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Development of Ethno-STEM Integrated Digital Teaching Material with Augmented Reality to Promote Students' 21st Century Skills

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Abstract: Research into the development of Ethno-STEM integrated digital teaching materials is urgently carried out because of the enormous potential of this approach in holistically improving students' 21st century skills. Ethno-STEM combines local cultural values with STEM concepts, creating a learning context that is relevant to students' everyday lives. The problem with this research is that students' 21st century skills scores are still in the low category, and the application of Information and Communication Technology (ICT) based teaching materials is also still low. The research solution is to develop integrated Ethno-STEM digital teaching materials assisted by Augmented Reality to improve students' 21st century skills. The research method is development research using the Ploomp model. Development research consists of 3 stages, namely the preliminary stage, development stage and assessment stage. The results of the research are that Etno-STEM integrated digital teaching materials have valid and practical criteria for use in physics learning. Ethno-STEM integrated digital teaching materials assisted by augmented reality are valid for aspects of material substance, learning design, visual communication and software utilization. Ethno-STEM integrated teaching materials assisted by Augmented Reality received practicality scores with good criteria in the aspects of useful, easy to use, interesting, clear, cost-effective and ETno-STEM.

Keywords: Augmented reality; Digital teaching materials; Ethno-STEM; practicality; Validity

Introduction

Twenty first century skills are becoming an important focus in education around the world due to rapid changes in technology, economics and social needs. According to the Partnership for 21st Century Skills (P21), these skills include the ability to think critically, creativity, collaboration and communication (Afandi et al., 2019; Hanisyah & Munahefi, 2024). One of the key skills is critical thinking, which involves the ability to analyze information in depth, make decisions based on evidence, and solve complex problems (Dutta et al., 2023; Kurniahtunnisa et al., 2023; Wang et al., 2022). Creativity is also an essential component, encouraging students to think outside the box, develop new ideas, and approach problems in unique and effective ways (Doyan et al., 2020; Kuo et al., 2021). Collaboration, as a third skill, teaches students to work together in teams, appreciate different perspectives, and achieve common goals through effective cooperation (Dillon et al., 2021; Pokimica, 2022). Lastly, effective communication is necessary, allowing students to convey ideas and information clearly and persuasively (Ayep et al., 2022; Ganayem & Zidan, 2018). These 21st century skills form an important foundation for students

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to become adaptive, creative and highly competitive individuals in the global job market.

The 21st century education for students emphasizes the application of essential skills to face modern-day challenges. This approach integrates critical thinking, creativity, collaboration, and communication in learning (Tang et al., 2020). Critical thinking is taught through methods that encourage students to analyze information, evaluate multiple perspectives, and solve problems systematically (Alsaleh, 2020). Creativity is developed by providing space for students to explore new ideas, innovate, and find unconventional solutions (Henriksen et al., 2021). Collaboration is facilitated through group projects, discussions, and activities that require teamwork (Igbinenikaro et al., 2024). Communication skills, both oral and written, are honed through presentations, debates, and assignments that require students to convey their thoughts clearly and persuasively (Sharma & Mishra, 2023). Thus, 21st century education aims to create a dynamic and relevant learning environment, which prepares students for a productive and meaningful life in the future.

Information and Communication Technology (ICT) plays a crucial role in 21st century learning, presenting various opportunities to improve the quality of education and prepare students to face the challenges of the future. ICT enables unlimited access to diverse information and learning resources, which enriches students' learning experience (Baabdullah et al., 2022). By using technological devices such as computers, tablets and the internet, students can access interactive learning materials, educational videos and e-learning platforms which make the learning process more interesting and effective.

The main problem in this research is that students' 21st century skills scores are still in the low category, and the application of Information and Communication Technology (ICT) based teaching materials is also still relatively low. In initial research, it was found that students' 21st century skills scores were in the low category. Learning physics certainly demands high levels of students' 21st century skills (Fricticarani et al., 2023). Students are expected to master critical thinking skills, creative skills and communication skills (Hardianti et al., 2022). Obtained for critical thinking skills worth 50 is in the low category. Creative thinking skills were obtained with a score of 49 in the low category. And communication skills obtained a value of 46 in the low category. Previous research has shown that a lack of effective integration of ICT in learning can affect the development of important skills such as critical thinking, creativity, collaboration, and communication.

Students' 21st century skills are low due to learning that is not in accordance with learning planning. Low student skills are caused by conventional teaching methods that do not provide sufficient space for the development of these skills (Lavi et al., 2021). Apart from that, the implementation of ICT-based teaching materials in schools is still minimal (Nuryani et al., 2022). This is caused by several factors, including a lack of adequate technological infrastructure, limited teacher skills in using technology, and a lack of relevant and quality digital resources (Charles et al., 2023; Sundari, 2024). Students who engage in ICT-based learning tend to have better 21st century skills compared to students who learn through traditional methods (Risnawati et al., 2023). However, this implementation is still hampered by limited access to technological tools and lack of institutional support.

It is important to develop digital teaching materials that are effective and accessible to all students to improve 21st century skills. This research aims to answer these challenges and find solutions that can be applied to improve the quality of education in the digital era. The solution provided by researchers is to develop integrated Ethno-STEM digital teaching materials assisted by Augmented Reality to improve students' 21st century skills.

The development of digital teaching materials to improve students' 21st century skills has become one of the top priorities in modern education. The development of digital teaching materials that are integrated with Augmented Reality (AR) technology has become a trend in education to improve the quality of learning (Suryanti et al., 2020; Virijai & Asrizal, 2023). The quality of learning can be seen from the development of students' skills in facing the challenges of the 21st century (Mutohhari et al., 2021). In studying physics, students are expected to be able to apply 21st century skills, especially in fluids. In the context of fluid material, the use of AR can help students understand fluid concepts better and be more interactive.

Digital teaching materials are an important innovation in education that offers solutions to improve students' 21st century skills. The integration of technology in teaching materials allows the learning process to be more interactive and interesting, facilitating skills development (Alenezi, 2020; Wekerle et al., 2022). The use of digital teaching materials such as learning videos, interactive simulations, and e-learning platforms can help students understand concepts more deeply and practically (Sinaga & Setiawan, 2022). Research shows that students who are exposed to digital teaching materials tend to perform better in 21st century skills compared to those who learn through conventional methods (Risnawati et al., 2023). In addition, digital teaching materials enable more flexible learning, where students can access materials anytime and anywhere, according to their individual learning pace.

Ethno-STEM is an innovative approach to education that combines the principles of science, technology, engineering, and mathematics (STEM) with local cultural values and knowledge. This approach aims to make STEM learning more relevant and contextual for students by integrating traditional knowledge and practices in a modern curriculum (Azis, 2021; Mahmud, 2021). Ethno-STEM recognizes that each culture has unique ways of understanding and solving problems that can be linked to STEM concepts. For example, the use of traditional methods in agriculture or architecture can be explained through the scientific and technical principles taught in STEM (Asrizal, 2023; Velychko et al., 2022). Research shows that this approach not only increases students' interest and engagement in STEM learning but also strengthens their cultural identity and respect for local heritage (Sumarni et al., 2020). By connecting STEM lessons to cultural contexts close to students' everyday lives, Ethno-STEM helps students see the immediate relevance of what they are learning and increases motivation and conceptual understanding. Therefore, Ethno-STEM offers education that can produce deeper and more sustainable learning, as well as preparing students to become problem solvers who are innovative and sensitive to cultural contexts.

Development of fluid digital teaching materials developed using interactive and multimedia technology. Ethno-STEM integrated fluid digital teaching materials with the help of Augmented Reality contain implications for students' 21st century skills. The aim of this research is to develop integrated Etno-STEM digital teaching materials assisted by Augmented Reality with valid and practical criteria for use in physics learning. Thus, it is hoped that this research can contribute to the development of digital teaching materials that are more effective and efficient in improving student skills.

Method

This research uses a development type research method. The development model used is the Ploomp development model. The Plomp model consists of 3 stages, namely: preliminary research; development or prototyping phase; and assessment phase (Plomp, 2013). The preliminary research stage is the stage of conducting needs analysis and reviewing literature. The next stage, namely the development or prototyping phase, is the stage of designing solutions to solve problems proposed by preliminary researchers, which consists of a portotype and formative evaluation and prototype revision. The final stage is the assessment phase, namely the stage of being tested and evaluated in learning practice.

The population in this research is class XI high school students in the odd semester of the 2023-2024 academic year. The instruments used in the research at the preliminary stage were learning problem analysis questionnaires, analysis of student characteristics and analysis of learning objectives. Instruments in the development stage are validity test sheets and practicality test sheets. The validation test was carried out by experts from 3 UNP physics lecturers. The data analysis technique in this research uses the Aiken's V formula. Then proceed with determining the practicality value. Practicality tests are carried out by students and teachers.

The final value data from the validity results is obtained using the formula (Aiken, 1985).

$$V = \frac{\Sigma s}{n(c-1)} \quad (1)$$

Based on the validity test equation, the valid parameter values of a product can be stated. The parameters used start from a score of one which is symbolized by L0, while the highest value that the validator can give is 5, symbolized by c. For the value given, the validator has variations from 1 to 5, symbolized by r. and the difference between the value given by the validator and the lowest value is symbolized by S. The validity of a product can describe whether the value given states whether the teaching material product is valid or not. The higher the product validity value, the more valid the teaching material product being developed. The number of validators also affects the validity value of a product. The more validators assess and provide suggestions for a teaching material product, the better the teaching material.

The assessment criteria for product validation results can be seen in Table 1.

Table 1. Interpretation of Product Validity (Aiken, 1985)

Interval Criteria Criteria	Interval Criteria Criteria
< 0.80 Valid	< 0.80 Valid
> 0.80 Invalid	> 0.80 Invalid

The formula used to see product practicality is as follows.

$$P = \frac{f}{N} x\ 100 \quad (2)$$

Table 2. Interpretation of Product Practicality

Interval Criteria Criteria	Interval Criteria Criteria
Very Good 81 – 100	Very Good 81 – 100
Good 61 – 80	Good 61 – 80
Just 41 – 60	Just 41 – 60
Less 21 – 40	Less 21 – 40
Very Less < 21	Very Less < 21

Practicality assessment uses the equation above with the symbols P, f, N. The symbol P states the final value of the practicality of the teaching material product. The symbol f states the value given by practitioners to teaching material products to express the product's practicality criteria. The symbol N represents the maximum number of marks that may be given by practitioners who use digital teaching materials. The practicality test of a teaching material product is used to see the practical criteria for using digital teaching materials in learning. Criteria for assessing product practicality results can be seen in Table 2.

Result and Discussion

Preliminary analysis in research is to determine initial research information. Initial research obtained the value of problems using teaching materials, analysis of student characteristics and analysis of learning objectives (Alenezi, 2020). Preliminary analysis was carried out to analyze learning problems and analyze student characteristics (Septiani et al., 2020). Preliminary analysis was carried out as a guide in determining the next steps in the research.

Analysis of learning problems was obtained through questionnaires distributed to students. The learning problems questionnaire has several components, namely problems applying physics teaching materials, problems applying STEM and problems applying Ethnoscience to teaching materials (Hoerunnisa et al., 2024). The problem score for applying digital teaching materials was 74 in the sufficient category. The problem of applying STEM to teaching materials is 68 in the sufficient category. The problem of applying Ethnoscience to teaching materials is 67 in the sufficient category. Based on the analysis value of physics learning problems, it was found that the average was in the sufficient category. This states that there are problems in the use of teaching materials in physics learning.

Analysis of student characteristics was obtained through distributing questionnaires to students. The components of the questionnaire are learning interest, learning motivation, learning attitudes and learning styles (Estari, 2020). Application of each component of student characteristics in physics learning. This resulted in scores for each component of learning interest, learning motivation, learning attitude and learning style with scores of 62, 63, 63 and 66 in the sufficient category. Judging from the average, the overall components of student characteristics are in the sufficient category.

Based on the results of the preliminary analysis, one learning resource that can be developed is Etno-STEM integrated fluid digital teaching materials. The aim of developing digital teaching materials is to improve students' 21st century skills. The teaching materials developed adapt the structure of the teaching materials, namely consisting of cover, learning objectives, materials, exercises, ethno-STEM activities, student worksheets and evaluation (Win & Wulandari, 2023). The teaching materials developed can be displayed as follows.

Figure 1. Cover of teaching materials

The cover of the teaching materials was created to be as attractive as possible by containing the colors blue and yellow. The cover of teaching materials contains the title of the teaching materials, teaching materials, characteristics of the teaching materials, class and name of the author. The cover contains images of people swimming for static fluid material and the flow of water in rice fields for dynamic fluid.

Physics digital teaching materials contain instructions for using ethno-STEM integrated digital fluid teaching materials for students' 21st century learning. Learning Objectives (TP) are derived from Learning Outcomes (CP), and indicators are derived from Learning Objectives (CP). The teaching materials created consist of two CP material for high school class XI semester 1 regarding static fluids and dynamic fluids.

The learning material presented in digital teaching materials begins with a context that is close to students' lives, ethnoscience, and the material is accompanied by images, animations and videos to support students' understanding of the material. The student worksheet contains the integration of Ethno-STEM and students' 21st century skills. Furthermore, in the teaching materials there is an ethno-STEM worksheet as follows.

The ethno-Stem worksheet is separated from the student virtual worksheet. On the ethno-STEM worksheet there are indicators of students' 21st century skills, namely critical and creative thinking skills. This Etno-STEM integrated physics digital teaching material was developed based on teaching material components by Andi Prastowo. This teaching material is digital-based and can be displayed using a cellphone. Teaching materials are accessed via links distributed to all students. Then students click and a display of fluid digital teaching materials appears on their smartphone.

Fluid digital teaching materials contain Ethno-STEM integration in teaching materials, student worksheets and evaluations. Fluid teaching materials contain indicators of critical thinking skills and creative thinking skills in the teaching materials section, student worksheets. Communication skills are included on student worksheets and in student reports. Fluid digital teaching materials were developed using Microsoft Word and converted into PDF. Next, the pdf of fluid digital teaching materials will be entered into the professional flip pdf application. Fluid digital teaching materials can be presented in the form of links after being published online using the flip psf professional application. At the development stage, revisions are carried out to produce teaching materials that are suitable for use in physics learning.

Next, the development of teaching materials is carried out by validity and practicality tests. The validity test contains components of material substance, visual communication display, learning design, use of software, and Etno-STEM assessment (Reffiane & Saptono, 2021). Practicality tests were carried out by teachers and students using fluid digital teaching materials.

At the validation stage, the digital fluid teaching material product was carried out by 3 validators by physics lecturers at FMIPA UNP. At the validity test stage, several suggestions and comments were obtained by the validator. Revision suggestions for digital teaching materials can be shown in table 3 as follows.

Table 3. Suggestions and Revisions to Digital Teaching Materials

Suggestions	Revision
It is recommended that every image and video displayed consistently be captioned. The information is accompanied by a number and it would be better if a reference source was added. Likewise, the formula or formulas used.	Improvements were made to images and videos in the materials
It would be better to add a problem which brings out the skills of the century 21 students.	Improvements were made to the teaching materials on issues that were able to improve students' 21st century skills consisting of critical, creative, and thinking skills communication.
Application of ethnoscience principles in Learning is about studying traditional knowledge from a particular ethnicity or culture using modern scientific methods.	The integration of ethnoscience is included in the teaching materials and on student worksheets by adapting the material to the teaching materials.

Based on the validation results above, improvements can be made according to the validator's suggestions. This aims to ensure that fluid digital teaching materials are valid for use in learning. At the validity test stage, improvements are made in such a way that a validation value is obtained by the validator. Improvements to teaching materials are made so that teaching materials can contain valid learning resources for use in learning. The results of the validation of teaching materials by experts are shown in Table 4.

Table 4. Validation Results by Validator

Aspects	Validity Values	Criteria
material substance	0.85	Valid
learning design	0.83	Valid
visual communication	0.90	Valid
Utilization of software	0.88	Valid
Ethno-STEM	0.82	Valid

Based on the data in table 4, it can be stated that the four aspects of validation with an Aiken's V value ≥ 0.6 are within the valid criteria. The average of the four aspects of validation by experts is 0.85 which is within the valid criteria. So it can be stated that Etno-STEM integrated digital fluid teaching materials are valid for use in physics learning. Teaching materials can be said to be valid so they can be used in learning (Annisa & Asrizal, 2022). Etno-STEM integrated fluid digital teaching materials can be used in physics learning.

Next, a practicality test of digital teaching materials was carried out. Practicality tests are carried out by students and teachers. This states that teaching materials can be useful in learning physics by students and teachers. Practicality tests were carried out for useful components, easy to use, attractiveness, clarity, cost-effectiveness and Ethno-STEM (Efendi et al., 2022). The results of the first practicality test were assessed by several students who used digital teaching materials known for their practicality one by one.

Etno-STEM integrated physics digital teaching materials were given to class XI students of SMAN 12 Padang with high, medium and low abilities. Students are asked to open digital physics teaching materials without being taught first. Practicality indicators consist of useful (UF), easy to use (EU), attractiveness (AT), clarity (CJ), cost-effective (CE), and Ethno-STEM (ES) (Asrizal et al., 2023; Nazifah & Asrizal, 2022). Researchers gave practicality instruments for digital teaching materials to three students. The practical results at stage one by one can be stated in Figure 2.

The results of one by one practicality were obtained from several students. The value of each indicator is the practicality of the useful indicator, namely 96, including very good, the practicality of the easy to use indicator, namely 85, including the very good category. Practicality on the attractiveness indicator, namely 86, is in the very good category, practicality on the clarity indicator, namely 84, is in the very good category. Practicality in the cost-effective indicator, namely 82, is in the good category and ethno-STEM, namely 93, is in the very good category. The overall average value of the practicality results of small group responses is 88 in the very good category. The results of the questionnaire stated that the Etno-STEM integrated digital fluid teaching materials developed were very good. Furthermore, the results of practicality tests in small groups will continue to gain practical value from digital teaching materials.

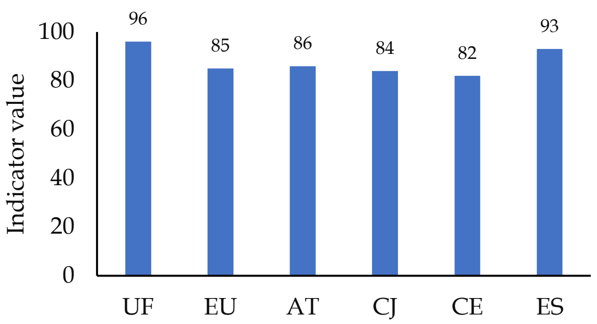

Figure 2. Practicality one by one

Small group evaluations are carried out after one-on-one evaluations are carried out. Small group evaluation by practicing valid digital physics teaching materials with 7 students. The results of the small group practicality test can be expressed in Figure 3.

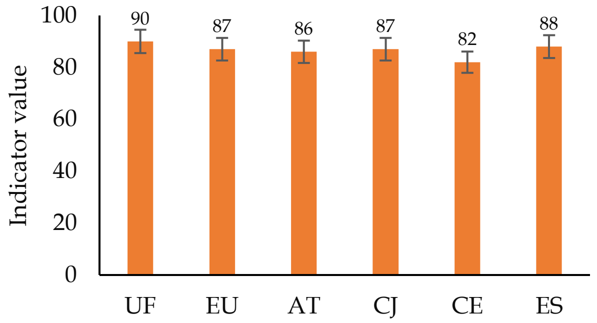

Figure 3. Small group practicality

The questionnaire instrument was developed in accordance with indicators of the practicality of digital teaching materials which include, useful, easy to use, attractiveness, clarity, cost-effective, and Ethno-STEM (Asrizal et al., 2023; Fauziah & Asrizal, 2023). The practicality of the useful indicator is 90, which is very good, easy to use, namely 87, which is in the very good category. Practicality in the attractiveness indicator is 86, which is in the very good category, clarity, which is 87, is in the very good category. Practicality in the cost-effective indicator, namely 82, is in the good category and ethno-STEM, namely 88, is in the very good category. The overall average value of the practicality results of the small group responses was 87 in the very good category. The results of the questionnaire stated that the Etno-STEM integrated digital fluid teaching materials developed were very practical. The results of practicality tests by students can be displayed in table 5 as follows.

Table 5. Practicality of Teaching Materials by Students

Components	Values	Criteria
Useful	84	Good
Easy to use	84	Good
Attractiveness	84	Good
Clarity	85	Very good
Cost effective	87	Very good
Ethno-STEM	87	Very good

Based on Table 5, it can be stated that the use of digital fluid teaching materials is practical for students in learning physics. This is proven by each practicality component value which has good and very good criteria. In this way, overall, the use of digital fluid teaching materials is practically used in physics learning. Digital teaching materials have good practical value so they can be used in learning (Mardian et al., 2022). Etno-STEM integrated digital teaching materials can be used in physics learning.

Furthermore, the practicality test of digital teaching materials was carried out by 2 physics teachers. The results of the practicality test by two teachers can be shown in table 6.

Table 6. Practicality of Teaching Materials by Teachers

Components	Values	Criteria
Useful	86	Good
Easy to use	92	Good
Attractiveness	88	Good
Clarity	92	Very good
Cost effective	88	Very good
Ethno-STEM	90	Very good

Based on Table 6, it can be stated that the practicality test by two teachers was in very good criteria. The results of the teacher practicality test showed an average score of 89, which is in very good criteria. So it can be stated that the use of digital fluid teaching materials by teachers can have practical value in physics learning. Teachers can use digital teaching materials well in physics learning.

In developing digital physics teaching materials, validity and practicality tests have been carried out. In the validity test assessment, digital fluid teaching materials are valid so they can be used in learning. At the practicality testing stage, digital teaching materials were categorized as good for use in learning. So that Etno-STEM integrated digital teaching materials can be used in physics learning.

Research into the development of integrated ethno-STEM digital teaching materials assisted by augmented reality (AR) aims to create teaching materials that are not only interesting and interactive, but also relevant to the local cultural context and able to increase understanding of physics concepts. The ethno-STEM approach integrates science, technology, engineering and mathematics with local cultural elements, which is expected to make learning more contextual and meaningful for students.

The research results show that the digital teaching materials developed have high validity and are practical for use in physics learning. This validity was tested through various stages, including validation by material experts, media experts, and trials on students. Research by Abdinejad et al. (2021) emphasized that AR-based teaching materials can increase students' conceptual understanding and learning motivation, especially in materials that require complex visualization. In addition, research by Guan et al. (2022) found that the integration of AR technology in physics learning helped students understand abstract concepts through three-dimensional visualization and direct interaction with virtual objects.

This digital teaching material is considered practical. The practicality of this teaching material was tested through limited field trials in two classes with static fluid and dynamic fluid material. The use of AR allows students to view and manipulate simulations of physical phenomena that are difficult to understand if only explained textually or in two dimensions. AR-based teaching materials increase student involvement and participation in learning, which in turn improves learning outcomes (Reza, 2023). The ethno-STEM approach in teaching materials can improve students' critical thinking and problem solving skills (Karamustafaoglu & Pektas, 2023). The findings of this research confirm that AR-assisted ethno-STEM integrated digital teaching materials are valid and practical to use in physics learning. In this study, students showed a significant increase in understanding concepts after using these teaching materials, compared to using conventional teaching materials.

However, this study also has several limitations. Trials were only carried out in two classes and were limited to two materials, namely static fluids and dynamic fluids. This limitation indicates that the research findings may not be generalizable to all physics materials or other learning contexts. Further research is needed to test the effectiveness of this teaching material on various other physics materials and at various levels of education. Research by Vidak et al. (2022) suggest the need for further research to explore the use of AR-based digital teaching materials in other materials in the physics curriculum.

Overall, despite its limitations, this research makes an important contribution to the development of innovative and contextual digital teaching materials, which are able to improve the quality of physics learning. The implementation of ethno-STEM and AR technology in digital teaching materials offers a potential new approach in science education, especially physics, and encourages further development in the field of physics education and learning.

Conclusion

Based on the research results, it was found that Etno-STEM integrated fluid digital teaching materials were rated as valid by 3 validators. Fluid digital teaching materials are valid for each component of the validity test. Etno-STEM integrated digital fluid teaching materials are practically used in physics learning. Fluid digital teaching materials are of good value for each component of the practicality test. So that Etno-STEM integrated fluid digital teaching materials can be used in physics learning.

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Author Contributions
The author's contributions include Asrizal: focus on methodology, and review of writing; Aprina Maharani ZAN: collecting data, analyzing data, writing original drafts.

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Conflicts of Interest
The authors declare that there is no conflict of interest not only in conducting research but also in scientific publication.

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