, animations, films, and mobile content, as variations in learning during the COVID-19 pandemic. Further research was conducted by Rasiman & Pramasdyahsari (2014) on the development of e-comic teaching materials from flipbook applications to improve the critical thinking competence of junior high school students. The application was designed like a book with various images on each page, so the teacher just creates content.

Comic research that aims to improve critical thinking skills with character values has been carried out (Manalu et al., 2017; Yunia, 2017). Developed digital comics based on character values as a medium for learning to account for the basic competencies of compiling financial reports for service companies for eleventh-grade senior high school students. Then, Yunia (2017) developed a biology digital comic learning media based on character values on the main material of the food digestive system for the eight-grade students of MTs Negeri 1 Bandar Lampung. However, both studies were not on learning mathematics. Further research was conducted by Manalu et al. (2017), who developed a mathematical comic media based on character values in trigonometry material for the tenth-grade senior high school students. In the third study, the subjects were not based on any criteria and were mostly aimed at high school students.

This research describes the process of developing comics as a digital learning media based on character values on students' critical thinking skills, responses, and learning outcomes after using the media. Based on previous research, no research has developed digital comic media based on character values on critical thinking skills in solving mathematical problems in terms of learning styles. Therefore, the novelty of this research lies in the development of digital comic learning media based on character values on the critical thinking skills of junior high school students in solving mathematical problems in terms of learning styles on geometry material.

METHODS

This research is a research and development research. The product developed is character-based digital comic media. The development model used was the 4D model (Thiagarajan et al., 1974), consisting of four stages: the definition stage, the design stage, the development stage, and the dissemination stage. The developed digital comic media was tested by the eight-grade students of the Assyfa Learning Center Foundation. The following is a description of the 4-D development model.

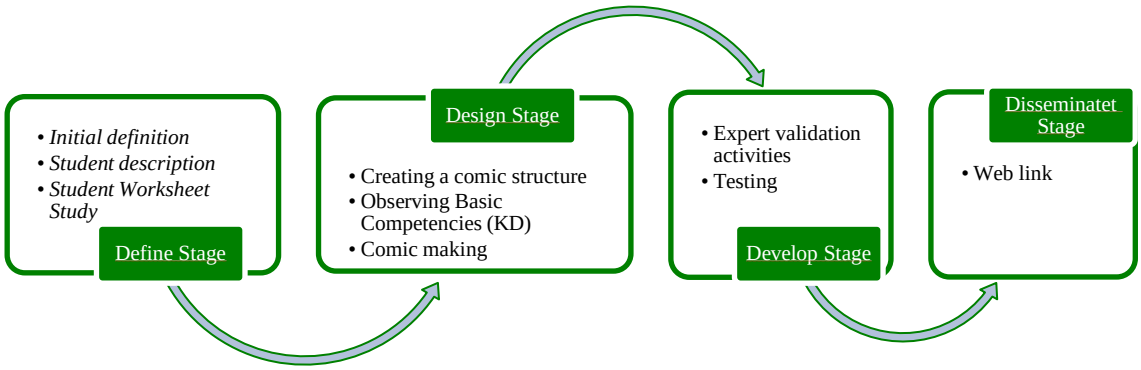


Figure 1. 4D Development Stages

The research began through observations using the 4D observation stage. Then the carried out processes consisted of (1) define (the formation process, which includes initial and final observations, student observations, task observations, and formulation of learning objectives), (2) design (formation process, namely the process of designing comics that is in sync with the geometry material based on the 2013 curriculum, (3) develop (the process which includes expert validation and testing). The last process was dissemination through online web links.

After using the developed comics, the qualitative descriptive data were collected through questionnaires and learning outcomes tests. The data were quantified to obtain results in numbers to be measured. The comic media revised based on the validation results will then be tested on 22 students. Student response sheets and test sheets were distributed to 22 eighth-grade students of the Assyfa Learning Center Foundation who had previously been grouped based on their learning styles. All students were given a questionnaire containing questions to help the researchers to determine the type of their learning style. After students filled out the questionnaire, the teacher then analyzed and sorted the students into groups according to their type of learning style. Furthermore, from the 22 students, the researcher focused on three students who had auditory, kinesthetic, and visual types of learning styles.

Material Validation

Material validation was carried out by two validators (two mathematics teachers). The validators investigated by filling out the material verification sheet using a four-choice Likert scale (4 = excellent, 3 = high, 2 = moderate, 1 = poor).

Table 1. Material Validation Sheet

No	Viewpoint	Instruction	Unit
1	Simplicity	Use	1, 2
		Shape and size	3, 4
2	Cohesiveness	Illustration	5
		storyline	6, 7
3	Language	Language compilation	8, 9, 10, 11, 12
4	Text	Fonts	13, 14
		Space	15
5	Colour	Composition	16
6	Arrangement	Layout	17, 18, 19
7	Attractiveness	Attractiveness	20, 21

source: Kustandi & Sutjipto (2013)

Media Validation

Table 2. Media Validation Sheets

No	Viewpoint	Instruction	Unit
1	Contents	Theory	1, 2, 3, 4, 5
2	Language	Language Compilation	6, 7, 8, 9, 10
3	Presentation	Material	11, 12
		Storyline	13
4	Appearance	Comic display	14
5	Character Value	Independent	15, 16
		Responsibility	17, 18
		Honest	19
		Curiosity	20

Student Response Questionnaire

Table 3. Student Response Questionnaire

No	Viewpoint	Unit
1	Interest in comics	1, 2, 3, 4, 5, 6
2	Material retention	7, 8, 9, 10
3	Display	11, 12, 13

Source: Adapted from Sari (2016)

Learning Outcomes

Questionnaires were used to see the results of student development after using comics as a learning medium. A questionnaire containing five questions that contained instructions for critical thinking skills was distributed separately from the comics. It was then measured based on Polya's steps in terms of students' learning styles.

Table 4. Students' Critical Thinking Ability

No	Indicator	Unit
1	Basic Clarification	1
2	Basic Support	2
3	Conclusion	3
4	Advanced Clarification	4
5	Strategy and tactics	5

Source: Adapted from Firdaus & Nisa, (2019)

Table 5. Polya Stage Classification

No	Indicator	Description
1	Understanding the Problem	Students who work on problems must first have the initial ability to understand the problem to determine the strategy to be used in solving the problem.
2	Planning a Plan	Students can use their ability to make plans or strategies by choosing the formula used through their reasoning in selecting and sorting out which formula to use.
3	Executing the Plan	Students can carry out the plans that have been prepared at the planning stage by performing calculations through predetermined formula.
4	Reviewing Results	Students can review the results they have written on the answer sheet by making a conclusion or re-evidence that is useful for checking whether what has been done is correct or not.

RESULTS AND DISCUSSION

The digital comic learning media was developed using 4D models. The model consisted of four stages: the definition stage, the design stage, the development stage, and the dissemination stage. The explanation is described as follows.

Definition Stage

The definition stage was started by studying the initial part and consulting with the mathematics teacher at the Assyfa Learning Center Foundation. The Assyfa Learning Center Foundation students attended different schools (state, private, or boarding schools). The problems found during the learning activities were the lack of interest in reading and the lack of interpretation and perception. The students were bored since their schools implemented an online system due to COVID-19. Student worksheets were boring because they only contained numbers with unattractive colors. The students' misunderstood the contents, which made their learning outcomes low. There were several complaints from the guardians of students because the teachers reprimanded their children because of their low grades. The students said that mathematics is difficult. The teacher only provided a link to a learning video for students to watch without explaining or reviewing the material. The teacher did not understand using technology-based media because almost all of their mathematics teachers lack technical knowledge. The teachers were forced to spend their energy and time because they had to teach twice a day per class with the same material. After all, the classes were divided into two shifts.

The next step in the define stage was student description. It was done by observing the mathematics learning. The students stated that they could learn and understand well in a quiet environment or by listening to music. They prefer to be explained through reading or repeating the material and trying it first. It was found that the students had different types of learning styles. One way to learn more about the learning styles is by distributing a questionnaire to the students based on their respective learning styles by using codes to make research easier. It was found that students had different learning styles, namely auditory, kinesthetic, and visual types.

The next step was studying the worksheet. Almost all worksheets used in the schools were the same. The teacher did not provide other media besides worksheets. The results of interviews and discussions with other mathematics teachers who teach at the Assyfa Learning Center Foundation stated that blocks and cubes' material understanding should be improved.

Furthermore, the integration process of learning activities, according to the 2013 curriculum, uses basic competencies 3.9 and 4.9 with an indicator of 3.9.1, which is to determine the surface area of blocks and cubes. The indicator 4.9.1 is the indicator of solving everyday problems related to the surface area of blocks and cubes.

Design Stage

Making the model was started by making the structure of the comic and observing the initial skills (KD) of the 2013 curriculum. The observation was performed more than once, and the formation of initial skills (KD) and instructions used in comics obtained good results.

Table 6. Initial Capability and Yield Index

Initial Ability	Indicators of Competency Achievement
3.9 Distinguish and determine the surface area and volume of flat shapes (cube, cuboid, prism, and pyramid)	3.9.1 Determining the surface area of Blocks and Cubes
4.9 Solve problems related to surface area and volume of plane figures (cubes, cubes, prime numbers, and pyramids), and their combinations	4.9.1 Solve everyday problems related to the surface area of blocks and cubes

After determining the initial skills (KD) and the results index, the researchers developed a comic with the title "Box Mystery Adventure BIMA ."The stages consisted of making a storyline, drawing initial illustrations, strengthening illustrations, coloring, scanning images, and making conversations. The steps are as follows:

a) Composing comic stories
b) Preparing the initial picture of the storyline.
c) Make an initial sketch of the story in the Canva application in jpg, png, or file form (doc, pdf, PPT), and later can be repaired.

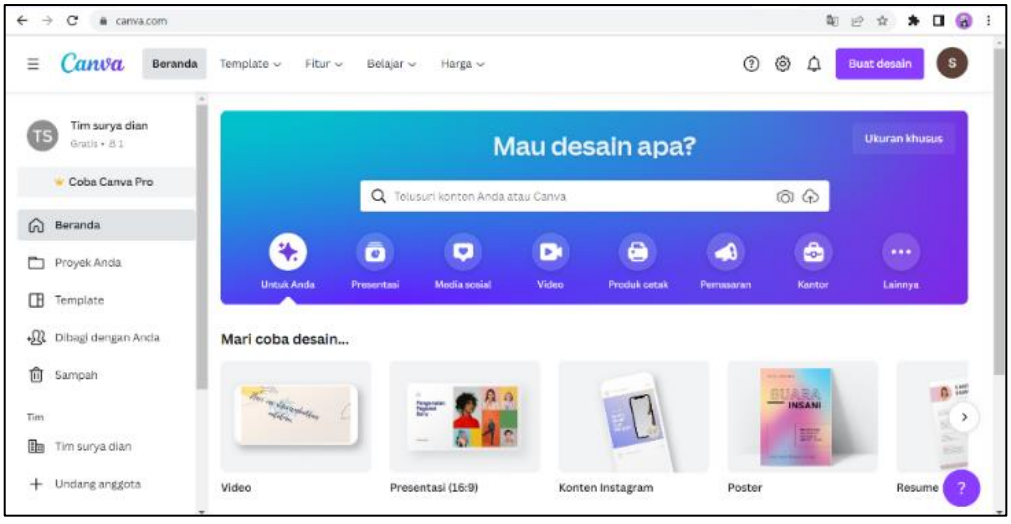


Figure 2. The Display of Applications for Sketching the Storyline

d) Sketch stabilization: Consolidation of sketches can also be done by creating them using the Canva application, which was created at the initial sketch stage by duplicating the initial design so that comparisons can be made later.

e) Sketching: Sketched and made to make it look real. The color selection was adjusted to the students' character, which can also be edited in the same application.

f) Image creation: Images can be selected in the same application according to the needs of the comics so that editing can be done on a computer or mobile phone.

g) Adding dialog text: Editing and adding dialog text to images was also done with the help of the Canva app.

h) Printing: when all images have been finished and edited, all images are printed and compiled into a digital comic book in the application, as shown in Figure 3 below.

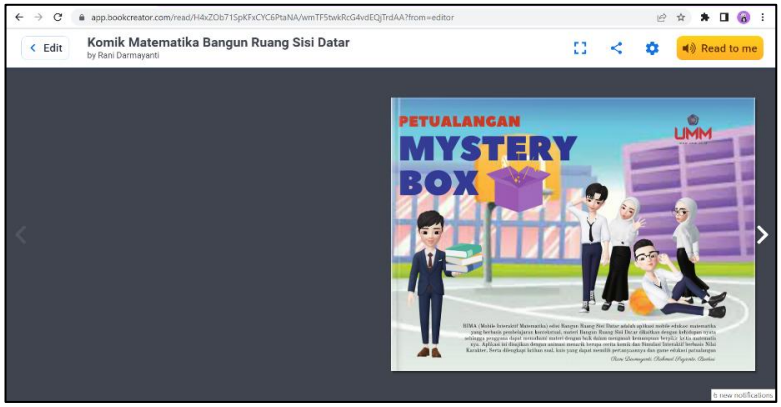


Figure 3. Application for Printing Digital Comics

Development Stage

The finished comic design will then enter the development stage, which consists of expert validation and trials. Expert validation consisted of material expert validation and media expert validation. The results of material validation obtained from the two validators are presented in Table 7. On the other hand, the results of media validation were obtained from two validators (two media experts who are experts in their fields). The validator investigated by filling out the material verification sheet using a four-choice Likert scale (4 = Excellent, 3 = high, 2 = moderate, 1 = poor).

Table 7. Results of Material Validation Data Analysis

Aspect	Average	Information
Aspect	3,6	Excellent
Contents	3,5	Excellent
language	3,4	Excellent
Presentation	3,7	Excellent
Appearance	3,8	Excellent

Overall, the average overall validation of the material in the table above is 3.60, which is in the valid category. In short, comic media contains quality material and deserves to be tested.

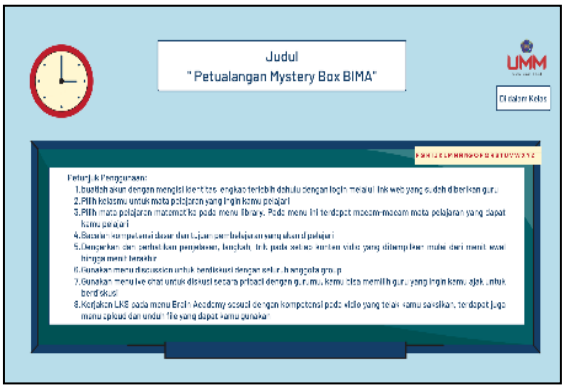
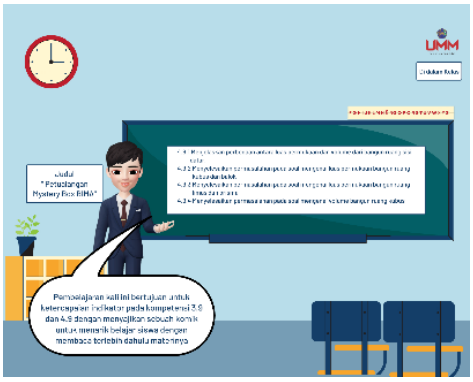
Table 8. Results of Media Validation Data Analysis

Aspect	Average	Information
Simplicity	3,4	Very Valid
Cohesiveness	3,3	Valid
Language	3,2	Valid
Text	3,3	Valid
Colour	3,8	Very Valid
Arrangement	3,7	Very Valid
attractiveness	3,8	Very Valid

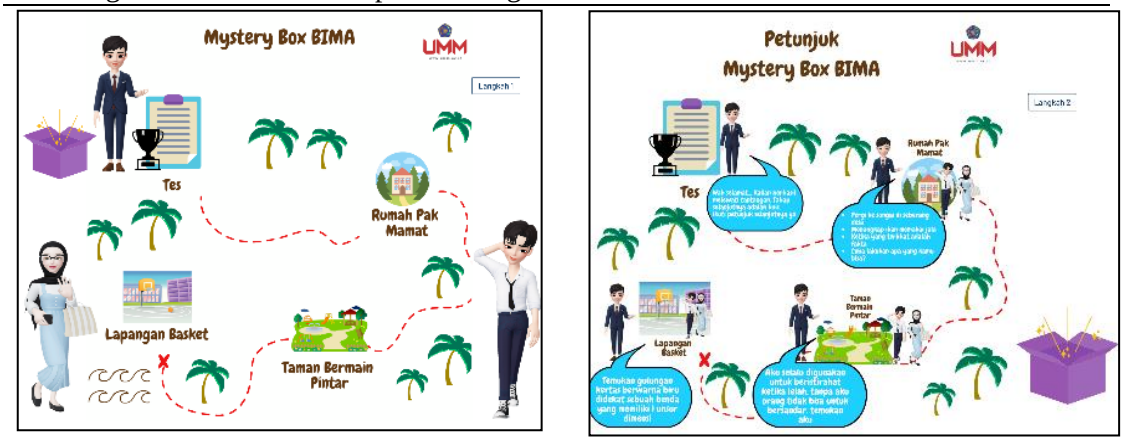
Overall, the average total media validation score is 3.50 within a valid category from the table above. It means that comic media are feasible to be tested.

Based on the validation processes, there were several critics and suggestions to improve the comic media; however, they did not change the context of the material. Minor revisions regarding the appearance and text of the media are presented in table 9.

Table 9. Development of Revised Comics from Validator

Before	After
1. The title and cover design changed from the previous "My Difficult Homework" Become a “BIMA Mystery Box Adventure” with a more attractive cover design.	
	
2. Improved the display of the user manual page.	
	
3. Designed each display on the comic page "Basic Competency Display."	
4. Designed each display on the comic page "Display Atmosphere in the Classroom."	
	

5. Designed an Adventure Map containing clues to solve in the comics.



The comic media was tested on 22 students with different learning styles in the Assyfa Learning Center Foundation. This media trial was conducted from 17 to January 18, 2022, for 80 minutes (2×40 minutes). The first time the link was distributed, almost some students thought this learning was not important. It could be seen from the facial expressions and actions taken by indirectly clicking on the link. However, something different was found after one of the students accessed the link. Some students began to appear interested in accessing it immediately. However, some students were not focused on reading since they talked to their friends. Some students were fast in completing the answers. Some repeated important parts or were considered interesting to them by conducting discussions. Some students started laughing, focused, surprised, and made various expressions. They did not hesitate to comment, "Oh, that's how it is," others commented, "Wow, it is easy," "poor father," and soon.

After the students had finished their reading, there was a little re-discussion on the material and practice questions. At the end of the activity, the students were given a test that contained critical thinking skills. Also, the teacher distributed questionnaires after using the comics. The teacher analyzed the data obtained from the test and the response questionnaire.

Disseminate Stage

The product was disseminated online to students by sharing links so that it could be used by other students and can be used as interactive teaching materials. The media can help students in learning, especially during the pandemic.

Results of Analysis and Discussion

The student responses were measured based on data obtained from the questionnaires filled out by 22 students. The average percentage of student responses was 92%, within the very positive category. In conclusion, the students like the use of comics as learning media.

The student learning outcomes obtained from a test with five questions were analyzed according to the minimum completeness criteria (KKM) used by the Asyifa Learning Center Foundation (75). The results showed that all students got scores above the KKM or more than equal to 75 with a percentage of 100%. Meanwhile, learning outcomes measured based on Polya's completion steps in terms of student learning styles are described as follows:

Critical Thinking Skills with Visual Learning Style

Based on the classification results, subject A1 was the subject with the correct answers and led to the visual learning style. Subject A1 can meet all the indicators of the Polya's steps. Umrana

et al. (2019) state that subjects that tend toward a visual learning style in solving mathematical problems can reach four of Polya's steps: understand problems, plan, implement plans, and consider problem-solving results.

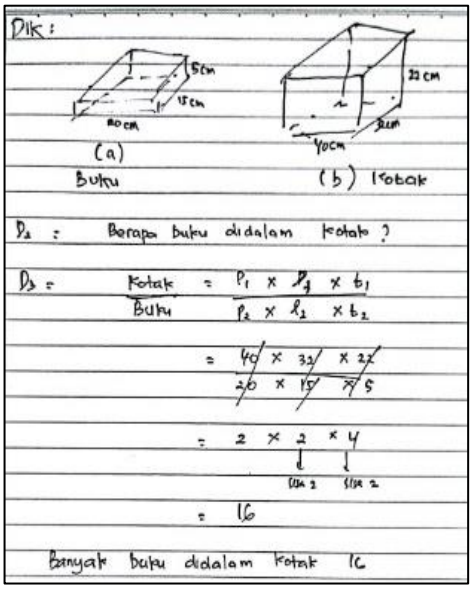


Figure 4. The Results of Students' Answers with Visual Learning Styles in Solving Problems through the Polya Step

The subjects had a strong tendency to learn visually. A1 could meet all the indicators of the Polya stage since the subject could draw and write what is known and needed, reason and suggest a formula or solution method that will be used to solve the problem, and replace what is known in the formula or method, record the results of problem-solving to conclude. Then, unstructured interviews were also conducted after A1 answered the test questions. Based on the interview results, when working on the test questions, A1 could fulfill four indicators from the four stages of Polya, namely understanding the problem, planning a plan, implementing, and reviewing the results of problem-solving.

Critical Thinking Skills with Kinesthetic Learning Style

Subject B1 was a kinesthetic style subject. Students with this style are known for/manipulative characteristics and direct learning, busy playing, physically oriented and active, and responding to physical attention. DePorter & Hernacki (1992) state that students learn in a kinesthetic style by moving, touching, and doing. Subjects B1 tended to have a kinesthetic learning style that responded to all indicators of the Polya stage. Umrana et al. (2019) state that subjects with a kinetic learning style tendency in solving mathematical problems can take four steps according to Polya, namely being able to understand problems, plan, implement plans, and check solutions. B1 test results can be seen in Figure 5.

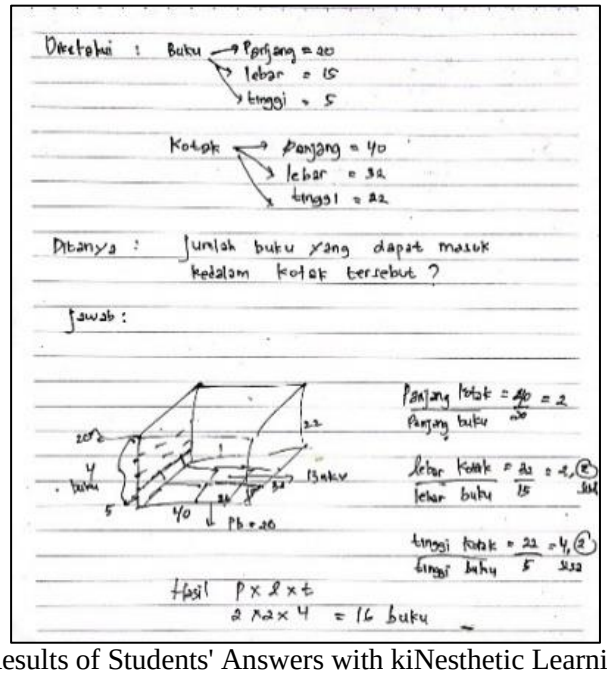


Figure 5. The Results of Students' Answers with kiNesthetic Learning styles in Solving Problems through the Polya Step

Subjects with kinesthetic style (B1) in problem-solving master all indicators of the Polya stage, namely: (1) understanding the problem. The subject understood the problem as a whole with what is known and developed; (2) When planning, subject B1 planned to solve the problem by reasoning and then to explain; (3) implementation of the plan, which can override what is already in the drawing formula or predetermined method; (4) Rechecked, subject B1 did not write a conclusion about the answers to the test questions. Then, unstructured interviews were also conducted after B1 answered the test questions. It can be concluded that B1 can complete the four stages of Polya, namely, understanding the problem, planning, implementing the plan, and seeing the review of the results.

Critical Thinking Ability with Auditory Learning Style

Subject C1 represented the auditory learning styles. DePorter & Hernacki (1992) claim that students rely on their academic success through their ears (hearing aids). Subjects with auditory learning types can respond to all Polya stage indexes. Umrana et al. (2019) state that subjects who have auditory learning tendencies in solving mathematical problems can be achieved in four stages according to Polya, namely understand the problems, plan the problem-solving, implement the plan, and review the results of problem-solving. C1's answers to the test questions can be seen in Figure 6.

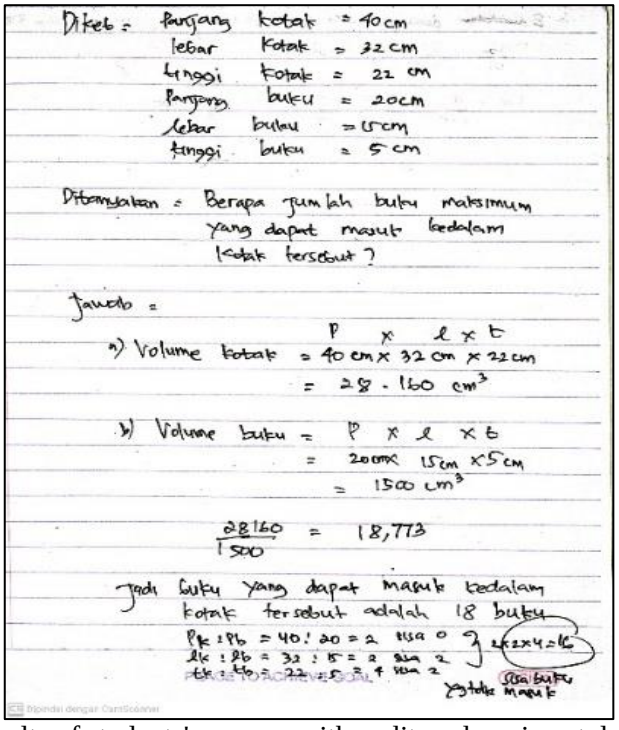


Figure 6. The results of students' answers with auditory learning styles in solving problems through the Polya step

Subjects with an auditory learning style (C1) in problem-solving can understand all the indicators of Polya's stages, namely (1) the subject can understand the problem by going through it. (2) When planning, the subject planned to solve the problem. (3) Implement a plan to perform all scheduled steps. (4) Ensure that the subject reconfirms and recalculates the completion process. The researchers also conducted an unstructured interview after subject C1 worked on the question. Based on the interview with C1, it can be concluded that the subject understood the four stages of Polya's steps, namely planning and reviewing the results of problem-solving.

The third is the analysis of academic achievement data of the three students with kinesthetic, auditory, and visual style learning styles. The subjects met all the indicators of Polya's steps and passed the KKM. Therefore, comic media can help and simplify the learning process. Based on research by Pardimin & Widodo (2017), comics can be used as a learning medium. Learning is said to be good if it meets three criteria, namely valid (worth trying), practical (easy to use as measured by student questionnaires), and effective (facilitating learning as measured by student learning outcomes tests). Sepriyanti & Tapia (2018) state that comics as a structured teaching material can refer more to the document's validity and the opinions of teachers and students, which show that the material is appropriate and easy to use.

The Adventure of the Mystery Box comic is valid or feasible to use. It obtained positive feedback from students after using the media and helped the student in the learning process. This research is also in line with Rais & Febrianto (2017). To help the learning process and improve student learning outcomes, quality learning media is needed that is relevant to the students' needs, accepted by students, and facilitates the student learning process. Salim & Tiawa (2014) claim that the right media is valuable in the learning process. It can be seen from the research results that the digital comic "The Adventure of the Mystery Box" has a good quality in terms of grades, positive student feedback, and overall student learning outcomes

CONCLUSIONS

Based on the description, digital comic learning media based on character values on critical thinking skills in terms of learning styles on geometry materials obtained valid results with a total average of 3.60 from the material experts. At the same time, media experts stated that it was valid with a total average of 3.50. The trials obtained positive student responses (92%). It means that students appreciate comics as a medium of learning. In terms of learning outcomes in terms of kinesthetic, auditory, and visual learning styles, all of them met all the indicators of Polya's steps and passed the minimum score requirements set by the school. Therefore, this digital comic media can help and facilitate the learning process. This media can be used as an alternative for teachers in developing materials and media for other learning materials.

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AUTHOR CONTRIBUTIONS STATEMENT

RS and RD shaped the ideas presented. RS developed the theory and performed calculations developed and supported by BB. CU and WW reviewed the analytical methods. BB and RD encouraged MS to emphasize [multiple aspects] and integrate the results of this study. All authors reported results and contributed to the final manuscript. RS and RD conducted development experiments to make digital comic media. RS wrote scripts with BB, CU, and WW's support. CU and WW produced XYZ models with diverse learning styles. BB, CU, and WW helped oversee the research and development. BB, CU, and WW combined attractive ideas. BB oversaw the project.

RS and RD developed theoretical formalism, performed analytical calculations, and performed numerical simulations. RS and RD contributed to the final version of the manuscript. RS oversaw the project. RS, RD, BB, CU, and WW organized and planned the development of the comic media experiment. MS and RD conducted validation tests on media and research materials for digital comic development. RS, RD, BB, CU, and WW designed and performed the simulation. RS, RD, BB, CU, and WW contributed to interpreting the results. RS was actively writing the scripts. All authors provided critical feedback and helped shape the study, development, analysis, and manuscript. RS and RD designed the model and development framework for computing and data analysis. BB, CU, and WW calculated validation and test results. RS and RD drafted the manuscript with input from all authors. BB, CU, and WW conducted the research and were responsible for overall planning and management. RS designed and conducted research development, modeling, and data analysis. XYZ supported RD. BB measurements helped to perform XYZ simulation. RS and RD wrote scripts with BB, CU, and WW. RS designed the project and main concept idea and proofread the outline. RD did almost all the technical details and performed the numerical calculations for the proposed experiment. BB went beyond quantum mechanics, assisted by CU and WW. BB verified XYZ numerical

results with independent implementation. CU and WW proposed the XYZ test in discussion with RS, RD, BB, and CU, where WW wrote the manuscript in article form.

REFERENCES

Afgani, M. W., & Paradesa, R. (2019). Perbedaan skala pada sumbu koordinat kartesius: Apa dampaknya dalam pembelajaran integral tentu?. *Jurnal Pendidikan Matematika*, *13*(2), 121–130.

Amah, D. M. A., & Jamiah, Y. (2019). Kemampuan penalaran adaptif ditinjau dari gaya belajar dalam materi barisan dan deret aritmetika. *Jurnal Pendidikan dan Pembelajaran Khatulistiwa*, *8*(9), 1–13.

Andayani, F., Maula, L. H., & Sutisnawati, A. (2020). Pengembangan media komik berbasis digital terhadap kemampuan berpikir kritis siswa pada materi metamorfosis di kelas tinggi. *DIKDAS MATAPPA: Jurnal Ilmu Pendidikan Dasar*, *3*(2), 308-318.

Ayuningrum, D. (2017). Strategi pemecahan masalah matematika siswa SMP ditinjau dari tingkat berpikir geometri van hiele. *Kreano, Jurnal Matematika Kreatif-Inovatif*, *8*(1), 27–34.

Badawi, A. (2015). Analisis kemampuan berpikir aljabar dan kemampuan berpikir kritis dalam matematika pada siswa SMP kelas VIII. *Skripsi. Semarang: Universitas Negeri Semarang*.

Cronin, M., Altimari, F., & Caria, M. (2016). Perledicreativita': Blended learning on a mooc model. *ICERI2016 Proceedings*, *1*.

de Kamps, M., Lepperød, M., & Lai, Y. M. (2018). Computational geometry for modeling neural populations: From visualization to simulation. *Computational Geometry for Modeling Neural Populations: From Visualization to Simulation*.

DePorter, B., & Hernacki, M. (1992). Quantum learning: Unleashing the genius in you. *New York Dell Publishing*, *Terjemahan: Alwiyah Abdurrahman*, 310.

Fadella, E. F., Sugiarto, & Prabowo, A. (2018). Keefektifan problem-based learning berbantuan komik matematika terhadap kemampuan pemecahan masalah dan rasa ingin tahu. *PRISMA (Prosiding Seminar Nasional Matematika)*, *1*, 77–86.

Fauzi, I., & Arisetyawan, A. (2020). Analisis kesulitan belajar siswa pada materi geometri di sekolah dasar. *Jurnal Matematika Kreatif Inovatif Kreano*, *11*(1), 27–35.

Rais, M., & Febrianto, F. (2017). Analisis penerapan media pembelajaran prezi terhadap hasil belajar siswa kelas X TPHP pada mata pelajaran pengendalian mutu dalam proses pengolahan di SMK Negeri 3 Takalar. *Jurnal Pendidikan Teknologi Pertanian*, *4*(1), 349-355.

Fitriani, H. (2012). Pengembangan soal cerita sistem persamaan linear menggunakan animasi komik kelas X sekolah menengah atas (SMA). *Jurnal Pendidikan Matematika Universitas Sriwijaya*, *8*(2), 1–11.

Firdaus, A., Nisa, L. C., & Nadhifah, N. (2019). Kemampuan berpikir kritis siswa pada materi barisan dan deret berdasarkan gaya berpikir. *Kreano, Jurnal Matematika Kreatif-Inovatif*, *10*(1), 68–77.

Huda, I. A. (2020). Perkembangan teknologi informasi dan komunikasi (TIK) terhadap kualitas pembelajaran di sekolah dasar. *Jurnal Pendidikan Dan Konseling (JPDK)*, *2*(1), 121–125.

Kemdikbud. (2021). *Kementerian pendidikan, kebudayaan, riset, dan teknologi*. *021*.

Kintu, M. J., Zhu, C., & Kagambe, E. (2017). Blended learning effectiveness: the relationship between student characteristics, design features and outcomes. *International Journal of Educational Technology in Higher Education*, *14*(1), 1–20.

Knisley, J. (2002). A four-stage model of maathematical learning. *A Four-Stage Model of Mathematical Learning*. *12*(1), 11–16.

Kurniyati, E., & Arwen, D. (2020). The implementation of character education to generation Z in Indonesia. *Atlantis Press SARL*, *477*(Iccd), 244–248.

Kustandi, C., & Sutjipto, B. (2013). *Media Pembelajaran Manual dan Digital*. Ghalia Indonesia.

Lewis, C. C., Perry, R. R., Friedkin, S., & Roth, J. R. (2012). Improving teaching does improve teachers: Evidence from lesson study. *Journal of Teacher Education*, *63*(5), 368–375.

Lonto, A. L., Wua, T. D., Pangalila, T., & Sendouw, R. (2018). Moral work, teaching profession and character education in forming students' characters. *International Journal of Engineering and Technology (UAE)*, *7*(4), 99–103.

Manalu, M. A., Hartono, Y., & Aisyah, N. (2017). Pengembangan media komik matematika berbasis nilai karakter pada materi trigonometri di kelas X SMA Negeri 1 Indralaya Utara. *Jurnal Elemen*, *3*(1), 35–48.

Naufal, H. (2021). Model pembelajaran konstruktivisme pada matematika untuk meningkatkan kemampuan kognitif siswa di era merdeka belajar. *Seminar Nasional Pendidikan Matematika*, *2*(1), 143–152.

Novianti, R. D., & Syaichudin, M. (2010). Pengembangan media komik pembelajaran matematika untuk meningkatkan pemahaman bentuk soal cerita pecahan pada siswa kelas V SDN Ngembung. *Jurnal Teknologi Pendidikan*, 74–85.

Nurrita, T. (2018). Pengembangan media pembelajaran untuk meningkatkan hasil belajar siswa. *Jurnal Misykat*, *03*(01), 171–187.

Nurseto, T. (2012). Membuat media pembelajaran yang menarik. *Jurnal Ekonomi Dan Pendidikan*, *8*(1), 19–35.

Pardimin, P., & Widodo, S. A. (2017). Development comic based problem solving in geometry. *IEJME Matehematics Education*, *12*(3), 233–241.

Patonah, S. (2014). Elemen bernalar tujuan pada pembelajaran IPA melalui pendekatan metakognitif siswa SMP. *Jurnal Pendidikan IPA Indonesia*, *3*(2), 128–133.

Polya, G. (1973). *How to Solve It.* New Jersey: Princeton University Press.

Pujiastuti, E., & Suyitno, A. (2016). Peningkatan keterampilan peer teaching yang berkarakter melalui implementasi perangkat perkuliahan daspros pembelajaran matematika 2 bercirikan konservasi. *Kreano, Jurnal Matematika Kreatif-Inovatif*, *7*(1), 41–46.

Putra, A., & Milenia, I. F. (2021). Systematic literature review: Media komik dalam pembelajaran matematika. *Mathema: Jurnal Pendidikan Matematika*, *3*(1), 30-43.

Rachmavita, F. P. (2020). Interactive media-based video animation and student learning motivation in mathematics. *Journal of Physics: Conference Series*, *1663*(1).

Rahman, R. (2018). Keterampilan guru abad 21 dalam variabel penguasaan media audio visual. *Departemen Pendidikan Bahasa Sunda*, *1*, 1-6.

Rakasiwi, N. (2019). Pengembangan media komik dengan metode picture and picture untuk meningkatkan keterampilan literasi matematika kelas IV. *AKSIOMA : Jurnal Matematika Dan Pendidikan Matematika*, *10*(1), 60–70.

Rakim, R., Wilonoyudho, S., & Widjanarko, D. (2017). Penerapan model pembelajaran shesil (soft, hard and environment skill integrated learning) pada kecakapan otomotif. *Journal of Vocational and Career Education*, *2*(2), 41–49.

Ramadhan, S., Effendi, M. M., Ummah, S. K., & Malang, U. M. (2021). Exploration of relational thinking skills using problem solving of geometry transformation. *Jurnal Matematika Kreatif Inovatif Kreano*, *12*(2), 288–301.

Rasiman, R., & Pramasdyahsari, A. (2014). Development of mathematics learning media e-comic based on flip book maker to increase the critical thinking skill and character of junior high school students. *International Jurnal of Education and Research*, *2*(11), 535–544.

Rochmah, N. W. (2017). *Analisis kemampuan siswa dalam pemecahan masalah berpikir tingkat tinggi atau HOT (Higher Order Thinking) berdasarkan langkah polya*. Fakultas Keguruan Dan Ilmu Pendidikan Universitas Muhammadiyah Purworejo.

Safitri, I., Kaniawati, I., & Rusnayati, H. (2020). Penerapan multirepresentasi pada pembelajaran inkuiri terbimbing terhadap penguasaan konsep dari gaya belajar. *Jurnal Pendidikan Fisika Dan Teknologi*, *6*(2), 169-174.

Sakti, B. P. (2017). Indikator pengembangan karakter siswa sekolah dasar. *Magistra Unwidha Klaten*, *30*(101), 1–10.

Salim, K., & Tiawa, D. H. (2014). Development of media-based learning animation for mathematics courses in electrical engineering, University Riau Kepulauan. *Development*, *3*(10), 8332–8336.

Sari, D. (2016). *Pengembangan Komik Sebagai Media Pembelajaran pada Materi Transformasi Kelas VII SMP*. Universitas Muhammadiyah Malang.

Setyani, B., Murtono, M., & Utomo, S. (2020). Pengaruh model pembelajaran pbl terhadap hasil belajar matematika pada siswa SDN Sari 1 kelas V kecamatan Gajah Kabupaten Demak. *VIVABIO: Jurnal Pengabdian Multidisiplin*, *2*(1), 28–43.

Sepriyanti, N., & Tapia, C. (2018). The development of mathematics comics media on linear equations and linear inequalities of one variable. In *SHS Web of Conferences* (Vol. 42, p. 00115). EDP Sciences.

Sunzuma, G., & Maharaj, A. (2019). Teacher-related challenges affecting the integration of ethnomathematics approaches into the teaching of geometry. *Eurasia Journal of Mathematics, Science and Technology Education*, *15*(9), 1–15.

Suparno, W., Cletus, S., Rahman, A., Ghani, A., Fatayan, A., Burmansah, B., Taridi, T., Jauhari, A., Ripki, H., Wulandari, A., & Putra, R. (2020). Student character development: The implementation of the 2013 Indonesian school curriculum strategy. *International Journal of Innovation, Creativity and Change*, 13(10), 1058–1079.

Syukri, R., Winarni, S., & Hidayat, R. (2018). Pengembangan media pembelajaran komik matematika berbasis problem based learning dengan manga studio V05 dan geogebra. *EDUMATICA | Jurnal Pendidikan Matematika*, *8*(2), 81–91.

Taufiqulloh, T., Wardhani, S., & Sulistyawati, A. E. (2018). Needs analysis in efl reading class: A study to promote learner autonomy through self-assessment. *English Review: Journal of English Education*, *7*(1), 167–176.

Thiagarajan, S., Semmel, D. S., & Semmel, M. I. (1974). *Instructional development for training teachers of exceptional children: A sourcebook*. In indiana university, Bloomington, Indiana.

Umrana, U., Cahyono, E., & Sudia, M. (2019). Analisis kemampuan pemecahan masalah matematis ditinjau dari gaya belajar siswa. *Jurnal Pembelajaran Berpikir Matematika*, *4*(1), 67-76.

Utami, C. T. P., Mardiyana, & Triyanto. (2019). Profile of students' mathematical representation ability in solving geometry problems. *IOP Conference Series: Earth and Environmental Science*, *243*(1), 1–8.

Wicaksono, A. G., Jumanto, J., & Irmade, O. (2020). Pengembangan media komik komsa materi rangka pada pembelajaran IPA di sekolah dasar. *Premiere Educandum : Jurnal Pendidikan Dasar Dan Pembelajaran*, *10*(2), 215–226.

Widodo, S. A. (2018). Improving mathematical problem-solving skills through visual media. *Journal of Physics: Conference Seies*, *May*, 309–326.

Witanta, V. A., Baiduri, B., & Inganah, S. (2019). Pengembangan komik sebagai media pembelajaran matematika pada materi perbandingan kelas VII SMP. *Lentera Sriwijaya : Jurnal Ilmiah Pendidikan Matematika*, *1*(1), 1–12.

Wolski, M. (2020). Type in pictures. Comic book lettering in contemporary American comics. An overview. *Kultura Popularna*, *60*(2).

Yulianti, Y. A., & Wulandari, D. (2021). Flipped classroom: Model pembelajaran untuk mencapai kecakapan abad 21 sesuai kurikulum 2013. *Jurnal Kependidikan: Jurnal Hasil*

Penelitian Dan Kajian Kepustakaan Di Bidang Pendidikan, Pengajaran Dan Pembelajaran, *7*(2), 372-384.

Yunia, N. (2017). *Pengembangan media pembelajaran komik digital biologi berbasis nilai karakter pada materi pokok sistem pencernaan makanan untuk kelas VIII Mts Negeri 1 Bandar Lampung* (vol. 110265). Institut Agama Islam Negeri (IAIN) Raden Intan Lampung.

Zakaria. (2021). Kecakapan abad 21 dalam pembelajaran pendidikan dasar masa pandemi covid-19. *Jurnal Dirasah*, *4*(2), 81–90.