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Bilingual Pop Up Mathbook Based on Bangka Belitung Culture: An Innovative Learning Media of Geometry

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Abstrak

Tiga jenis literasi yang baiknya dikuasai adalah literasi matematika, bahasa, dan science. Sayangnya, laporan PISA tahun 2022 menunjukkan ketiga literasi tersebut menurun. Ditambah minimnya media ajar inovatif yang mampu memvisualisasikan konsep dan pemahaman abstrak matematika. Siswa Sekolah Dasar memerlukan integrasi pembelajaran yang meningkatkan kreatifitas, kolaborasi, komunikasi, serta cara berpikir yang kritis sesuai dengan keterampilan abad 21. Penelitian bertujuan mengembangkan pop up mathbook bilingual dengan sajian budaya Bangka Belitung yang valid pada materi bangun ruang. Penelitian menggunakan model Pengembangan ADDIE dengan lima tahapan penelitian yang terdiri dari tahap Analyze, Design, Development, Implementation dan Evaluation. Instrumen menggunakan lembar validasi, dan angket. Hasil validitas instrumen didapat bahwa bilingual pop up mathbook berbasis budaya Bangka Belitung sangat valid dengan nilai konten 100%, konstruk 96,59% dan Bahasa 90,63%. Sehingga pop up mathbook dapat diimplementasikan kepada siswa untuk menyiapkan generasi abad 21. Adapun hasil respon siswa didapat bahwa media dinyatakan sangat praktis digunakan dengan nilai 87,23%. Media yang dihasilkan memiliki karakteristik khas menggunakan bentuk bangun rumah adat, jembatan, makanan, alat transportasi serta produk pangan khas Bangka Belitung.

***Kata Kunci**: Budaya; Buku Pop up; Dua bahasa; Matematika dalam 4C.*

Abstract

Three types of literacy that should be mastered are mathematical, linguistic, and scientific literacy. The 2022 PISA report shows that three types of literacy have declined. Lack of innovative teaching media capable of visualizing abstract mathematical concepts and understanding. Students need learning that enhances creativity, collaboration, communication, and critical thinking to 21st-century skills. This study aims to develop a valid bilingual pop-up mathbook with Bangka Belitung cultural. Research uses the ADDIE development model with steps of the Analyze, Design, Development, Implementation, and Evaluation. The results showed that Bangka Belitung culture-based bilingual pop-up mathbook was very valid, with a content score of 100%, a construct score of 96.59%, and a language score of 90.63%. Therefore, the pop-up mathbook teaching book can be implemented for students to prepare the 21st-century generation. The results of student responses showed that the media was stated to be very practical to use with a value of 87.23%. The resulting media has unique characteristics using the forms of traditional houses, bridges, food, means of transportation and typical Bangka Belitung food products.

Keywords: Culture; Pop-up book; Bilingual; Mathematics in 4C.

I. INTRODUCTION

Literacy has a broad meaning, but the three types of literacy that are important to master are mathematical, linguistic, and scientific literacy. Unfortunately, the 2022 PISA report shows a downward trend in the scores for these three literacies compared to the previous period (OECD, 2023a, 2023b). Specifically in mathematical literacy, the decline in scores was quite significant, at 11.8%. In 2018, the PISA score for mathematical literacy was 379 and declined rapidly in 2022 to 366. This means that Indonesian students mathematical literacy is still low (Amelia et al., 2021; Yuniati et al., 2020) and requires analytical studies that can support the improvement of mathematical literacy, especially at the elementary level (Syah et al., 2024).

As a PISA participant, Indonesia must continue to learn. In order to compete globally, it is necessary to understand mathematics in two languages. (Rahim et al., 2020). Elementary school students need learning that integrates creativity, collaboration, communication, and critical thinking in line with 21st-century skills, also known as 4C skills. (Azmi et al., 2024; Irham et al., 2022; Pikir Wisnu Wijayanto et al., 2024; Romirio, 2015; Suyitno et al., 2021). To support this goal, elementary school students need stimulating, relevant, adaptive, and tangible stimuli to stimulate and improve their mathematical literacy and foreign language communication skills.

In Bangka Belitung, learning is still teacher-centered. Monotonous learning (Irawan & Kencanawaty, 2017) and learning exploration are only carried out by a few researchers who are conducting research on mathematics learning in schools in Bangka Belitung. In fact, elementary school students tend to learn mathematics using methods that are fun, varied, and not boring. Especially engaging 3D visual learning and learning through stories that can stimulate active learning (Ika et al., 2021; Leighton, 2022). The stories contained in the lessons can be obtained from legends and culture.

Legends and local culture can be used as sources for learning mathematics to stimulate logical thinking processes (Clarkson, 2006). Packaging stories with attractive and interactive designs is very popular with students (Ika et al., 2021), like a pop-up book (Isti & Haqiqi, 2024; Muthmainnah et al., 2020; Oktaviana et al., 2020; Yunanda Pradiani et al., 2023). Pop-up books contain relevant information and visuals that can be used as learning resources in elementary schools to make learning fun for students. Pop-up books are very suitable to be presented with the culture of a region.

There is so much to explore in the culture of Bangka Belitung. Starting with the golden bridge (Amaliah et al., 2023), part of the building has a rectangular prism shape. Regional dance (Lathiifah & Agustine, 2023), whose movements can form angles. There sre also historical objects in the museum timah (Apriani & Agustine, 2019), like a locomobil which has a tubular shape. Also a replica of a dredger that has a triangular and rectangular prism shape. This cultural potential is very suitable to be disseminated in two languages. Therefore, combining the local culture of Bangka Belitung with two languages is very possible, considering that Bangka Belitung is also a holiday destination.

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Teaching mathematics in two languages, Indonesian and English, is very suitable for students to become accustomed to foreign language dialogue. Learning through bilingual pop-up books is also effective for improving writing skills (Hidayah et al., 2020). Students who are familiar with foreign languages will find it easier to learn anywhere. A sustainable education system will support improvements in the quality of education (Holst et al., 2020). The mental readiness of elementary school students in Bangka Belitung to compete and face global challenges, given that Bangka Belitung has international tourism potential. Armed with these issues, the purpose of this study is to develop a pop-up math book based culturally Bangka Belitung that is valid to support the 21st-century math competencies of elementary school students in the subject of spatial figures.

II. METHOD

This study uses a research and development method with the ADDIE model (Branch, 2010) selected because it has easy and comprehensive research stages with evaluations conducted at each stage. The research conducted on fourth-grade students at Al Azhar Pangkalpinang Islamic Elementary School because this school has implemented bilingual learning with mathematics taught in Indonesian and English.

There are five steps of research, namely Analyze, Design, Development, Implementation, and Evaluation, which are carried out at each stage. But This article only discusses the development stage where the product is declared valid.

The first step in the ADDIE model is Analyze. An analysis of the school curriculum and student characteristics is conducted to prepare teaching materials that are appropriate for the students' characteristics. The second step is Design, which involves creating the pop-up book product design and the instruments needed for the research, including validator and student questionnaires. The third step was the development phase, which involved creating a pop-up book that had been designed previously into a mathematics textbook in Indonesian and English.

After the product was revised by the research team, it was then tested for validity by two validators and a teacher from Al-Azhar Elementary School to assess the validity and usefulness of the product for students. Then it was revised again and then tested on students in one-to-one and small groups. After a practical product is obtained, the product is implemented in large groups. The evaluation stage is carried out at each stage carried out.

The research instruments used questionnaires and interviews. Questionnaires were used to determine the validity of the books developed based on the validators' assessments. Interviews were used to explore the validity of the books, their suitability in terms of content, structure, and language, as well as other aspects not covered by the questionnaires.

Data analysis uses qualitative and quantitative analysis. Qualitative analysis was conducted to collect and evaluate data from interviews with validators. Meanwhile, quantitative analysis was used to calculate the validity of the book based on

questionnaires filled out by validators using a Likert scale. Validity criteria based on content, construct, and language assessments were then calculated using averages with categories presented in Table 1. The practicality assessment is presented in table 2.

Table 1.
Validity Criteria

Value category	Conversion score	Criteria
3,4 - 4	85 - 100	Very Valid
2,8 - 3,3	70 - 84	Valid
2,4 - 2,76	60 - 69	Sufficiently Valid
2,01 - 2,3	51 - 59	Less Valid
0 – 2	0 - 50	Invalid

Table 2.
Practicality Criteria

Interval (%)	Criteria
81 - 100	Very Practical
61 - 80	Practical
41 - 60	Sufficiently Practical
21 - 40	Less Practical
0 – 20	Practical

III. RESULT AND DISCUSSION

This study uses a research and development method with the ADDIE model shown in Figure 1 below.

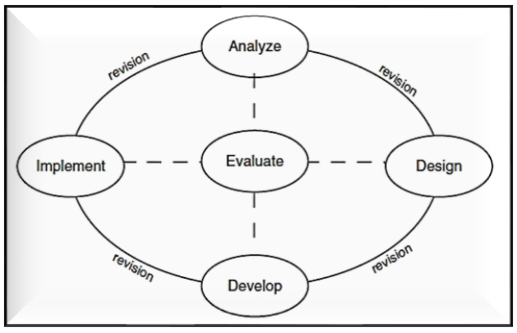

Figure 1. ADDIE Research Steps

The research began with an analysis of the curriculum and research subjects. The analysis showed that the material for fourth-grade students was an introduction to spatial figures, with learning objectives including:

1) Recognizing spatial figures based on their characteristics
2) Identifying elements of simple spatial figures
3) Determining and describing the position of spatial figures in relation to other objects
4) Understanding various forms of spatial figure nets

The shapes used in the research include rectangular prisms, namely cubes and cuboid, triangular prisms, cylinders, and spheres. In addition to reviewing the curriculum and materials, researchers also observed fourth-grade students at Al Azhar Elementary School in Pangkalpinang. The results of the observation show that fourth-grade students have an excellent understanding of flat shapes, which are the basis for learning about three-dimensional shapes.

Media needs analysis was conducted on both students and teachers in grade 4. Table 3 presents the results of the student needs survey.

Table 3.
Results of the Student Needs Questionnaire

Name	Score				Sum	Percent
	1	2	3	4		
A.N.A	1	0	4	6	37	84%
A.A.W	0	4	5	2	31	70%
H.R	0	3	6	2	32	73%
S.A	0	1	6	4	36	82%
I.A.D	0	5	4	2	30	68%
K	1	4	3	3	30	68%
M.A	1	2	7	1	30	68%
M	0	2	2	7	38	86%
H.D	1	0	2	8	39	89%
A.P	0	3	5	3	33	75%
A	3	2	3	3	28	64%

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R	2	2	6	1	28	64%
S.A	1	3	4	3	31	70%
Z	3	6	1	1	22	50%
Al	0	0	6	5	38	86%
Z.A.A	0	0	8	3	36	82%
A.M	2	1	3	5	33	75%
M.A.K	0	0	6	5	38	86%
N.A.Z	0	0	3	8	41	93%
T.S.R	0	2	5	4	35	80%
A.Q	2	3	3	3	29	66%
Total Score					690	
Maximum Score					924	
Average Percentage of Needs						**75%**

The results of the student needs analysis showed that all students felt that they needed interactive and interesting mathematics learning media. In addition, 75% of students stated that they would be more motivated to learn mathematics if they used media that could be moved. Figure 2 shows a photo taken during the initial observation.

Figure 2. Student Observation

Needs analysis was conducted among mathematics teachers and fourth-grade teachers, with the result that teachers found it difficult to create innovative learning media. The results of the needs survey, which consisted of 14 statements, showed that 89% of teachers needed innovative learning media in two languages for classroom learning. Figure 3 shows the documentation compiled with the teachers.

Figure 3. Teacher Observation

In addition to needs analysis, researchers also conducted an initial diagnosis of fourth-grade students' conceptual understanding. Students' concept understanding was assessed using seven questions with three concept understanding indicators, namely:

1) Identifying examples and non-examples
2) Restating concepts
3) Classifying objects

Then, an analysis of each student's answers was conducted, and the results of the analysis of students' conceptual understanding are presented in Table 4.

Table 4.
Concept Understanding Indicator

No	Concept Understanding Indicators	Score
1	Identifying examples and non-examples	54%
2	Restate the concept	16%
3	Classify objects	71%

These results indicate that, although some students were able to distinguish between examples and non-examples, they still had difficulty understanding the concept. For this reason, a pop-up mathbook based on the culture of Bangka Belitung was developed. The material used in the study was geometrys, which is an advanced topic in plane geometry.

The second step was design, where the researcher and the team created the initial design of the pop-up math book using Canva. The researcher designed the background for each page, then determined

the content for each page, starting with the cover, learning objectives, and then the material in the order of blocks, cubes, triangular prisms, cylinders, and spheres. Each material provides an introduction to real objects from Bangka Belitung according to their shape, followed by a description of their characteristics and networks. Each material is presented in different ways to avoid monotony. Various short questions are also included. At the end of each material, there are practice questions and evaluations.

The third step is development, where the design is then created in the form of a pop-up math book. The media is created in three phases. In the first phase, researchers and the team created 3D models of the structures, but the appearance was still very simple and plain because it was still in the testing phase to ensure that the desired 3D models could stand and move. Figure 4 shows the initial design of the pop-up mathbook.

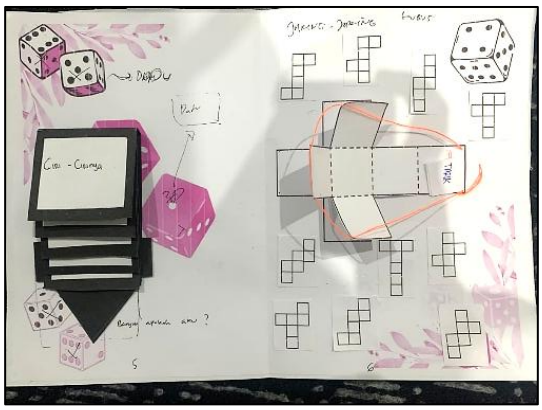

Figure 4. Initial Development of Pop Up Mathbook

After finishing and forming the 3D model, the second phase was carried out using colored cardboard and moving designs that were spread across every page of the book. Figure 5 shows the results of the second phase.

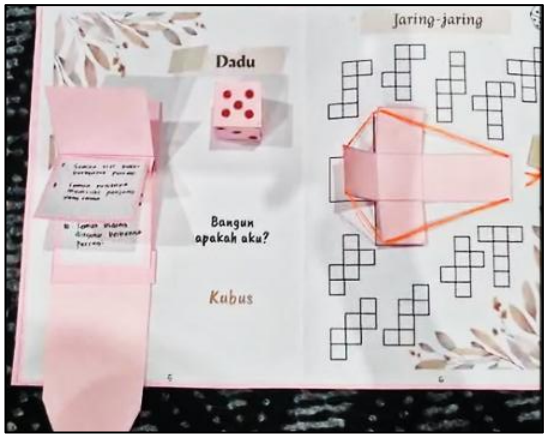

Figure 5. Further Development of Pop-up Mathbook

The third phase was carried out by printing the pop-up mathbook at a professional book printing service. The book was then validated by two mathematics experts, PCA and AA. The validation was carried out to assess the suitability and appropriateness of the book's content in terms of content, structure, and language. Figure 6 shows the documentation with the validators.

Figure 6. Product Validation Activities

The validators' suggestions and comments provided input for researchers to evaluate the initial product. Some of the PCA validators' suggestions included providing instructions for each spatial figure, revising the characteristics of spatial

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figures, and making the colors more appealing to student. The suggestions from validator 2 include removing spatial structure characteristics such as diagonals and other elements that students do not yet need to understand, adding examples of net problems with instructions to encourage interaction in each material, and changing the position of the triangular prism image to match its characteristics. The results of the validation by the validators, which have been analyzed, are presented in Table 5.

Table 5.
Product Validity Results

Name	Content	Construction	Language
PCA	100	93,18	87,5
AA	100	100	93.75
SAR	95	95,45	87,5
Average	98,33	96,21	89,58

The values presented are conversion percentages. Based on the analyzed values, it was found that the developed textbook is highly valid because it is in the range of 85–100 based on the conversion values in Table 1. Figure 7 shows the results of the pop-up mathbook product that has been revised according to the suggestions and declared to be highly valid. In figure 8, one of the typical Bangka foods is shown, namely talam cake, which is cube-shaped. In figure 8 is the material for the net of a cuboid, if the side edges are pulled, it can form a cuboid.

Figure 7. Typical Bangka food in the shape of a cube

Figure 8. Nets of cuboids

The next stage is trial the product on 4th grade students. The first is tested on students individually, which is called the one to one stage. At this stage, three students individually study the pop up mathbook. After the one-to-one stage was carried out, several revisions were made to the pop-up mathbook, including changing the size of the book to be smaller so that it would be more practical for students to use. Also revised the shape of the cuboid which is less open when the book is opened. After that, the book was reprinted to carry out the small group trial stage. At this stage, students work in groups to use pop-up books to see the practicality of the book. The results of the practicality test obtained an average value of 87.23% with a very practical category. Next is implementation stage. At this stage, the pop-up mathbook was given to one class of students, class 4b, who were not the product's trial subjects.

The final step in the research is evaluation, which is carried out at the end of each stage of the research. It begins with evaluation at the analysis stage, where researchers evaluate the materials to be used in the research, namely prisms, cubes, triangular prisms, cylinders, and spheres. The evaluation was also conducted at the design stage, where the researchers and the team evaluated the initial design of the pop-

up mathbook product. The evaluation was also carried out at the development stage, starting from the creation of the product in phase one to the product validity stage based on comments and suggestions received from validators.

One alternative medium that is suitable for use in mathematics learning is pop-up books. Pop-up books are books that have three-dimensional elements and can move when opened (Kazeykina, 2024; Pratiwi, 2023; Fajriah, 2022; Nisaa' & Adriyani, 2021; Raffa, 2019). The development of a Bangka Belitung culture-based pop-up mathbook for spatial geometry material is expected to improve the abilities of fourth-grade students and become a reference source for teachers in teaching spatial geometry material to students.

The research began with an analysis steps, in which the researcher adjusted to the characteristics of students who really liked concrete objects and were more enthusiastic when learning with colorful books. Initial analysis also showed that students' abilities in flat shapes were good and sufficient to move on to spatial shapes. The results showed that students' initial understanding of the concept for the indicator of identifying examples and non-examples was 54%, the indicator of restating concepts was 16%, and the indicator of classifying objects was 71%.

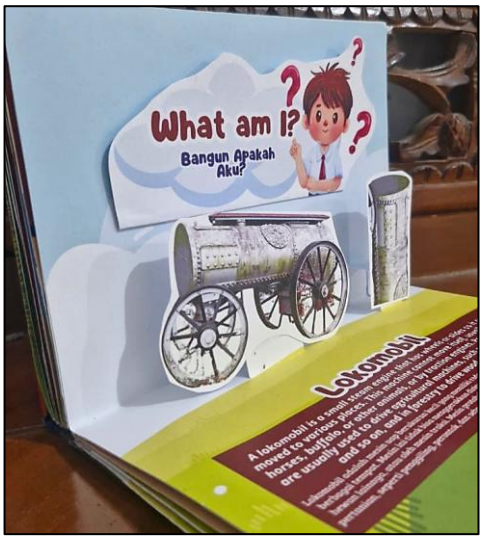

Figure 9. Locomobil as an Introduction to the Shape of a Cylinders

The second step is that the book is designed to contain elements of Bangka Belitung culture in each spatial material, namely cuboid, cubes, triangular prisms, cylinders, and spheres. Figure 9 shows a Locomobil, which is a historical object, displayed at the Timah Museum as an introduction to the shape of cylinders. Questions are also provided to motivate students in understanding spatial geometry material.

The next step in development is to create a book where each page has three-dimensional elements. Each material begins with elements of Bangka Belitung that form the structure of each material and can move. The material contains the characteristics of each geometry and the nets of geometrys that students can form themselves when opening the book. Each page presents brief instructions for students to learn while playing with geometrys.

The book was then validated by two mathematics experts and one mathematics teacher at Al Azhar Elementary School in Pangkalapinang. Validation was given to three assessment categories. The content

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category validation results obtained an average score of 100%, the construct category obtained an average score of 96.59%, while the language category obtained a score of 90.63%. Thus, the overall validation results obtained a score of 94.71% with a category of very valid. The researcher success in creating precise folds that close perfectly is a determining factor in the high validity score of this pop-up book design.

The main challenge in creating this interactive pop-up math book was mechanical synchronization to overcome gutter interference. Precision of the center point of the fold (v-fold) was crucial to avoid the "spring effect" that prevents the book from closing completely. This is complicated by the paper caliper, which requires accurate clearance calculations to ensure the accumulated fold thickness does not exceed the book's hinge capacity. Furthermore, the geometric demands of 90° versus 180° angles require mathematical calculations on the support legs to prevent collisions. Also the complexity of calculating the position of the folds so that the geometric structure opens perfectly when the book is opened. Success in balancing these technical variables has proven to increase the validity score of the design, ensuring that the functionality of the book is in harmony with the visual aesthetics of the book.

The validated pop-up mathbook products have characteristics, materials developed specifically for the introduction of spatial figures accompanied by characteristics and nets of geometric shapes. The second characteristic is that the pop-up mathbook is based on the culture of Bangka Belitung, where each piece of material presented begins with objects typical of Bangka Belitung that have spatial shapes and elements.

The Pop Up Mathbook that has been developed is expected to motivate students to enjoy learning mathematics more. This is in line with research that states that interactive textbooks can help students learn complex concepts more efficiently (Liu et al., 2020; Abidah, Jamaludin, & Sutirna , 2025; Irma et al., 2025; Erawati et al., 2025) and enhance students' creative thinking (Tang et al., 2025; Amanah et al., 2025). Active students are greatly influenced by the teacher's confidence and enjoyment in delivering learning materials (Rahmadhani & Yulia, 2023; Adiwijaya & Palupi, 2024; Purnamasari, 2024; Du et al., 2025).

IV. CONCLUSION

The research has successfully developed a culturally-based bilingual pop-up mathbook for Bangka Belitung with a high validity rate of 94.71%. This result was obtained from assessments given by three validators using questionnaires. The validity of the product was assessed based on content that was in line with the learning objectives for grade 4 geometric shapes, including prisms, cylinders, and spheres. It is also valid based on the assessment of the construct, where the bilingual pop-up mathbook that has been developed is in accordance with the introduction of spatial shapes, characteristics, and spatial nets with various question types and movements on each page. he material and questions are also in line with indicators of students

understanding of mathematical concepts. They are valid in terms of language, which is appropriate for the students' age group, and use both Indonesian and English. This valid textbook can therefore improve the 21st-century mathematical competence of elementary school students.

This research makes a significant contribution in visualizing abstract mathematical concepts into real and manipulative three-dimensional forms. In line with Bruner's theory (Bruner, 1974), by bridging the iconic to enactive cognitive stage, this media has been proven to be able to strengthen students spatial abilities and reduce learning barriers in geometry material through multisensory learning experiences.

This research confirms that physical media innovation remains relevant in the digital era to create interactive and enjoyable learning. This encourages teachers to be more creative in integrating art elements into the curriculum to increase students emotional engagement and memory retention of difficult material.

The researchers also suggest to experimentally test the effectiveness of pop-up books on more complex materials such as geometric transformations. Researchers also suggest the development of hybrid media that integrates physical books with Augmented Reality (AR) technology to dynamically enrich data visualization.

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