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TPACK-Integrated Zoology Vertebrate Booklet: Expert Validation of a Print Media Innovation Supporting Digital Learning

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Abstract

The development of technology in the field of education requires innovation in the development of learning media that are not only print-based but also able to integrate pedagogical and technological aspects. However, many printed learning media are less than optimal in supporting digital learning. Therefore, this study aims to describe the validity value of the TPACK integrated vertebrate zoology booklet as an innovative learning media that supports the integration of technology in biology education. This type of research uses the Plomp development model which consists of three stages, namely preliminary research, prototype making, and assessment. The preliminary research stage has been carried out in previous studies, and in this follow-up study only the prototype making stage was carried out. The assessment stage will be carried out in the next survey. Validation was carried out by three expert validators, namely media experts, material experts, and learning experts. The validation results from media experts, material experts, and learning experts for this learning media are included in the valid and feasible category. In conclusion, the TPACK integrated vertebrate zoology booklet is feasible to use in learning. It is recommended to conduct further research to test the effectiveness and practicality of this TPACK integrated vertebrate zoology booklet in improving various competencies in students.

Keywords: booklet; TPACK; expert validation; zoology vertebrate

INTRODUCTION

Technology development in education has changed how learning is delivered at various levels of education (Parikesit *et al*., 2021). Digitalization in learning is growing rapidly, driving a shift from conventional methods to more innovative and technology-based approaches (Alenezi, 2023). In the current vertebrate zoology course, the available learning media is still dominated by conventional printed teaching materials that do not accommodate the needs of 21st century learning (Eliana *et al*., 2022; Nurfitri *et al*., 2022; Puspitasari *et al.*, 2023). This results in a lack of student involvement in education and limited access to higher quality and interactive learning resources. In fact, the vertebrate zoology course is one of the compulsory courses in the biology education study program, because it provides a deep understanding of the structure, function, and evolution of vertebrate animal groups. Good knowledge of vertebrate zoology is essential for prospective biology educators to teach biology concepts comprehensively to students. Therefore, effective learning media are needed to improve the quality of vertebrate zoology learning in higher education (Zukmadini *et al.*, 2024).

In line with technological developments, the concept of Technological Pedagogical and Content Knowledge (TPACK) has been introduced as an approach that integrates technology, pedagogy, and content in a balanced way in learning (Koh, 2020). This approach allows the development of print-based

learning media and supports access to broader digital resources. However, in the context of biology education, the application of TPACK is still more focused on developing digital media, such as e-learning and web-based applications. In contrast, the integration of this concept in print media that supports digital learning is still limited (Shaha, 2023). Current research trends show that innovation in developing TPACK-based learning media focuses more on digital platforms, such as Learning Management Systems (LMS), interactive videos, and computer-based simulations (Vasodavan, 2020). Previous studies have examined the effectiveness of TPACK-based learning models in improving students' understanding of science concepts and critical thinking skills (Zahroh, 2025). However, there is still a research gap related to the application of TPACK in printed learning media that can be connected to digital resources to improve students' learning experiences.

On the other hand, print media still has advantages in learning, especially in areas with limited access to digital technology (Nyambane, 2021). Textbooks and booklets are still the primary sources for learning vertebrate zoology, but most have not been designed to accommodate TPACK-based learning (Bariroh & Surtikanti, 2024). Therefore, developing TPACK-based booklets is an innovative solution that can overcome the limitations of conventional print media while still supporting access to digital resources. In addition, obstacles in implementing technology-based learning in several regions, such as limited internet access and technological infrastructure, are also challenges in digitalizing education (Timotheou *et al.*, 2023). Therefore, innovative solutions are needed to accommodate technology integration in learning without entirely relying on internet access or expensive digital devices. One potential alternative is the development of a TPACK-based vertebrate zoology booklet, which combines the advantages of print media with digital learning support features, such as QR codes that direct students to additional resources in the form of videos, animations, or scientific articles. (Timotheou *et al*., 2023) States that there are obstacles to implementing technology-based learning in several regions, such as limited internet access and technological infrastructure, which are also challenges in digitalizing education. Therefore, innovative solutions are needed to accommodate technology integration in learning without entirely relying on internet access or expensive digital devices. The vertebrate zoology booklet developed is integrated with TPACK, namely containing videos that have QR codes and technology-based quizzes, has learning steps, contains vertebrate zoology material, and contains knowledge related to verses of the Qur'an and the local potential of Riau Malay culture.

Developing TPACK-based booklets helps improve conceptual understanding and supports 21st-century skills such as digital literacy, collaboration, and technology-based problem-solving (Vasodavan, 2020). Students can access richer learning resources by integrating various multimedia elements through QR codes or interactive links than conventional print media (Atika, 2022). This study aims to describe the validity of the TPACK-based vertebrate zoology booklet as an innovative and relevant learning medium to meet the needs of modern education. This booklet is designed to integrate the TPACK concept in a printed format that still supports access to digital-based learning materials. Thus, it is hoped that this media can be a solution for educational institutions still experiencing obstacles in implementing digital technology entirely, and increasing the effectiveness of vertebrate zoology learning in higher education. In addition to providing solutions to technology-based learning constraints, developing this booklet is also expected to contribute to research in biology education. This innovation can be a model for developing teaching materials in various other fields of science that want to adopt the TPACK approach without completely replacing traditional print media. With this innovation, this research contributes to filling the existing research gap and providing new alternatives for developing TPACK-based learning media. It is hoped that this booklet can be a model that can be adapted to the development of teaching materials in various disciplines, while supporting the transformation of education towards a more inclusive and sustainable digital era.

METHOD

This type of research is research and development. The development of TPACK integrated booklet learning media uses the Plomp development model, which consists of three stages: preliminary research

phase, prototyping phase, and assessment phase (Plomp & Nieveen, 2013). The first stage, namely the preliminary research phase, has been carried out in previous studies-- in this study, it was only carried out up to the prototyping phase due to time constraints. Data collection techniques in this study include self evaluation sheet, it is conducted to analyze the completeness of the TPACK integrated booklet components developed before the validation test is carried out by expert validators. The grid of the self-evaluation sheet can be seen in Table 1 below.

Table 1. Self-evaluation sheet grid

Indicator
Cover
Introductory Part.
Content Section.
Final Part.

Next, a validation sheet for the TPACK integrated vertebrate zoology guidebook was created to determine the feasibility of the product developed in terms of media, materials, and learning. The validation sheet in this study contains statement items to assess the developed learning media. The validation sheet grid for media, materials, and learning experts can be seen in Tables 2, 3, and 4 below.

Table 2. Media expert validation sheet grid

Aspect	Indicator
Appearance	Cover Design.
	Text Readability.
	Standard Booklet.
	Attractiveness.
	Clarity of Image and Video Display.
	Interactive.
	TPACK Integrated Vertebrate Zoology Booklet.

Researcher Modification from (Saputri, 2023)

Table 3. Material expert validation sheet grid

Aspect	Indicator
Eligibility of Content	Systematic Material.
	Depth of Material.
	Suitability of Material to Learning Indicators.
	TPACK Integrated Vertebrate Zoology Booklet.

Researcher Modification from (Saputri, 2023)

Table 4. Learning expert validation sheet grid

Aspect	Indicator
Display Layout	Appearance.
	Clarity of Course Achievement Section.
	Compliance of Course Learning Outcomes with the Course Achievement Section.
	Compliance of the Course Achievement Section with Learning Indicators.
	Systematic and Clear Logical Flow.
Language	Language.
Readability	Readability.
	Easy to Understand.

Researcher Modification from (Saputri, 2023)

Data analysis techniques in this study consist of the following. The research instrument validation sheet was analyzed using the following formula, and the validity value criteria can be seen in Table 5. below:

$$Vins = \frac{TSe}{TSh} x\ 100\%$$

Table 5. Research instrument validation scoring criteria

Intervals	Criteria
85% - 100%	Very Valid
69% - 84%	Valid
53% - 68%	Quite Valid
37% - 52%	Less Valid
20% - 36%	Invalid

(Paramita *et al*., 2019)

RESULT AND DISCUSSION

The results of the Self-Evaluation show that the TPACK-integrated Vertebrate Zoology booklet has a good structure and is based on the principles of developing TPACK-based teaching materials. Several technical and content aspects need to be improved so that the booklet is more optimal in supporting Vertebrate Zoology learning. The results of this evaluation are the basis for improvement before experts enter the validation stage. The validation results of media, material, and learning experts can be seen in Tables 6, 7, and 8 below.

Table 6. Media expert validation results

Aspect	Indicator	Percentage (%)
Appearance	Cover Design.	100
	Text Readability.	100
	Standard Booklet.	100
	Attractiveness.	100
	Clarity of Image and Video Display.	100
	Interactive.	75
	TPACK Integrated Vertebrate Zoology Booklet.	100
Average		96,42

Table 7. Material expert validation results

Aspect	Indicator	Percentage (%)
Eligibility of Content	Systematic Material.	100
	Depth of Material.	100
	Suitability of Material to Learning Indicators.	100
	TPACK Integrated Vertebrate Zoology Booklet.	100
Average		100

Table 8. Learning expert validation results

Aspect	Indicator	Percentage (%)
Display Layout	Appearance.	100
	Clarity of Course Achievement Section.	100
	Compliance of Course Learning Outcomes with the Course Achievement Section.	100%
	Compliance of the Course Achievement Section with Learning Indicators.	100%
	Systematic and Clear Logical Flow.	100%
Language	Language.	75%
Readability	Readability.	100%
	Easy to Understand.	100%
Average		97,22%

The average expert validation results can be seen in Figure 1 below.

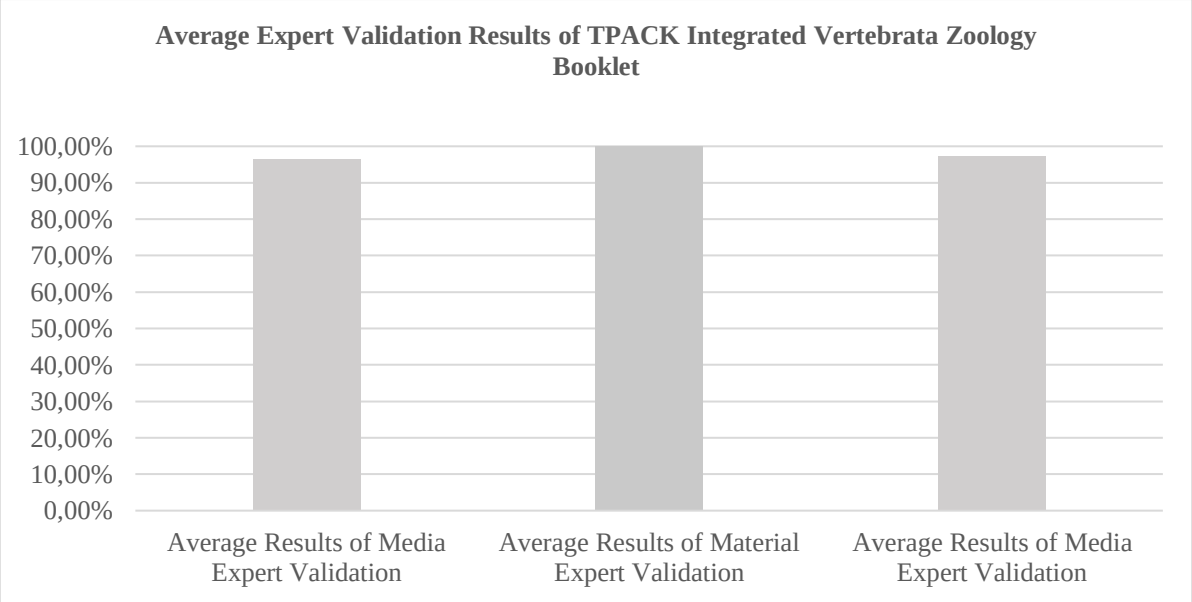

Figure 1. Average expert validation results of TPACK integrated vertebrata zoology booklet

The results of the research at the Self-Evaluation stage in developing the TPACK-integrated Vertebrate Zoology booklet using the Plomp model focused on the initial analysis of the booklet design before experts carried out the validation test. This evaluation includes four leading indicators: cover, introduction, content, and closing. In the cover section, aspects evaluated include visual design, the title's readability, and the illustration's relevance to the booklet's contents. The initial evaluation showed that the cover design was attractive and followed the theme of Vertebrate Zoology. However, some adjustments were needed to increase color contrast to make the title more manageable. In addition, selecting images more representative of the booklet's contents was also considered to increase visual appeal and relevance to the material presented. (Yulia *et al.*, 2021) states that the cover design of the learning media must be attractive and follow the theme of the course, but it is necessary to increase the color contrast so that the

title is more readable. The selection of illustrations is also adjusted to be more representative of the booklet's contents, increasing the visual appeal and relevance of the material.

In the introduction, the evaluation focused on presenting the background, learning objectives, and the structure of the booklet content. The evaluation results showed that the background was transparent enough to explain the importance of learning Vertebrate Zoology and the urgency of TPACK integration in print media. However, there are some notes regarding the formulation of the Course Achievement Section to be more specific and in line with the expected learning indicators. In addition, the systematic presentation of the table of contents needs to be clarified so that users can more easily navigate the material. (Fujianti *et al*., 2024) states that the formulation of the Course Achievement Section needs to be more specific to match the learning indicators. In addition, the systematic table of contents needs to be clarified to improve ease of navigation of the material.

In the content section, the evaluated aspects include content accuracy, completeness of the material, integration with TPACK aspects, and text readability. The evaluation results show that the Vertebrate Zoology material has been systematically arranged and is based on relevant scientific references. TPACK integration in the booklet has also been implemented by including QR codes that connect students to various digital learning resources, such as interactive videos, 3D simulations, and supporting scientific articles. However, some revisions are needed when using technical terms to make them easier for students to understand. In addition, the illustrations and diagrams used in the booklet are suggested to be clarified to support optimal understanding of the concept. (Pratama *et al*., 2024) states that revisions are needed on technical terms to make them easier to understand, and improvements to illustrations and diagrams to improve conceptual understanding.

In the closing section, the evaluation includes the presentation of conclusions and reflections on learning. The evaluation results show that this section has provided a good summary of the material presented and directed students to reflect on the concepts learned. However, additional recommendations are given to include several discussion-starting questions to increase student interaction and involvement in learning. (Putri & Susanto, 2023) states that the conclusion summarizes the material well and encourages reflection on learning. It is recommended that discussion questions be added to increase student interaction and engagement. The results of the Self-Evaluation show that the TPACK-integrated Vertebrate Zoology booklet has a good structure and follows the principles of developing TPACK-based teaching materials. Several technical and content aspects need to be improved so that the booklet is more optimal in supporting Vertebrate Zoology learning. The results of this evaluation are the basis for improvement before experts enter the validation stage of the booklet.

The development of this booklet aims to overcome the limitations of conventional print media by integrating elements of technology, pedagogy, and content to improve learning effectiveness. Through a validation process by media, material, and learning experts, this booklet was evaluated based on design aspects, material accuracy, and its suitability with technology-based learning strategies. The validation results show that this booklet has a very high level of validity, so it can be used as a learning resource that supports a deeper and more interactive understanding of the concept of Vertebrate Zoology. Further discussion will outline the findings of this study and its implications for biology learning in the digital era. The vertebrate zoology booklet integrated with TPACK can be seen below in Figures 2, 3, and 4.

Figure 2. Cover booklet

b. Tetrapoda

Tetrapoda adalah hewan vertebrata yang berkaki empat, kaki atau seperti kaki. Kelas yang termasuk tetrapoda adalah Amphibia, Reptilia, Aves dan Mammalia. Perbedaan keempat kelas tersebut adalah pada ruang jantung menunjukkan perbedaan pada tingkat kesempurnaan organ.

Klasifikasi utama :

1. Amphibi : Hidup di dua habiatat (air dan darat), contohnya katak.
2. Reptil : Bersisik dan bertelur didarat, contohnya ular dan kadal.
3. Aves : Memiliki bulu dan bisa terbang, contohnya burung elang.
4. Mammalia : Berbulu, menyusui anak, contohnya harimau dan paus.

Ciri-ciri Sub Filum Vertebrata :

1. Memiliki otak yang kompleks, relative besar dan dilindungi oleh tulang tempurung kepala (os. Cranium).
2. Memiliki columnna vertebralis (ruas-ruas tulang belakang) sebagai penyokong tubuh.
3. Tubuh dapat dibedakan menjadi bagian Cephal (kepala), Cervix (leher), Trunchus (badan) dan Caudal (ekor).
4. Memiliki rahang : rahang atas (maxilla) dan rahang bawah (mandibular). Kecuali Agnatha, termasuk kelas tidak berahang.
5. Jantung (Cor) berkembang baik, memiliki ruangan : Atrium (serambi) dan Vertcel (bilik).
6. Darah mengandung Heamoglobin (Hb) sebagai respirasi.
7. Memiliki sepasang mata dan sepasang telinga. Mammalia berdaun telinga.
8. Gand terpisah, fertilisasi external atau internal, dan cara reproduksi : Ovivar, Vivivar atau Ovovivipar.
9. Memiliki sepasang atau beberapa pasang extremitas (anggota gerak): extremitas anterior dan posterior.
10. Memiliki jaringan Epithel, ikan, adipose (lemak), Darah, Lymphe, Cartilago, Ostium, Musculus dan Syaraf.

Figure 3. The vertebrate zoology booklet is integrated with TPACK

Integrasi Dakwah Islamiah

Qs. An-Nur (24:45)

وَاللّٰهُ خَلَقَ كُلَّ دَاۤبَّةٍ مِّنْ مَّاۤءٍ ۚفَمِنْهُمْ مَّنْ يَّمْشِيْ عَلٰى بَطْنِهٖ وَمِنْهُمْ مَّنْ يَّمْشِيْ عَلٰى رِجْلَيْنِ وَمِنْهُمْ مَّنْ يَّمْشِيْ عَلٰٓى اَرْبَعٍ ۗيَخْلُقُ اللّٰهُ مَا يَشَاۤءُ ۗاِنَّ اللّٰهَ عَلٰى كُلِّ شَيْءٍ قَدِيْرٌ

Artinya :

"Dan Allah menciptakan semua jenis hewan dari air, maka sebagian dari mereka ada yang berjalan di atas perutnya, sebagian berjalan dengan dua kaki, dan sebagian lagi berjalan dengan empat kaki. Allah menciptakan apa yang Dia kehendaki. Sungguh, Allah Maha Kuasa atas segala sesuatu".

Maknanya :

Dalam ilmu biologi, semua makhluk hidup termasuk filum Chordata berawal dari lingkungan akuatik. Filum Chordata mencakup hewan-hewan yang memiliki notokorda (struktur pendukung tubuh seperti tulang belakang pada manusia dan vertebrata lainnya). Ayat ini menggambarkan asal mula makhluk hidup yang secara biologis dapat dihubungkan dengan teori evolusi awal kehidupan, di mana air dianggap sebagai media pertama munculnya kehidupan.

FUN FACT

POTENSI BUDAYA MELAYU RIAU
Pantun dan Petuah Tradisional

Figure 4. The vertebrate zoology booklet is integrated with TPACK

The results of media expert validation of the TPACK-integrated Vertebrate Zoology booklet showed that the appearance aspect obtained a validation value of 96.42%, which is categorized as very valid. This confirms that the booklet design has met good visual standards and is suitable for use as a learning medium in biology education. Cover design indicator: This booklet has an attractive and

informative visual appearance. The selection of colors, illustrations, and typography has been adjusted to the theme of Vertebrate Zoology, reflecting the material's contents. The booklet cover not only functions as a media identity but also has an appeal that can increase students' interest in studying it further. Previous research shows that an attractive cover design relevant to the material's content can increase students' interest in learning and strengthen the identity of the learning media (Antara *et al.*, 2022).

The text readability indicator shows that the selection of font type, font size, and contrast of background and text colors follows the principles of instructional design. The text in this booklet can be read clearly without causing visual fatigue, ensuring students' comfort while learning. In addition, using scientific but straightforward sentence structures helps students understand the concept of Vertebrate Zoology more effectively. Previous research has shown that selecting the right font, letter size, and color contrast can improve readability and student learning comfort. At the same time, clear sentence structures make it easier to understand scientific concepts (Amelia *et al.*, 2025). The standard booklet indicator's overall design follows the rules for making suitable teaching materials, with a neat layout and a balanced proportion between text and images. The presentation of information is made in a modular format, making it easier for students to understand the material gradually. This is also supported by straightforward navigation, allowing readers to find the information they need more quickly. (Negoro *et al*., 2024) states that a neat layout, balanced proportions of text and images, and a modular format in teaching materials can increase ease of navigation and gradual understanding of the material.

Attractiveness indicator, this booklet gets high appreciation because of the use of harmonious color combinations, relevant illustrations, and an engaging presentation structure. This attractive design can increase students' motivation to study Vertebrate Zoology, making learning more enjoyable and less monotonous. (Novita *et al.*, 2024) states that a harmonious combination of colors, relevant illustrations, and attractive designs can increase students' motivation and make learning more interactive and enjoyable. The clarity indicator of the image and video display shows that all illustrations included in the booklet have high resolution and are presented in colors that match the original objects. Each image is clearly described to help students better understand vertebrates' anatomical and morphological structures. In addition, this booklet also provides access to interactive videos via QR codes so that students can see a visual representation of the material being studied. (Azhar *et al*., 2024) states that high-quality illustrations and interactive videos in teaching materials can improve conceptual understanding and strengthen student engagement in learning. This aligns with research results (Eliana *et al.*, 2022), which states that booklets designed with concise and systematic explanations, pictures, and video illustrations can make it easier for students to understand learning materials.

Although in printed media, this booklet is designed to connect students with various digital learning resources. Technology integration is carried out through links and QR codes that lead to learning videos, 3D simulations, and other reference sources that support conceptual understanding. This approach allows students to explore the material further in a more flexible way and supports independent learning. Research (Aprisha *et al.*, 2024) integrating QR codes into printed learning materials can increase students' access to digital learning resources, enrich the learning experience, and support independent learning more effectively. The TPACK integrated Vertebrate Zoology booklet indicator shows that this booklet has succeeded in combining aspects of technology, pedagogy, and content. The TPACK approach applied in the design of this booklet ensures that the learning media not only presents information textually but also optimizes the use of technology to increase learning effectiveness. With this integration, students can gain a more in-depth, collaborative, and digital-based learning experience, which aligns with the demands of the modern education era.

The expert validation of the TPACK-integrated Vertebrate Zoology booklet showed that the content feasibility aspect obtained a validation value of 100%, which is categorized as very valid. This confirms that the booklet's contents have met the academic and didactic feasibility standards, making them suitable for learning media in biology education. In the systematic material indicator, the presentation of the contents in this booklet is structured and logical, starting from basic concepts to more complex topics. Each chapter is arranged based on a gradual hierarchy of understanding so that students can understand the material sequentially without experiencing confusion. The material in this booklet also follows a

pattern that follows the biology education curriculum, thus supporting effective and efficient learning. Research (Gultom *et al*., 2025) has shown that presenting material systematically and gradually can improve students' conceptual understanding and minimize confusion in learning more complex topics.

The material depth indicator shows that the information presented in the booklet has comprehensively covered the conceptual aspects, principles, and applications of Vertebrate Zoology. The material is descriptive and provides an in-depth understanding of various vertebrate groups' classification, morphology, anatomy, physiology, and adaptation. In addition, this booklet also integrates the latest scientific studies that enrich students' insights into the development of zoology. Previous research shows (Sari *et al.*, 2021) that material presented comprehensively, covering conceptual to application aspects, can increase in-depth understanding and enrich students' insights into the development of science. The indicator of the suitability of the material with the learning indicators, this booklet has been compiled based on the learning outcomes set in the biology education curriculum. Each sub-material is designed to be relevant to the competency indicators students must achieve, ensuring that this booklet supports the learning process based on achievement targets. Presenting case examples, illustrations, and case studies that follow the real world also helps students connect theory with practice. (Febriana, 2021) the material presented comprehensively, covering conceptual to application aspects, can increase in-depth understanding and enrich students' insight into the development of science.

The TPACK integrated booklet indicator shows that the development of the material in this booklet not only considers the content aspect (Content Knowledge) but also applies the principles of pedagogy (Pedagogical Knowledge) and technology integration (Technological Knowledge). This booklet presents information in text form and directs students to explore digital-based learning resources through external links, QR codes, and interactive multimedia. With the integration of TPACK, this booklet supports an adaptive and contextual learning model following technological developments in the digital era. (Hakim & Abidin, 2024) TPACK integration in teaching materials can increase learning effectiveness by connecting aspects of content, pedagogy, and technology, thus creating a more adaptive and contextual learning experience in the digital era. Overall, the validation results by material experts show that the TPACK-integrated Vertebrate Zoology booklet has content that is very suitable for use in biology learning. Systematic presentation of materials, comprehensive depth of content, conformity to learning indicators, and technology integration make this booklet an effective, quality, and relevant learning media innovation to the needs of modern education.

The expert validation of the TPACK-integrated Vertebrate Zoology booklet showed that display layout, language, and readability obtained an average value of 97.22%, which is included in the very valid category. This confirms that the booklet has met the pedagogical standards that support the effectiveness of biology learning regarding presentation structure and ease of student understanding. Regarding display layout, this booklet is considered to have a systematic and informative design. The appearance of the booklet is arranged with an attractive and professional layout, thus providing a comfortable reading experience for students. The clarity of the Course Achievement Section (Course Learning Outcomes) is a primary concern, where each Course Achievement Section is presented explicitly and is easily recognized by students as a guide in understanding the material. In addition, the suitability of Course Learning Outcomes with the Course Achievement Section has been guaranteed, where each topic discussed has relevance to broader learning objectives. (Noviadji & Hendrawan, 2021) a systematic and informative layout of teaching materials can increase reading comfort and help students understand the relationship between learning objectives and the material presented.

The suitability of the Course Achievement Section with the learning indicators has also been well calculated, ensuring that each section in the booklet makes a real contribution to the expected learning outcomes. Finally, a systematic and explicit logical flow allows students to follow the discussion in the booklet sequentially without experiencing confusion in understanding the relationship between concepts. (Fakhriyah *et al*., 2023) Alignment between the Course Achievement Section and learning indicators is important in ensuring that each material contributes to the expected learning outcomes, and a systematic flow helps students understand the relationships between concepts better. In terms of language, this booklet uses language that follows academic rules but remains communicative and easy for students to

understand. Using terms in vertebrate zoology has been adjusted to scientific standards to maintain academic accuracy without reducing readability. In addition, the language style in the booklet has been arranged so that it is not too rigid and remains interesting to read, which can increase students' interest in learning. (Puspita & Susmita, 2024) communicative academic language can improve students' readability and understanding without reducing scientific accuracy, and a language style that is not too rigid can increase interest in learning.

Regarding readability, this booklet received a very good assessment based on readability and ease of understanding indicators. The sentences are not too long and complex, so students can easily digest them. In addition, the paragraph structure in the booklet has been arranged clearly and cohesively, ensuring that each piece of information is conveyed effectively without causing ambiguity. The clarity of the delivery of this material is very important in supporting the understanding of vertebrate zoology concepts, which often require detailed and systematic explanations. (Latifah *et al*., 2020) simple sentence structures and logically structured paragraphs can improve readability and make it easier for students to understand complex scientific concepts. Integrating the TPACK approach in booklet development, this medium functions as a source of independent learning and a link between conventional and digital learning. Integrating technology in the booklet allows students to access materials anytime and anywhere, supporting blended learning, which is increasingly applied in higher education. In addition, pleasing visual appeal and readability can increase student engagement in the learning process, ultimately contributing to a better understanding of concepts and improved learning outcomes. Thus, the TPACK-integrated Vertebrate Zoology booklet can be an innovative model for developing biology learning media that is adaptive to technological developments in the digital era.

CONCLUSION

Based on the results of the study, the TPACK integrated vertebrate zoology booklet has a validation value of 97.88% which is included in the very valid category, so this booklet can improve student understanding and support hybrid learning by integrating technology into print media. In addition, this booklet improves students' digital literacy and becomes a model of innovative biology learning media. More broadly, this study supports the transformation of digital education in Indonesia by providing valid and creative learning resources. It is hoped that biology education graduates will be better prepared to face the challenges of the world of work. The TPACK approach in this booklet can also be adapted to develop learning media in the context of national education, including those based on local wisdom. Thus, this study improves the quality of vertebrate zoology learning and contributes to educational innovation that is more adaptive to technological developments. This research is beneficial for the nation, especially teachers, because it can be a reference for creating more interesting and innovative learning media. In addition, it is useful for further researchers to develop research by testing the practicality and effectiveness of the TPACK integrated vertebrate zoology booklet.

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