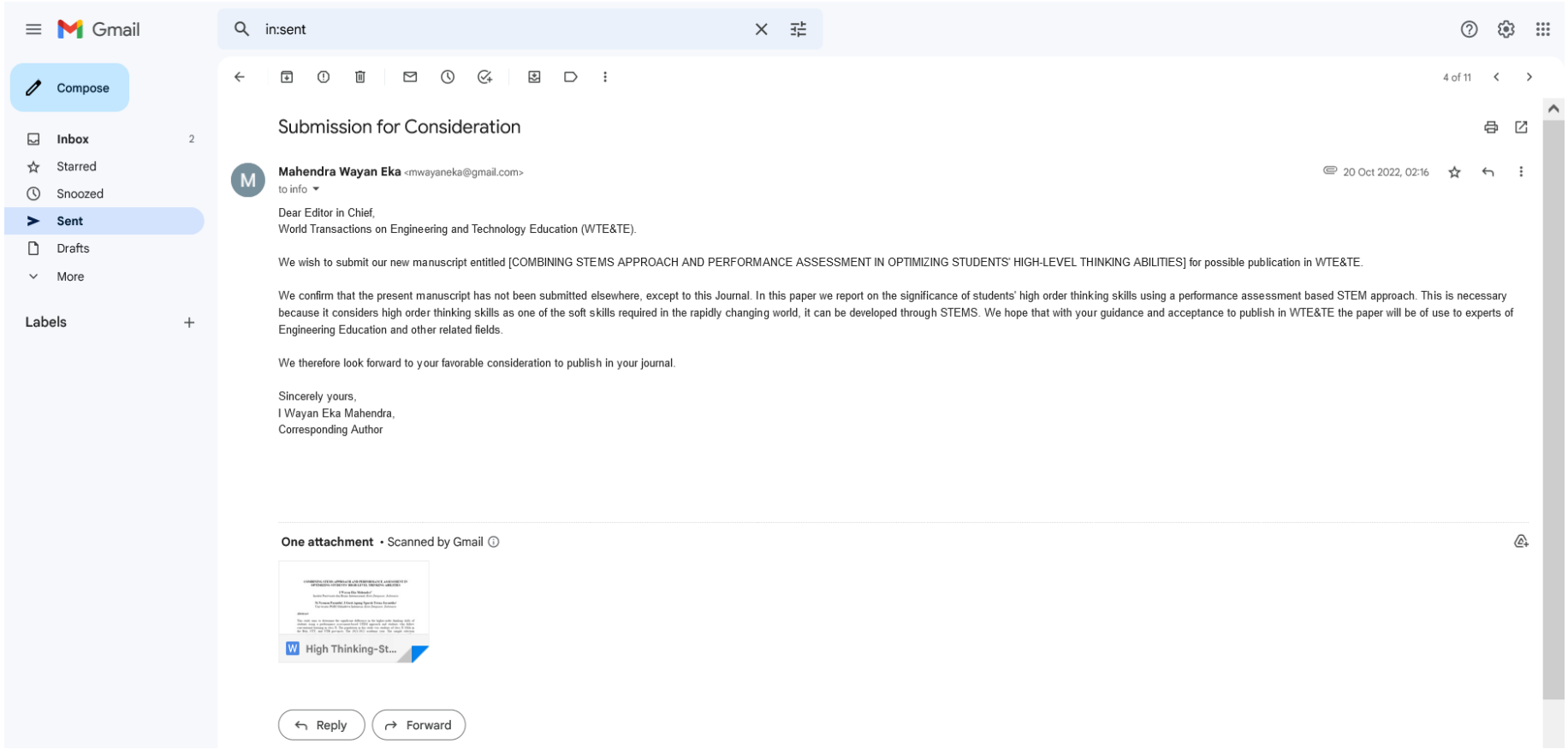
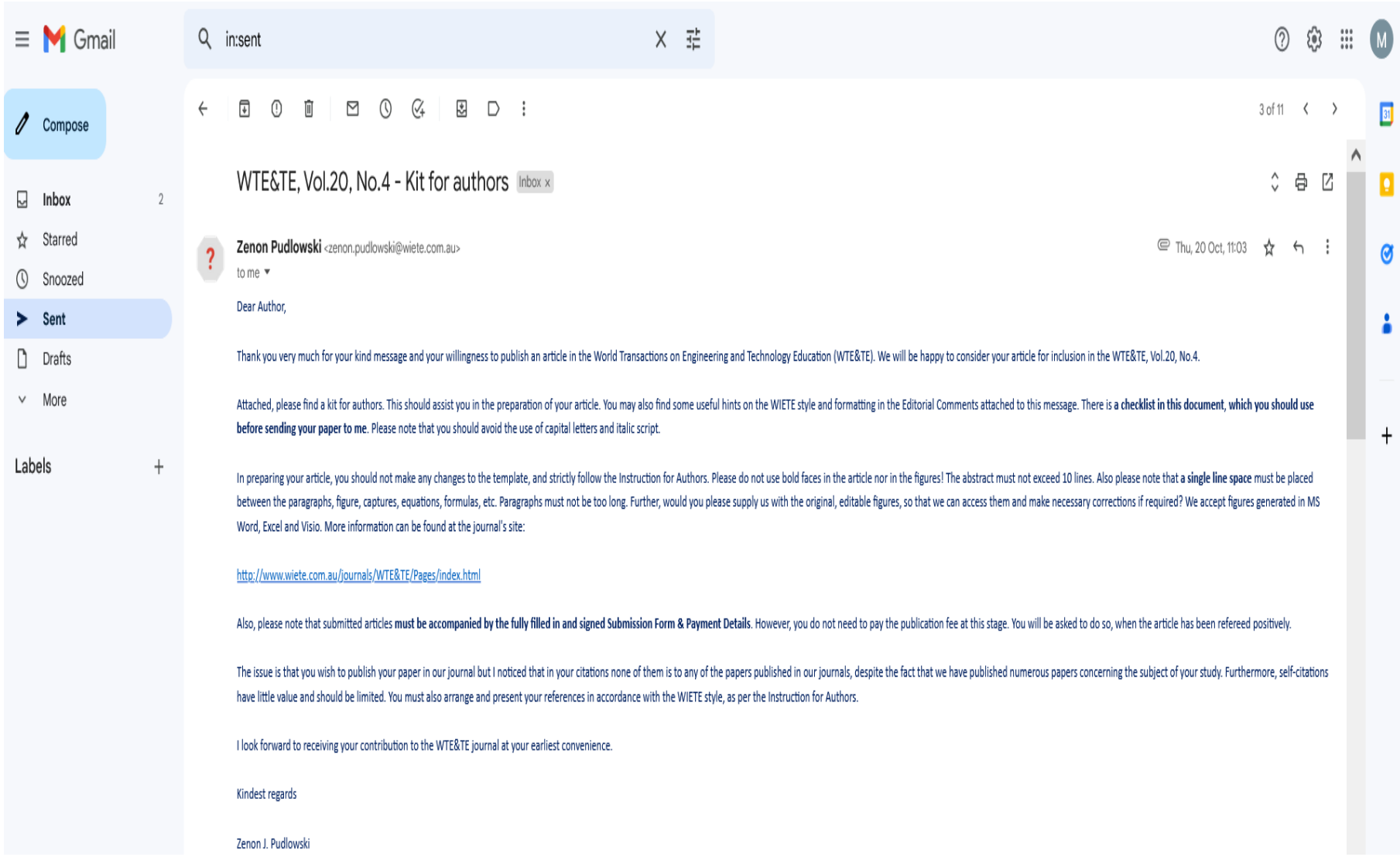
Correspondence
for the Article Published in
World Transactions on Engineering and Technology Education (WTE&TE).

by

I Wayan Eka Mahendra[1]*, Ni Nyoman Parmithi[2], I Gusti Agung Ngurah Trisna Jayantika[3]

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WTE&TE, Vol.20, No.4 - Kit for authors
Inbox x
Zenon Pudlowski <zenon.pudlowski@wiete.com.au>
to me
Thu, 20 Oct, 11:03
Dear Author,
Thank you very much for your kind message and your willingness to publish an article in the World Transactions on Engineering and Technology Education (WTE&TE). We will be happy to consider your article for inclusion in the WTE&TE, Vol.20, No.4.
Attached, please find a kit for authors. This should assist you in the preparation of your article. You may also find some useful hints on the WIETE style and formatting in the Editorial Comments attached to this message. There is a checklist in this document, which you should use before sending your paper to me. Please note that you should avoid the use of capital letters and italic script.
In preparing your article, you should not make any changes to the template, and strictly follow the Instruction for Authors. Please do not use bold faces in the article nor in the figures! The abstract must not exceed 10 lines. Also please note that a single line space must be placed between the paragraphs, figure, captures, equations, formulas, etc. Paragraphs must not be too long. Further, would you please supply us with the original, editable figures, so that we can access them and make necessary corrections if required? We accept figures generated in MS Word, Excel and Visio. More information can be found at the journal's site:
http://www.wiete.com.au/journals/WTE&TE/Pages/index.html
Also, please note that submitted articles must be accompanied by the fully filled in and signed Submission Form & Payment Details. However, you do not need to pay the publication fee at this stage. You will be asked to do so, when the article has been refereed positively.
The issue is that you wish to publish your paper in our journal but I noticed that in your citations none of them is to any of the papers published in our journals, despite the fact that we have published numerous papers concerning the subject of your study. Furthermore, self-citations have little value and should be limited. You must also arrange and present your references in accordance with the WIETE style, as per the Instruction for Authors.
I look forward to receiving your contribution to the WTE&TE journal at your earliest convenience.
Kindest regards
Zenon J. Pudlowski

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3 of 11

Mahendra Wayan Eka <mwayaneka@gmail.com>

to Zenon

Thu, 3 Nov, 02:57

Dear Editor in chief,
World Transaction on Engineering and Technology Education,

I write to submit the signed submission and payment form plus the transfer slip together with the formatted manuscript as advised in the editorial comments. I look forward to your further advice.

Kind regards,
I Wayan Eka Mahendra,
Lecturer and Director,
Institute for Research and Community Services,
Institut Pariwisata Dan Bisnis Internasional, Bali, Indonesia

4 Attachments • Scanned by Gmail

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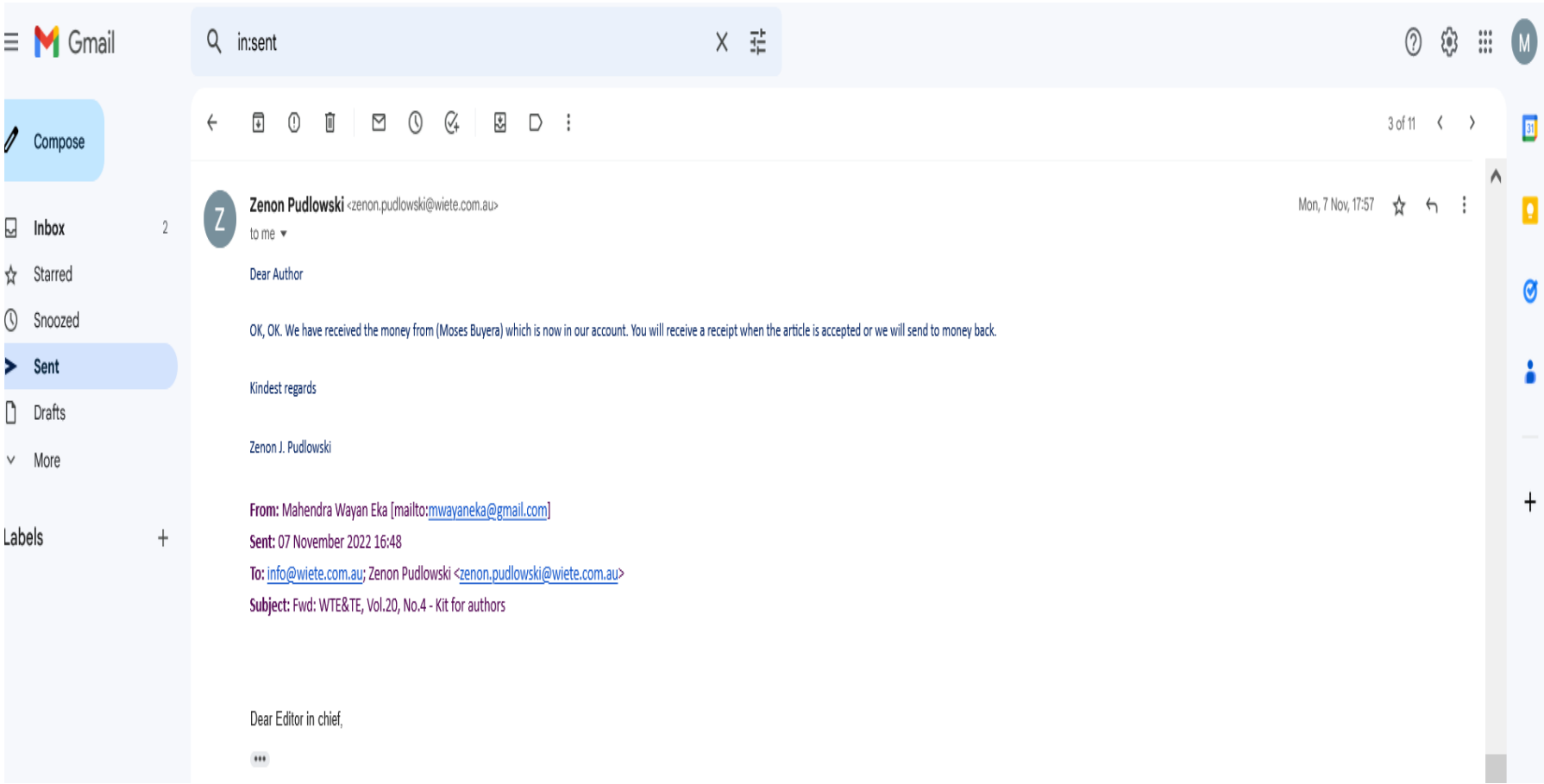
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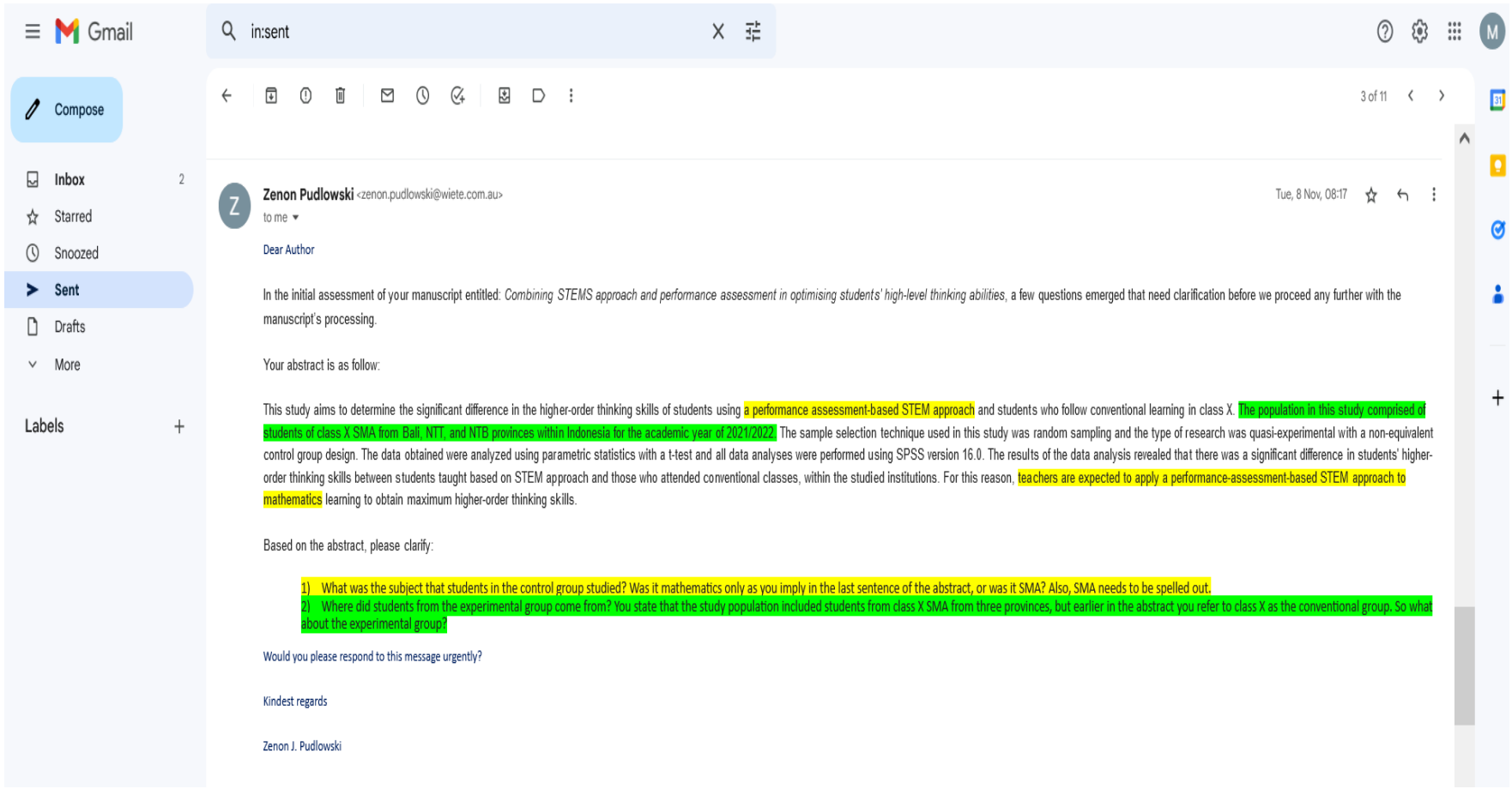
3 of 11
Zenon Pudlowski <zenon.pudlowski@wiete.com.au>
to me
Mon, 7 Nov, 17:57
Dear Author
OK, OK. We have received the money from (Moses Buyera) which is now in our account. You will receive a receipt when the article is accepted or we will send to money back.
Kindest regards
Zenon J. Pudlowski
From: Mahendra Wayan Eka [mailto:mwayaneka@gmail.com]
Sent: 07 November 2022 16:48
To: info@wiete.com.au; Zenon Pudlowski <zenon.pudlowski@wiete.com.au>
Subject: Fwd: WTE&TE, Vol.20, No.4 - Kit for authors
Dear Editor in chief,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3 of 11
Zenon Pudlowski <zenon.pudlowski@wiete.com.au>
to me
Tue, 8 Nov, 08:17
Dear Author
In the initial assessment of your manuscript entitled: Combining STEMS approach and performance assessment in optimising students' high-level thinking abilities, a few questions emerged that need clarification before we proceed any further with the manuscript's processing.
Your abstract is as follow:
This study aims to determine the significant difference in the higher-order thinking skills of students using a performance assessment-based STEM approach and students who follow conventional learning in class X. The population in this study comprised of students of class X SMA from Bali, NTT, and NTB provinces within Indonesia for the academic year of 2021/2022. The sample selection technique used in this study was random sampling and the type of research was quasi-experimental with a non-equivalent control group design. The data obtained were analyzed using parametric statistics with a t-test and all data analyses were performed using SPSS version 16.0. The results of the data analysis revealed that there was a significant difference in students' higher-order thinking skills between students taught based on STEM approach and those who attended conventional classes, within the studied institutions. For this reason, teachers are expected to apply a performance-assessment-based STEM approach to mathematics learning to obtain maximum higher-order thinking skills.
Based on the abstract, please clarify:
1) What was the subject that students in the control group studied? Was it mathematics only as you imply in the last sentence of the abstract, or was it SMA? Also, SMA needs to be spelled out.
2) Where did students from the experimental group come from? You state that the study population included students from class X SMA from three provinces, but earlier in the abstract you refer to class X as the conventional group. So what about the experimental group?
Would you please respond to this message urgently?
Kindest regards
Zenon J. Pudlowski

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M **Mahendra Wayan Eka** <mwayaneka@gmail.com> Tue, 8 Nov, 11:40

to Zenon ▾

Dear Prof. Zenon,

Thank you for the response and the communication regarding our manuscript.

Sincerely,
I Wayan Eka Mahendra

•••

Mahendra Wayan Eka <mwayaneka@gmail.com>
to Zenon

Tue, 8 Nov, 21:27

Dear Prof. Zenon,
Editor in chief,

I write to submit revised abstract, based on the advice provide in the previous email.

Sincerely yours,
Eka Mahendra

On Tue, 8 Nov 2022 at 12:18, Zenon Pudlowski <zenon.pudlowski@wiete.com.au> wrote:

> **From:** Zenon Pudlowski [mailto:zenon.pudlowski@wiete.com.au]
> **Sent:** 08 November 2022 12:17
> **To:** 'Mahendra Wayan Eka' <mwayaneka@gmail.com>
> •••

One attachment • Scanned by Gmail

Revised abstract...

Z

Zenon Pudlowski <zenon.pudlowski@wiete.com.au>

Wed, 9 Nov, 04:48

to me

Dear Author

Your abstract MUST not exceed 10 lines!

Hence, you have to cut it back and the resubmit.

Regards

•••

Mahendra Wayan Eka <mwayaneka@gmail.com>
to Zenon

Wed, 9 Nov, 09:49

Dear Editor in chief,

Allow me to attach a revised abstract reducing the wordings. Thank you for the review advice.

Sincerely yours,
I Wayan Eka Mahendra,
IPB Bali

•••

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Revised abstract...

Zenon Pudlowski <zenon.pudlowski@wiete.com.au>
to me

14 Nov 2022, 09:37

Dear Ms Mahendra

Your article is in the process of editing, including language corrections. However, we have five questions regarding some parts of the article, and hence have placed references to those questions in the relevant part of the article. The questions are highlighted in red, and the part in question is highlighted in yellow. The below questions are also included in the article:

Q1: Reference needed! - who has undertaken this study? The authors of this article?
Q2: Is any text starting at this point and to the end of the article a direct quotation? For direct quotations please use italic and acknowledge authorship with appropriate references!
Q3: Reference needed! Is this David Douglas High School (Oregon, US) test for mathematics?
Q4: Is this correct? Is conventional assessment based on real-life situations, is it based on application/analysis/synthesis? Authors to check!
Q5: Is this a direct quotation? The phrase *various academic concepts juxtaposed with the real world* is used in at least three publications! For direct quotations please use italic and acknowledge authorship with appropriate references!

Please respond to these questions by Friday, 18 November 2022. Should you fail to answer the question, we will postpone the publication of this article, until satisfactory answers are received.

Attached, please find a Word file of your article. Please do not interfere with the text not formatting. If you really need to make any correction in this text, you MUST use a red colour font, so that we can easily identify the changes.

•••

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WT14-Eka Mahen...

Mahendra Wayan Eka <mwayaneka@gmail.com>
to Zenon

19 Nov 2022, 00:15

Dear Editor in chief,
Thank you for the comment regarding the necessary improvement before finally accepted for publication. We have responded following each question or comment as seen below:

Q1: Reference needed! - who has undertaken this study? The authors of this article?

We did not provide reference because the introductory (or preliminary) study was part of the research, act as a basis for the study. So, we found it not necessary to quote. But however, we have revised the sentence in the body of the paper as pointed out by the reviewer.

Q2: Is any text starting at this point and to the end of the article a direct quotation? For direct quotations please use italic and acknowledge authorship with appropriate references!

Point Q2 is not a direct quotation.

Q3: Reference needed! Is this David Douglas High School (Oregon, US) test for mathematics?

No, it is not David Douglas High School, but H. Douglas Brown's work on language assessment principles and classroom practices

The reference is
Brown, H.D. Language Assessment Principles and Classroom Practices: San Francisco, California. September (2003).

Q4: Is this correct? Is conventional assessment based on real-life situations, is it based on application/analysis/synthesis? Authors to check!

We meant based on application.

Q5: Is this a direct quotation? The phrase *various academic concepts juxtaposed with the real world* is used in at least three publications! For direct quotations please use italic and acknowledge authorship with appropriate references!

This has been revised directly within the sentence pointed out

I humbly request that you receive the revisions as presented above. Thank you for guiding us on how to improve our final paper. We are open to more advice where necessary.

Sincerely,
I Wayan Eka Mahendra
Corresponding Author

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WTE&TE, Vol.20, No.4 - Proofs of your article

Inbox ×

Zenon Pudlowski <zenon.pudlowski@wiete.com.au>
to me

Sun, 20 Nov, 08:46

Dear Ms Mahendra

Attached, please find the final proofs of your article corrected and formatted by us in accordance with the WIETE style, language and formatting requirements, to be included in this issue.

Please note that at this stage, only obvious typos or simple mistakes can be corrected. No additions, rewriting or other changes are permitted.

Your urgent response to this message will be very much appreciated. We need to hear from you by Tuesday, 22 November 2022 at 5 pm Australian Standard Eastern Time.

Kindest regards

Zenon J. Pudlowski

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PDF WT14-Eka Mahen...

Mahendra Wayan Eka <mwayaneka@gmail.com> Mon, 21 Nov, 11:14

to Zenon

Dear Prof. Zenon,
Editor in chief,
WIETE,

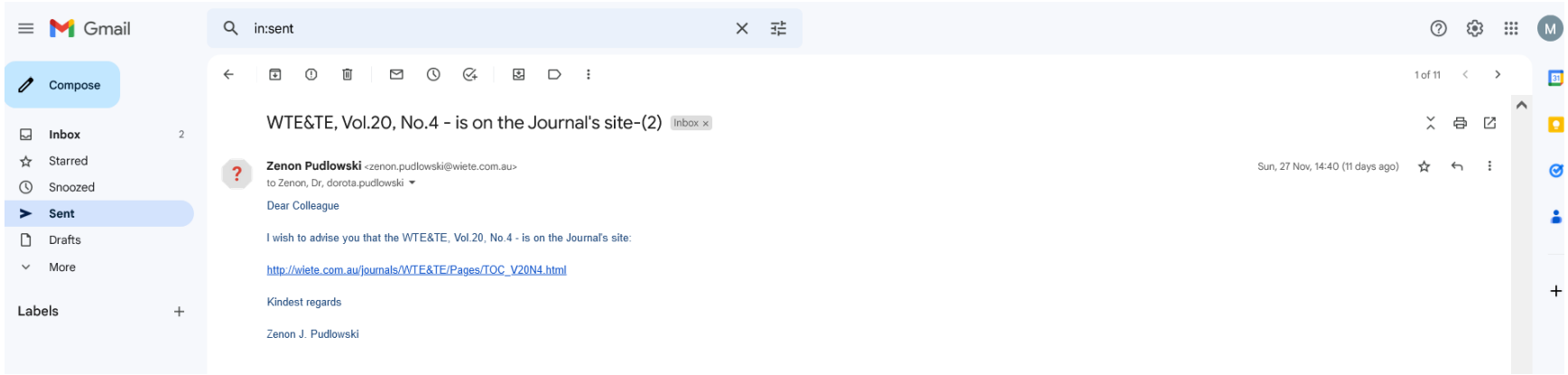
With honor, I wish to say that all is okey with final layout please go on with the publication.

Thank you.

Sincerely yours,

I Wayan Eka Mahendera

Reply Forward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WTE&TE, Vol.20, No.4 - is on the Journal's site-(2)
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Zenon Pudlowski <zenon.pudlowski@wiete.com.au>
to Zenon, Dr, dorota.pudlowski
Sun, 27 Nov, 14:40 (11 days ago)
Dear Colleague
I wish to advise you that the WTE&TE, Vol.20, No.4 - is on the Journal's site:
http://wiete.com.au/journals/WTE&TE/Pages/TOC_V20N4.html
Kindest regards
Zenon J. Pudlowski

Mahendra Wayan Eka <mwayaneka@gmail.com>
to Zenon, Dr, dorota.pudlowski

Tue, 29 Nov, 05:06 (9 days ago)

Dear Prof. Zenon,

Thank you for the information.

Sincerely yours,

I Wayang Eka Mahendra

•••

Reply | Reply to all | Forward

COMBINING STEMS APPROACH AND PERFORMANCE ASSESSMENT IN OPTIMIZING STUDENTS' HIGH-LEVEL THINKING ABILITIES

I Wayan Eka Mahendra[1*]
Institut Pariwisata dan Bisnis Internasional, *Kota Denpasar, Indonesia*

Ni Nyoman Parmithi[2], **I Gusti Agung Ngurah Trisna Jayantika**[3]
Universitas PGRI Mahadewa Indonesia, *Kota Denpasar, Indonesia*

Abstract

This study aims to determine the significant difference in the higher-order thinking skills of students using a performance assessment-based STEM approach and students who follow conventional learning in class X. The population in this study was all students of class X SMA in the Bali, NTT, and NTB provinces. The 2021/2022 academic year. The sample selection technique used in this study was a random sampling technique; however, the class was randomized. This type of research was quasi-experimental with a non-equivalent control group design. The instrument used to collect data was a test of higher-order thinking skills in the form of a descriptions. The data obtained were then analyzed using parametric statistics with a t-test, which previously carried out prerequisite tests in the form of a normality test of data distribution and a homogeneity of variance test. All data analyses were performed using SPSS for Windows, version 16.0. The results of the data analysis showed that there was a significant difference in students' higher-order thinking skills with a performance assessment-based STEM approach and students who underwenttook conventional learning in class X SMA in the 2021/2022 academic year. For this reason, teachers are expected to apply a performance-assessment-based STEM approach to learning mathematics learning to obtain maximum higher-order thinking skills.

Keywords: *STEM approach, performance assessment, higher order thinking skills*

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Commented [2]: It looks like your abstract is not a structured abstract. It is recommended that the abstract follows a structured format to help readers quickly understand the abstract.

Introduction

The development of the times is getting faster, and the tendency has changed towards being more digital. The mastery of science and technology is currently an important key in facing the challenges of the 4.0 industrial revolution era in improving the quality of life, equitable development, and quality of education. The better the quality of education applied, the higher the quality of human resources produced. Education is thea benchmark for national progress. Education can also be a force into making better changes. Education provides the possibility for students to gain opportunities, hope, and knowledge to live a better livesife. However, along with the demands of thise growing era, the problem of education has become increasingly complex. One of them is the problem of the current quality of education, which still requires special attention from education experts because, until now, the quality of education is still consideredfelt to be less than optimal.

In the survey, the quality of education issued by the Program for International Students (PISA) in Indonesia ranked 72 out of 77 countries. This data places Indonesia in the sixth lowest rank, still far from neighbouring countries such as Malaysia and Brunei Darussalam. The results of the PISA study showed that Indonesia scored 371 for the reading category, 379 for mathematics, and 396 on reading, mathematics, andfor knowledge (science). AThe very low

quality of education in Indonesia is judged by an education system that is too old and shackled, and teacher competence is low.

In the era of Education 4.0, lecturers are not the main resource persons in the learning system, but as companions, encouragement, and facilitators. This makes learning fun, allowingand students tocan explore the concepts of their knowledge. The success of student learning outcomes can be seen infrom the students'student's level of understanding, mastery of the material, and way of thinking. The higher the students' understanding and thinking abilities, the higher is their level of learning success. But what is happening now is showing that students' thinking skills are not optimal, it can be seen that it is still difficult for students to ask questions and solve problems they face. Thus, in the learning process, a learning approach that can help students solve problems is needed, in this perspective, the STEM approach can be used (*science, technology, engineering, arts, and mathematics*). The STEM approach is used to implement plans that have been prepared in the form of real and practical activities to achieve the learning objectives. This STEM approach refers to the five components of science: knowledge, technology, engineering, art, and mathematics. The STEM approach is an alternative learning approach in theis Fourth Industrial Revolution Era, which helps to respond to the challenges of laying a basis for students.

Through STEM, lecturers are capable of helping students with learning problems, mostly those who often attain low scores on final assignments or tests. This indicatesshows that some students dido not achieve their learning objectives without appropriate learning approaches or techniques. To determine whether the learning objectives have been achieved, it is necessary to conduct a performance test each time the learning material is presented. The function of this assessment is to provide feedback to lecturers to improve their teaching and learning processes. ThroughWith assessment, teachers can overcome the challenges faced in teaching, therebyhence influencing students' educational achievements. Currently, the concept of educational assessment has a broad direction, which does not only refers to learning outcomes but also helps to determine how the learning process takes place (Muslich, 2011).

Based on this paradigm, the term assessment (assessment) is defined as the process of collecting, reporting, and using information about student learning outcomes obtained through measurements to analyze or explain performance or learning performance and achievement in performing tasks. The assessment process includeds evidence that indicatinges the achievement of the learning outcomes. This assessment is carried out in an integrated manner with learning activities; therefore, so it is referred to as a performance-based assessment.

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Problem of Research

Based on the background of the problem, it can be formulated as follows: Is there a significant difference in students' higher-order thinking skills between a performance-assessment-based STEM approach and conventional learning in class X SMA students in the 2019/2020 school year? In line with the formulation of the problem above, the goal of this study is to determinefind out the significant differences in the higher-order thinking skills of students with a performance assessment-based STEM approach and students who take conventional learning in class X in the 2021/2022 academic year.

Research Focus

This study aims to examine the differences in higher-order thinking skills of students using a performance assessment-based STEM approach, basically between students who learn using the conventional approaches andin comparison with those taught using the STEM approach. The population in this study was all students inof class X of randomly chosen senior high schools in

Bali, NTT, and NTB provinces for the academic year 2021/2022. The sample selection technique used in this study was a random sampling technique. In other words, ~~the~~ respondents were randomly selected in a randomized manner.

In addition, Malaysia also collaborates with America to improve students' abilities by using the STEM approach as one of the preparations to face competition in the era of I~~i~~ndustrial R~~r~~evolution 4.0. Learning using the STEM approach is expected to build and develop students so that they not only memorize concepts, but are also guided to integrate science, technology, engineering, and mathematics. According to Torlakson (2014), STEM combines five fields of science, creating~~making~~ a harmonious collaboration ~~of fields~~ of science fields between problems that occur in the real world. The first STEM approach promoted subjects that required new emphasis in schools. The STEM approach implies that a program is the best that science education can provide in a school, but now, from the STEM approach, it combines the fields of design and innovation or adds music. Later, ~~the~~ Rhode Island Design School coined the acronym STEM approach, specifically adding art to the mix. This is intended to show that good design elements and a creative approach are also incorporated into teaching so that it turns into STEM, which stands for science, technology, engineering, arts, and mathematics, and is a learning approach ~~that is~~ prepared to respond to the development of the Fourth Industrial Revolution Era.

In ~~the field of~~ science, students are required to use scientific methods to solve everyday problems. In the field of technology, students collaborate in the use of technology to process data and convey the information they receive. In the field of Engineering (engineering), students ~~will~~ collaborate on their findings to create a product or find appropriate solutions. In the field of arts, students create ~~their~~ products or findings so that they can be accepted by the community or how to promote these findings. ~~Next, I~~in the field of mathematics (mathematics), students ~~will~~ use a mathematical approach to process the data they obtain~~get~~. Problems that use various approaches, including science, technology, engineering, art, and mathematics, train students to develop higher-order thinking skills. This is suitable for application in mathematics because studying mathematics not only discusses mathematical formulas, but also uses other components, such as technology and engineering, to understand problem-solving.

The STEM approach is a new learning approach in the educational world that will provide important innovations for a developing economy in the technological era. The STEM approach provides an education system that creates opportunities for students to connect their knowledge and skills as an applied learning method. It uses an interdisciplinary approach that presents a cohesive learning paradigm to learn various academic concepts juxtaposed with the real world by applying five disciplines: science, mathematics, engineering, art, and technology (Joko Siswanto, 2018). The STEM approach does not separate learning according to the subject matter~~,~~ but rather on how to collaborate or apply all the components in these class lessons. Requires students to process data and solve problems in everyday life.

The STEM approach promotes collaborative learning. Students are involved in solving real problems in their daily lives~~life.~~ The approach using STEM can seek to bring out skills in oneself, such as~~for example,~~ the ability to solve problems and conduct investigations. These skills are important in improving human resources.

The STEM approach wa~~i~~s used to implement plans prepared in the form of real and practical activities to achieve the learning objectives. If all of these~~at~~ can be implemented correctly as expected, then the overall competence covering four domains, namely the competence of spiritual attitudes, social attitudes, knowledge, and skills, will be achieved by students following the demands of the Graduate Competency Standards (SKL). According to Roberts and Cantu (2012), three STEM approaches can be used~~applied~~.

The Silo Approach emphasizes students' opportunities to gain knowledge rather than technical skills. The silo approach has several characteristics, including learning in the classroom, which provides few opportunities for students to become active. The silo approach emphasizes the knowledge that is judged.

Embedded Approach: This approach emphasizes the mastery of knowledge through the real world and ways to solve problems within the social, cultural, and functional scope. This approach emphasizes the integrity of the subject and links prioritized materials to~~with~~ supporting or embedded materials.

Integrated Approach: This approach emphasizes combining various STEM fields and making them one subject. This approach combines various contents, such as critical thinking skills, problem-solving, and scientific information, which become~~s~~ a solution to a problem by integrating the material taught in different classes and at different times.

The use of the STEM approach to integrate~~ing~~ several multidisciplinary disciplines is referred to as interdisciplinary integration, and the merging of several courses at different times is known as multidisciplinary integration. STEM learning (science, technology, engineering, art, and mathematics) is a strategic approach to honing the four competencies, especially critical thinking and problem ~~-~~solving, creativity, and building character, especially curiosity. ~~The following~~ Table shows the definitions of STEM literacy in the five interrelated fields of study.

Table 1. Description of STEM Literacy

Science	**Scientific Literacy:** The ability to use scientific knowledge and processes to understand the world and nature and the ability to participate in making decisions to influence it.
Technology	**Technology Literacy:** Knowledge of how to use new technologies, how new technologies are developed, and the ability to analyze how technology affects individuals, communities, nations and the world.
Engineering	**Design Literacy:** An understanding of how technology can be developed through engineering or design processes using project-based lesson themes by integrating different subjects (interdisciplinary).
Arts	**Art Literacy:** It takes good design, art and aesthetics to be taken into account in a project
Mathematics	**Mathematical Literacy:** Analyze, and communicate ideas effectively and from how to behave, formulate, solve, and interpret solutions to mathematical problems in applying different situations.

Source: A Modification from Asmuniv (2015).

Application of the STEM Approach

The application of the STEM approach was divided into three levels. At ~~the~~ L~~l~~evel I, the projects given are short, meaning that they are only to be completed in two to 2-6 learning periods. Level II project completion can take to 1-3 months and students are asked to make reports in the form of e-portfolios, posters, or videos. In level 3, the project is a long-term project that takes up to 5-6 months S~~s~~tudents are asked to conduct research or findings either individually or in groups. They are then given guidance on the tools that they will make.

According to Duran et al. (2016), eight learning characteristics seek to develop STEM education: (1) asking questions (for science)~~,~~; (2) developing and using models~~,~~; (3) planning and carrying out investigations~~,~~; (4) analyzing and interpreting data~~,~~; (5) using mathematics and computational thinking~~,~~; (6) constructing explanations (for science)~~,~~; (7) making arguments from evidence~~,~~; and (8) obtaining, evaluating, and communicating information. STEM education has echoed in various countries, both developed and developing, which view STEM education as a solution to the problem of the quality of human resources and the competitiveness of each country (Firman, 2015). There we~~a~~re four characteristics of this study.~~:~~

- The quality lecturer supports ~~connecting~~ the connection of dots using logic, soft skills, and mathematical communication. Making science, technology, engineering, and

mathematics more visual and creative leads students to see connections and expand their thinking skills.

- The space to devote~~make~~ the program ~~devoted~~ to the movement of the makerspace is a combination of constructivism and inquiry-based learning. More than one space wa~~i~~s considered to be a mindset. Maker s~~S~~paces focus on turning the generations of tech consumers into creators, developers, and innovators.
- Solving real problems provides rich learning opportunities because students have to research, hypothesize, create, test, analyze, revise, and synthesize. ~~Great~~ STEM programs bring the outside world into the classroom and challenge critical thinking skills.
- Student feedback is valued~~,~~ and successful and enduring STEM programs require honest and constructive feedback. By asking students to participate in anonymous surveys and/or polls, one~~you~~ can determine what works and ~~what~~ does not.

The steps in implementing the STEM approach include the following: (1) L~~l~~isted in the 2013 curriculum, in principle, already applying STEM rules in basic competencies. To apply~~For the application of~~ the STEM approach to be more optimal, form a curriculum development team to identify basic competencies that can be given STEM content, formulate indicators of success, evaluate learning process time, and structure formation in learning process activities; (2) make learning thematic; (3) make projects by integrating several basic competencies; (4) conduct research in each educational unit; and (5) use crosscutting concepts to understand the similarity of thoughts from the point of view of different disciplines.

Higher Order Thinking Skills (HOTS)

The HOTS is a component of creative and critical thinking skills. Creative and critical thinking can lead a person to be more innovative, ~~have good~~ creativ~~e~~ity~~,~~ ~~and be~~ ideal, and imaginative. HOTS or higher-order thinking skills are defined as ~~the~~ broader use of the mind to identify new challenges. This higher-order thinking ability allows students to apply new information or prior knowledge, and manipulate information to reach possible answers in new situations. Higher-order thinking skills are an important aspect~~s~~ of teaching and learning. People believe that learning can affect ~~the~~ learning ability, speed, and effectiveness~~ of learning~~. Therefore, thinking skills are associated with the learning processes. Students trained in thinking have a positive impact on their educational development (Heong et al, 2011).

Based on this opinion, it can be concluded that higher-order thinking skills are thinking activities that do~~are~~ not merely memoriz~~e~~ing and convey~~ing~~ known information. However, higher-order thinking skills are also the ability to construct, understand, and transform the knowledge and experience already ~~possessed to be~~ used in making decisions and solving problems in new situations, which cannot be separated from everyday life. ~~In thinking skills,~~ S~~s~~everal principles must be considered in thinking skills.

- Thinking skills are not automatically owned by students.
- Thinking skills are not a direct result of teaching a field of study.
- Students rarely transfer these thinking skills on their own; therefore, ~~so~~ guided practice is needed.
- Teaching thinking skills requires a student-centred learning model.

In Bloom's taxonomy, revised by Anderson and Krathwohl, there are three aspects of~~in~~ the cognitive domain that are part of higher-order thinking skills. These three aspects are analysis, evaluation, and creating/creation~~creating/creating~~. Three other aspects in the same realm, namely aspects of remembering, aspects of understanding, and aspects of the application (applying), are included in the lower-order thinking section (Suyono & Hariyanto, 2014: 167). The indicators of higher-order thinking skills used in this study were as follows:~~:~~

Commented [A5]: Conventions: Abbreviations are usually defined at the first use in the abstract as well as in the main text. Check whether 'cognitive' should be defined here.

- Analyzing can examine and parse, formulate problems, and provide appropriate solution steps.
- Evaluation is the ability to assess, refute, or support an idea, and provide reasons that can strengthen the answers obtained.
- Creativity is the ability to design a way to solve a problem or combine information into the correctright strategy.

Math Performance Assessment

Assessment is a systematic procedure used to collect information that can be used to refer to student characteristics. Assessment is not something that is only given to students but is more of a process that directs students to improve their learning competencies. The results of this assessment will be useful forto students and lecturers. Students find new learning strategies to improve their competence. Meanwhile, Llecturers can apply new learning techniques to address students' strengths and weaknesses. Several assessment techniques can be used to collect this information, such as formal and informal observations, paper-and-pencil tests, selected response tests, student performance oin assignments, research, projects, and oral questions.

In the world of education, including mathematics learning, assessment has a very long history of development. The assessments and learning activities carried out generally focused on activities related to academic achievement (cognitive) and paid less attention to psychomotor (behavioural) and affective (attitude) aspects.

Until now, Athe scoring system washas been used using the test technique. Assessment using standardized test techniques is called conventional assessment. Conventional assessments do not completely describe student learning progress as a whole, because the results obtained from these conventional assessments often tend to be in the form of numbers or abstract letters. Other techniques, suchknown as performance assessments, can be used to complete the picture of progress in learning outcomes. Conventional assessment is often associated with the term "test" (test) while performance assessment is often associated with the term "task" (task). Performance assessment leads students to perform reasoning and acquire skills toin completeing various interesting and challenging tasks in real-life contexts. The Pperformance was assessed to reflect the actual ability of the students.

The purpose of performance assessment is to evaluate the actual process, in this case, the natural sciences and mathematics. This assessment can examine the application of students' abilities into solve real (actual) problems. The difference between the performance assessment and the conventional (conventional) assessment adopted by Douglas is presented in Table 2.

Table 2. Differences between Performance Assessment and Ordinary Assessment (Conventional)

Aspect	Performance Assessment	Ordinary Assessment (Conventional)
Appraisal activities	Doing the task	Choose the Answer
The nature of the activity	Created by lecturer	Based on the real-life
Cognitive Level	Knowledge/achievement	Application/analysis/synthesis
Assessment objectivity	Difficult to achieve	Easy to achieve
Proof of mastery	Direct evidence	Indirect evidence

The performance assessment rubric is often used to discuss the assessment scores. AThe rubric was used as the scoring guide. The rubric contains criteria that describe what students need to complete the given tasks and measures the level of students' ability to complete the task. From Tthe rubric, the quality of the student work in the classroom was obtained from the rubric. The rubric created by the lecturer must be consistent and uniform for all the students. The rubric format wais divided into two parts: athe holistic rubric (general) and anthe analytical rubric (specific). A holistic rubric (general) is an assessment that shows the overall assessment of

Commented [A6]: Conventions: Abbreviations are usually defined at the first use in the abstract as well as in the main text. Check whether 'actual' should be defined here.

students at each level. A holistic rubric was used for the ~~final~~ large-scale assessment. The analytic rubric is an assessment guide that shows the student performance for each specific criterion on a separate scale. The rubrics for the holistic and analytical performance assessments are presented in Table~~s~~ 3. and 4.

Table 3. Holistic Rubric for Assessment of Mathematical Performance (Description of the Quality of Student Performance for each Level)

Indicators	Score	Description
Demonstrate a precise and thorough understanding of concepts, Counting correctly, Using tables, figures, and graphs accurately and thoroughly, Using the right strategy, as well as the right and reasonable reasons.	4	Highly Understood
Demonstrate a precise and thorough understanding of concepts, Counting correctly, Use tables, pictures, and graphs carefully, but not very carefully Using the right strategy, as well as the right and unreasonable reasons.	3	Understood
Demonstrate a precise and thorough understanding of concepts, Counting is not accurate, Using tables, figures, and graphs is not accurate, Using the wrong strategy, and the wrong reason.	2	Less Understood
Demonstrate a precise and thorough understanding of concepts, Counting less, Not using tables, pictures, graphs, Using the wrong strategies, and the wrong reasons.	1	Not Understood

Table 4. Performance Assessment Analytical Rubric

No	Problem-solving aspect	Score		
		1	2	3
1	Understanding the problem	Do not understand	Can understand	Can understand
2	Completion of the plan	Not Exactly	Partially right	Right
3	Response	Not Correct	partially true	Correct

Performance differs from a product or result because it presents what can be seen. Examples of performance include oral presentations, demonstrations~~, performances~~, debates, and discussions. In performance assessment, the assessment is carried out based on~~by~~ the performance, behavio~~u~~r, or interaction of students in the classroom. Interactions can take~~be in~~ the form of students with high school students, students with lecturers, or students with teaching materials. Thus, the performance assessment is more concerned with the process without compromising the results. Performance assessment is not only an assessment of the process but also an assessment of student work. In the assessment of student work, the targets for achieving learning outcomes include the following aspects:1) knowledge (knowledge)~~,~~; 2) reasoning (knowledge in various problem-solving contexts)~~,~~; 3) skills (skills in various types of communication skills, visuals, works of art, and others)~~,~~; 4) product (results)~~,~~; and 5) affect related to feelings, attitudes, values, interests, and motivations.

Methodology of Research

General Background of Research

This study uses a quasi-experimental type of research (quasi-experimental), which has a control group but cannot ~~function~~ fully ~~to~~ control external variables affecting the implementation of the experiment (Sugiyono, 2015). This study aimed~~s~~ to determine the differences in students' higher-order thinking skills between performance assessment-oriented STEM learning and students who follow the conventional approach.

Learning is defined as the attempt to acquire knowledge, intelligence, or skills. According to Sugihartono as cited by Kate (2014), learning is a change in ability that lasts for a long time and does not originate from thea growth process. Learning refers to changes in individual behaviour or potential as a result of experience, either experienced or intentionally designed so that an individual will have competence in the form of skills and knowledge.

The term learning is a teaching and learning process that shows two types of activities that are inseparable. These activities included learning and teaching. These two aspects will collaborate in an integrated manner in an activity when the teacher and student interactions occur. According to Sugihartono (2014), learning is an effort made by teachers to convey knowledge, organize, and create learning activities effectively and efficiently, but also to train students in behaviour and logical thinking patterns.

Learning is a combination of structured combinations that include human elements, materials, facilities, equipment, and procedures that influence each other in achieving the learning objectives. Learning is an effort that is carried out intentionally, directed, and planned, with predetermined goals before the process is carried out, and its implementation is controlled with the intention that learning occurs in a person. From some of these understandings, it can be concluded that the core of learning is an activity carried out by educators so that learning activities are carried out by students to achieve the desired learning outcomes or goals.

The term STEM approach was first launched by the United States National Science Foundation in the 1990s under the name SMET, but itthe term was not approved by several parties and was later changed to the theme of the education reform movement in the four disciplines to grow the workforce in the STEM field and develop citizens. countries that master STEM science (STEM literate) as well as the increasing global foreign power of the United States in science and technology innovation.

Sample of Research

This study involved 82 students, using a simple random sampling technique. The learning approach is divided into two types, namely:, the STEM approach based on performance assessment and the conventional approach as an independent variable. The dependent variable was the students' higher-order thinking ability. A test was used in the form of a description to collect data on the students' higher-order thinking skills. The collected data were analyzed using parametric statistics with a t-test, which previously carried out prerequisite tests in the form of a normality test of data distribution and a homogeneity of variance test. All data analyses were performed using SPSS for Windows, version 16.0.

Data Analysis

A normality test was performedcarried out to ensure that the statistical tests used in the hypothesis testing could be performedcarried out. This is important because if the data are not normally distributed, then a t-test, which is a parametric statistic, cannot be performed. The normality test used Kolmogorov – Smirnov data on both groups of students' higher-order thinking skills, as shown in Table 5.

Table 5. Tests of Normality

	Kolmogorov-Smirnov[a]			*Shapiro-Wilk*		
	Statistic	*df*	*Sig.*	*Statistic*	*df*	*Sig.*
Y_1	.102	41	.200*	.976	41	.528
Y_2	.093	41	.200*	.979	41	.640

a. Lilliefors Significance Correction

**. This is a lower bound of the true significance.*

Analysis of the Kolmogorov-Smirnov and Shapiro-Wilk tests showed that sig. > 0.05 for both groups of data, namely, data on higher-order thinking skills in the experimental group (Y_1) and the control group (Y_2), as shown in the Table above. This means that H_0 is accepted (failed to be rejected) and both sample groups are normally distributed.

Results of Research

The object of this research is the differences in students' higher-order thinking abilities as a result of treatment between learning approaches. The learning approach in this study was divided into two forms: the STEM approach, based on performance assessment, and the conventional learning approach. This study used a non-equivalent control group design with a t-test as thea data analysis tool.

Thus, the data in this study weare grouped into higher-order thinking skills of students who follow the STEM approach, based on performance assessment, and higher-order thinking skills of students who follow conventional learning approaches. The results of the analysis of the central measure (mean, mode, and median) and the size of the data spread (variance and standard deviation) on students' higher-order thinking ability scores are shown in Table 6.

Table 6. Recapitulation of Students' Higher Order Thinking Ability Scores

Statistics

		Y_1	Y_2
N	Valid	41	41
	Missing	41	41
Mean		73.1220	61.1951
Median		74.0000	61.0000
Mode		74.00[a]	60.00
Std. Deviation		5.36281	5.24985
Variance		28.760	27.561
Range		22.00	23.00
Minimum		60.00	48.00
Maximum		82.00	71.00
Sum		2998.00	2509.00

a. Multiple modes exist. The smallest value is shown

Description:
Y_1 = higher order thinking ability of the experimental group
Y_2 = higher order thinking ability control group

Variance Homogeneity Test

The homogeneity of variance test wais intended to ensure that the differences obtained from the t-test came from differences between groups, not from differences within groups. From the results of the analysis of the homogeneity of variance test using SPSS 16.0, the following results were obtained.:

Table 6. Test of Homogeneity of Variances

Y (High Thinking Capacity)

Levene Statistic	df1	df2	Sig.
.126	1	80	.723

From the analysis results, we obtained the value of sig. > 0.05 or 0.723 > 0.05; so H_0 is accepted. This means that both groups originatedcame from populations with the same or homogeneous

variance. Thus, ~~the~~ data on ~~students'~~ higher-order thinking skills were obtained from a homogeneous population. Based on the results of the prerequisite test, namely~~,~~ the normality test of the data distribution and the homogeneity of variance test, it can be concluded that the students' higher-order thinking ability data come from a population that is normally distributed and has the same or homogeneous variance. Therefore, hypothesis testing was~~can be~~ performed using ~~a~~ t-tests.

Hypothesis testing

The recapitulation of the data analysis results using parametric t-test statistics is presented~~shown~~ in Table 6. below.

Table 7. Recapitulation of Data Analysis Results Using t-test

(Independent Samples Test)

		Lavene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Y	Equal variances assumed	.126	.723	10.176	80	.0001	11.92683	1.17204	9.59440	14.25926
	Equal variances not assumed			10.176	79.964	.0001	11.92683	1.17204	9.59438	14.25928

From the ~~above~~ output above, it can be seen that the t-count significance for the equal variances assumed for the two-tailed test is 0.001. So, the value of sig. < of 0.05 or 0.001 < 0.005. This means that H_0 is rejected, and H_1 is accepted. It can be said that there are differences in higher-order thinking skills between students who follow the STEM approach based on performance assessment and students who follow the conventional learning approach. The results of the data analysis also showed that the group that followed the STEM approach based on performance assessment had a higher-order thinking ability score of 73,122, whereas~~while~~ the group of students who followed the conventional learning approach had an average high-order thinking ability score of 61.195. Thus, the average higher-order thinking ability of the group of students who followed the STEM approach based on performance assessment was higher than the average of the higher-order thinking ability of the group of students who followed the conventional approach.

Discussion

The results of data analysis using a t-test showed ~~that there were~~ differences in higher-order thinking skills between students who followed the STEM approach based on performance assessment and those who followed the conventional learning approach. This also shows that for students' higher-order thinking skills to be reliable, it is necessary to improve the quality of learning using~~in this case~~ the learning approach ~~used~~. The superiority of the performance assessment-based STEM learning approach over the conventional learning approach can be seen in the average high-order thinking abilities~~y~~ of students. The average higher-order thinking ability of the experimental group was 73,122, which was higher than the average of the control group's higher-order thinking ability of 61.195.

The results of the data analysis indicated the superiority of the STEM approach based on performance assessment over the conventional approach. This advantage is not limited to a

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For example,
Original: *There were* many people standing in line.
Revised: Many people were standing in line.

theoretical description, but has been empirically tested in the field. The application of approaches and assessments in the learning process plays an important role, because it is a conceptual framework in the form of a systematic learning plan. The STEM approach, based on performance assessment, is a learning approach that can challenge students to actively solve problems by connecting their knowledge and skills. As an applied learning approach that uses an interdisciplinary approach, it presents a cohesive learning paradigm to learn various academic concepts juxtaposed with the real world by applying five disciplines, namely, science, mathematics, engineering, art, and technology, increasingly showing the advantages of the STEM approach overcompared to conventional approaches.

Mathematics is an important subject for many students. Through mathematics learning, students can rationally solve everyday problems rationally. The role of lecturers as educators should be to manage to learn to create interesting learning to foster student learning activities. If students already have an interest in learning, theyit can improveincrease theirthe achievement of activities and learning outcomes.

Research by Afriana et al. (2016) further strengthens the advantages of the STEM approach compared to conventional approaches, namely that STEM can improve scientific literacy and motivate learning, help understand teaching materials, and form creative attitudes, and students are increasingly aware of the importance of protecting the environment. This approach can provide new experiences for students, so that their motivation and interest in learning will increase through real experiences in learning. In STEM learning, students are invited to engage in meaningful learning to understand concepts. Students weare invited to explore a project activitiesy so that they weare actively involved in the process. This fosters students to think critically, creatively, and analytically, and improves their higher-order thinking skills (Ismayani, 2016).

Conclusions

Based on the findings and discussion, the application of the STEM approach in assessments of the learning process plays an important role, because it is a conceptual framework in the form of a systematic learning plan. The STEM approach is a learning model that is expected to challenge students to actively solve problems by connecting their knowledge and skills. It is an applied learning approach that uses an interdisciplinary approach to present a cohesive learning paradigm forto learning various academic concepts juxtaposed with the real world by applying five disciplines. namely, science, mathematics, engineering, arts, and technology. Therefore, Tthe purpose of the STEM approach is to provide students with the knowledge and skills required to deal with unexpected changes in the world.

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Ethical Compliance:

This research is classified as experimental research in the field of education, involving students and mathematics teachers in Indonesia, which is followsing the code of ethics for scientific research.

Data Access Statement:

The rResearch data supporting this publication are available from the IPB Internatsional repository located at http://repository.ipb-intl.ac.id/.

Conflict of Interest declaration:

The authors declare that they have noNO affiliations with or involvement in any organization or entity with any financial interest in the subject matter or material discussed in this manuscript and are free from eElements of *SARA* (ethnicity, religion, race, and inter-group).

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Combining STEAM learning and performance assessment to optimise students' higher-level thinking abilities

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ABSTRACT:

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ABSTRACT

This study aimed to determine the difference in the higher-order thinking skills of 41 students (18 males and 23 females) who followed a performance assessment-based STEAM (science, technology, engineering, the arts, mathematics) approach, and 41 students (24 males and 17 females) who were taught in conventional classes. The students were selected from four high schools located in Bali, East Nusa Tenggara (Nusa Tenggara Timur - NTT) and West Nusa Tenggara (Nusa Tenggara Barat - NTB) provinces in Indonesia, in the 2021/2022 year. The sample selection technique used was random sampling and the type of research was quasi-experimental with a non-equivalent control group design. The data obtained were analysed using parametric statistics with a *t*-test and all data analyses were performed using SPSS version 16.0. The analysis revealed that there was a significant difference in the higher-order thinking skills of the students that followed the STEAM approach and those who attended conventional classes. Based on the assessment, the experimental group learned more effectively and demonstrated better outcomes as compared to the control group.

INTRODUCTION

Today, global development is aligned with faster transformations, and the tendency of human interaction has changed towards being more digital. The mastery of science and technology is currently key to helping countries handle challenges posed by this new environment, including the Fourth Industrial Revolution (4IR) [1][2]. The education system plays an important role in addressing these challenges, as the appropriate preparedness of human resources for the demanding labour market and every-day life depends on the quality of education [3]. This acts as a benchmark for national progress. Studies have revealed that education can be a force that initiates and leads to the required or even better than expected changes. It also offers a wider spectrum of life opportunities for those who obtain the sought-after skills and knowledge [4]. Although information and communication technologies have led to development across the globe, due to the constantly increasing demands for change and ever-faster transformations, the problems of education have become increasingly complex. Currently, one of the most crucial problems is the quality of education. In Indonesia, this issue still requires special attention from education experts, because, until now, the quality of the country's education is still low when compared to other countries in the region [5].

In a survey on the quality of education administered by the Program for International Students (PISA), Indonesia ranked 72 out of 77 countries that participated in the survey [6]. The rankings were organised and compiled based on individual variables provided by the OECD and a G20 expert team on data availability and accessibility [6]. According to this data, Indonesia is in the sixth lowest rank, still far from neighbouring countries, such as Malaysia and Brunei Darussalam. For instance, the results of the PISA study showed that Indonesia scored 371, 379, and 396 on reading, mathematics and knowledge (science) respectively [6]. These results reflect a very low quality of education in

Indonesia, which is caused by an education system that is too old and shackled, and they also reveal that teacher competencies maybe too low or inadequate.

Revised In an introductory (or preliminary) study conducted by the authors of this article in 2020 as a basis for the paper, it was established that there is a significant difference in higher-order thinking skills between those students that were taught using a performance assessment-based STEAM (science, technology, engineering, the arts, mathematics) approach compared to those that followed conventional learning in class X of purposively selected high schools in Indonesia. Based on this, the present study aimed to examine closer the differences in higher-order thinking skills of students using the performance assessment-based STEAM approach (experimental group), and those taught with conventional approaches (control group). The population in this study included students from class X of the randomly chosen senior high schools in Bali, East Nusa Tenggara (Nusa Tenggara Timur - NTT) and West Nusa Tenggara (Nusa Tenggara Barat - NTB) for the year 2021/2022. There experimental group was comprised of 41 students (18 male and 23 female) and the control group also 41(24 male and 17 female). The sample selection technique used was random sampling, with research respondents randomly chosen.

Applying the STEAM (Science, Technology, Engineering, the Arts, Mathematics) Approach for Enhancing Higher-Order Thinking Skills among Students

The use of the STEAM approach to integrate several disciplines, where the disciplinary boundaries are crossed and disciplines merged, is referred to as interdisciplinary integration, and the involvement of several courses at different times is known as multidisciplinary integration. STEAM learning is a strategic approach to honing key competencies, especially critical thinking and problem solving, creativity, and building character, particularly curiosity. Table shows the definitions of STEAM literacy in the five interrelated fields of study, based on Asmuniv [8].

Table 1: Description of STEAM literacy.

Science	Scientific literacy: The ability to use scientific knowledge and processes to understand the world and nature, and the ability to participate in making decisions, and to influence it.
Technology	Technology literacy: Knowledge of how to use new technologies, how new technologies are developed, and the ability to analyse how technology affects individuals, communities, nations and the world.
Engineering	Design literacy: An understanding of how technology can be developed through engineering or design processes using project-based topics and integrating different subjects (interdisciplinary approach).
Arts	Art literacy: The ability to incorporate art and aesthetics into a design project.
Mathematics	Mathematical literacy: Analyse and communicate ideas effectively and in appropriate manner, the ability to formulate, solve and interpret solutions to mathematical problems in different situations.

Source: a modification from Asmuniv [8]

The application of the STEAM approach was divided into three levels. At level I, the projects given to students are short-term, meaning that they are to be completed in two to six learning periods. Level II project completion can take from one to three months, and students are asked to make reports in the form of e-portfolios, posters or videos. At level III, the project is a long-term project that takes up to five-six months Students are asked to conduct research and come up with findings either individually or in groups. At that time, they are given guidance on the tools that they will make.

Performance Assessment Approach in Mathematics Teaching and Learning

Assessment is a systematic procedure to collect information that can be used to refer to student performance and characteristics [9]. Assessment is not only given to students to check on their performance at a given point of time, but it is a process that can, through different means, guide students to improve their learning competencies [10]. *No it is not direct quotation* With assessment, students find new learning strategies to improve their competence, while lecturers can apply new learning techniques to address students' learning challenges. Several assessment techniques can be used to collect information, such as formal and informal observations, paper-and-pencil tests, selected response tests, student performance on assignments, research projects and oral questions.

In the world of education, including mathematics, assessment has a long history of development. The assessments and learning activities carried out generally focus on activities related to academic achievement (cognitive) and pay less attention to psychomotor (behavioural) and affective (attitude) aspects [11].

For the case of this research, a scoring system was used in the form of standardised assessment test techniques referred to as conventional assessment. Conventional assessment do not completely describe student learning progress as a

whole, because the results obtained from these conventional assessments often tend to be in the form of numbers or abstract letters [12]. Other techniques, such as performance assessments, can be used to complete the picture of progress in learning outcomes. Conventional assessment is often associated with the term *tes*t (test), while performance assessment is often associated with the term *task* (task). Performance assessment leads students to perform reasoning and acquire skills to complete various interesting and challenging tasks in real-life contexts. Performance assessment is conducted to reflect the actual ability of the students.

The purpose of performance assessment is to evaluate the actual process, in this case, natural sciences and mathematics. This assessment can examine the application of students' abilities in solve real (actual) problem. The difference between the performance assessment and the conventional (conventional) assessment *[Revised]* adopted from Brown for application in this study as presented in Table 2.

Table 2: Differences between performance assessment and ordinary assessment (conventional

Aspect	Performance assessment	Ordinary assessment (conventional)
Appraisal activities	Doing the task	Choose the answer
Nature of the activity	Created by lecturer	Based on the application
Cognitive level	Knowledge/achievement	Application and Analysis
Assessment objectivity	Difficult to achieve	Easy to achieve
Proof of mastery	Direct evidence	Indirect evidence

The performance assessment rubric is often used to discuss the assessment scores. A rubric was used as the scoring guide. The rubric contains criteria that describe what students need to complete the given tasks and measures the level of students' ability to complete the task. The quality of the student work in the classroom was obtained from the rubric. The rubric created by the lecturer must be consistent and uniform for all the students.

Higher-Order Thinking Skills (HOTS)

The higher-order thinking skills (HOTS) is a component of creative and critical thinking skills. Creative and critical thinking can lead a person to be more innovative, creative, ideal and imaginative. The HOTS are defined as a broader use of the mind to identify new challenges. This higher-order thinking ability allows students to apply new information or prior knowledge, and manipulate information to reach possible answers in new situations. Higher-order thinking skills are an important aspect of teaching and learning. People believe that learning can affect learning ability, speed, and effectiveness. Therefore, thinking skills are associated with the learning processes. Students trained in thinking have a positive impact on their educational development [13].

Based on these observations, it can be concluded that higher-order thinking skills are thinking activities that do not merely allow to memorise and convey known information. But they are also the ability to construct, understand and transform the knowledge and experience already used in making decisions and solving problems in new situations, which cannot be separated from everyday life. Several principles must be considered in thinking skills:

- Thinking skills are not automatically owned by students.
- Thinking skills are not a direct result of teaching a field of study.
- Students rarely transfer these thinking skills on their own; therefore, guided practice is needed.
- Teaching thinking skills requires a student-centred learning model.

In Bloom's taxonomy, revised by Anderson and Krathwohl, there are three aspects of the cognitive domain that are part of higher-order thinking skills [14]. These three aspects are analysis, evaluation and creation. Three other aspects in the same realm, namely aspects of remembering, aspects of understanding, and aspects of the application, are included in the lower-order thinking section [14][15]. The indicators of higher-order thinking skills used in this study were as follows:

- Analysis refers to the ability to examine and parse, formulate problems and provide appropriate solution steps.
- Evaluation is the ability to assess, refute or support an idea, and provide reasons that can strengthen the answers obtained.
- Creativity is the ability to design a way to solve a problem or combine information into the correct strategy.

RESEARCH METHOD

This study was a quasi-experimental type of research, with a control group, but external variables affecting the implementation of the experiment could not be fully controlled [16]. It aimed to determine the differences in higher-order thinking skills between students that followed performance assessment-oriented STEAM learning and students who were taught with the conventional approach.

This study involved 82 students, using a simple random sampling technique. There were two types of learning approaches examined: the STEAM approach based on performance assessment and the conventional approach that was used as an independent variable. The dependent variable was the students' higher-order thinking ability. A descriptive

test was conducted to collect data on the students' higher-order thinking skills. The collected data were analysed using parametric statistics with a *t*-test; prerequisite tests were carried out in the form of a normality test of data distribution and a homogeneity of variance test. All data analyses were performed using SPSS version 16.0.

A normality test was performed to ensure that the statistical tests used in hypothesis testing could be conducted. This is an important step, because if the data are not normally distributed, a *t*-test, which is a parametric statistic, cannot be performed. The normality tests - Kolmogorov-Smirnov and Shapiro-Wilk – were performed on data for both groups of students' higher-order thinking skills, as shown in Table 3.

Table 3: Tests of normality.

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Y_1	0.102	41	0.200*	0.976	41	0.528
Y_2	0.093	41	0.200*	0.979	41	0.640

[a] Lilliefors significance correction
* Lower bound of the true significance

Analysis of the Kolmogorov-Smirnov and Shapiro-Wilk tests showed that sig. > 0.05 for both groups of data; namely, the data on higher-order thinking skills in the experimental group (Y_1) and the control group (Y_2), mean that H_0 is accepted (failed to be rejected) and both sample groups are normally distributed.

RESULTS AND DISCUSSION

The objective of this research was to examine the differences in students' higher-order thinking abilities depending on the learning approach and assessment method. There were two groups involved: experimental that followed the STEM approach, based on performance assessment, and control based on conventional learning and conventional assessment. This study used a non-equivalent control group design with a *t*-test as the data analysis tool.

Thus, the data obtained in this study were clustered according to each group's higher-order thinking skills. The results of the analysis of the central measure (mean, mode and median) and the size of the data spread (variance and standard deviation) on students' higher-order thinking ability scores are shown in Table 4 below.

Table 4: Statistical summary of students' higher order thinking ability scores.

		Y_1	Y_2
N	Valid	41	41
	Missing	41	41
Mean		73.1220	61.1951
Median		74.0000	61.0000
Mode		74.00[a]	60.00
Standard deviation		5.36281	5.24985
Variance		28.760	27.561
Range		22.00	23.00
Minimum		60.00	48.00
Maximum		82.00	71.00
Sum		2998.00	2509.00
a. Multiple modes exist. The smallest value is shown			

Description:

Y_1 = higher order thinking ability of the experimental group.
Y_2 = higher order thinking ability control group.

Variance Homogeneity Test

The homogeneity of variance test was intended to ensure that the differences obtained from the *t*-test came from differences between the groups, not from differences within the groups. From the results of the analysis of the homogeneity of variance test using SPSS 16.0, the following results were obtained.

Table 5: Test of homogeneity of variances (Y – higher-order thinking ability).

Levene's statistic	df1	df2	Sig.
0.126	1	80	0.723

From the analysis results, the authors obtained the value of sig. > 0.05 or 0.723 > 0.05; so H_0 is accepted. This means that both groups originated from populations with the same or homogeneous variance. Thus, data on higher-order thinking skills were obtained from a homogeneous population. Based on the results of the prerequisite test, namely the normality test of the data distribution and the homogeneity of variance test, it can be concluded that the students' higher-order thinking ability data came from a population that is normally distributed and has the same or homogeneous variance.

HYPOTHESIS TESTING

A summary of the data analysis results using parametric *t*-test statistics is presented in Table 6.

Table 6: Summary of the data analysis results using *t*-test (independent samples test).

		Lavene's test for equality of variances		*t*-test for equality of means						
									95% confidence interval of the difference	
		F	Sig.	*t*	df	Sig. (2-tailed)	Mean difference	Std. error difference	Lower	Upper
Y	Equal variances assumed	0.126	0.723	10.176	80	0.0001	11.92683	1.17204	9.59440	14.25926
	Equal variances not assumed			10.176	79.964	0.0001	11.92683	1.17204	9.59438	14.25928

From the output above, it can be seen that the *t*-count significance for the equal variances assumed for the two-tailed test is 0.001. So, the value of sig. < of 0.05 or 0.001 < 0.005. This means that H_0 is rejected, and H_1 is accepted. It can be said that there are differences in higher-order thinking skills between students who followed the STEAM approach based on performance assessment and students who followed the conventional learning approach. The results of the data analysis also showed that the group that followed the STEAM approach had a higher-order thinking ability score of 73.122, whereas the group of students who followed conventional learning had an average higher-order thinking ability score of 61.195. Thus, the average higher-order thinking ability of the experimental group of students was higher than the average of the higher-order thinking ability of the control group of students.

DISCUSSION

The results of data analysis using a *t*-test showed differences in higher-order thinking skills between students who followed the STEAM approach based on performance assessment and those who followed the conventional learning approach. This also shows that it is necessary to improve the quality of learning, especially for students still taught with conventional methods. The superiority of the performance assessment-based STEAM learning approach over the conventional learning approach can be seen in the average higher-order thinking abilities of students. The average higher-order thinking ability of the experimental group was 73.122, which was higher than the average of the control group's higher-order thinking ability of 61.195.

This advantage is not limited to a theoretical description, but has been empirically tested in the field. The application of approaches and assessments in the learning process plays an important role, because it is a conceptual framework in the form of a systematic learning plan. The STEAM approach, based on performance assessment, is a learning approach that can challenge students to actively solve problems by connecting their knowledge and skills to challenging situations. *Revised* As an applied learning approach based on interdisciplinarity, it presents a cohesive learning paradigm to learn various academic concepts applied and categorised into five disciplines, namely, science, mathematics, engineering, art and technology. The advantages of the STEAM approach over conventional approaches can be demonstrated by evidence

Mathematics is an important subject for many students. Through mathematics learning, students can solve everyday problems rationally. The role of lecturers as educators should be to manage to learn to create interesting learning to foster student learning activities. If students already have an interest in learning, they can improve their activities and learning outcomes.

According to Afriana et al, the advantages of the STEM (STEAM) approach compared to conventional approaches can be further strengthened; namely, STEM (STEAM) can improve scientific literacy and motivate learning, help understand teaching materials and form creative attitudes, also it can make students more aware of the importance of protecting the environment [17]. This approach can provide new experiences for students, so that their motivation and interest in learning will increase through real experiences. In STEAM learning, students are invited to engage in meaningful activity to understand concepts. They are invited to explore project activities so that they can be actively involved in the process. This encourages students to think critically, creatively and analytically, and improves their higher-order thinking skills [18].

CONCLUSIONS

Based on the findings and discussion, the application of the STEAM approach in the learning process and assessment plays an important role, because it is a conceptual framework in the form of a systematic learning plan. The STEAM approach is a learning model that is expected to challenge students to actively solve problems by connecting their knowledge and skills with challenging situations. It is an applied learning approach based on interdisciplinarity that present a cohesive learning paradigm for learning various academic concepts from five disciplines; namely, science, mathematics, engineering, arts and technology, while connecting them with the real world. The purpose of the STEAM approach is to provide students with the knowledge and skills required to deal with unexpected changes in the world.

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Dear Editor in chief,
Thank you for the comment regarding the necessary improvement before finally accepted for publication. We have responded following each question or comment as seen below:

Q1: Reference needed! - who has undertaken this study? The authors of this article?

We did not provide reference because the introductory (or preliminary) study was part of the research, act as a basis for the study. So, we found it not necessary to quote. But however, we have revised the sentence in the body of the paper as pointed out by the reviewer.

Q2: Is any text starting at this point and to the end of the article a direct quotation? For direct quotations please use italic and acknowledge authorship with appropriate references!

Point Q2 is not a direct quotation.

Q3: Reference needed! Is this David Douglas High School (Oregon, US) test for mathematics?

No, it is not David Douglas High School, but H. Douglas Brown's work on language assessment principles and classroom practices

The reference is
Brown, H.D. Language Assessment Principles and Classroom Practices: San Francisco, California. September (2003).

Q4: Is this correct? Is conventional assessment based on real-life situations, is it based on application/analysis/synthesis? Authors to check!

We meant based on application.

Q5: Is this a direct quotation? The phrase *various academic concepts juxtaposed with the real world* is used in at least three publications! For direct quotations please use italic and acknowledge authorship with appropriate references!

This has been revised directly within the sentence pointed out

I humbly request that you receive the revisions as presented above. Thank you for guiding us on how to improve our final paper. We are open to more advice where necessary.

Sincerely,
I Wayan Eka Mahendra
Corresponding Author

Abstract

This study aimed to determine the significant difference in higher-order thinking skills between students taught using a performance assessment-based STEM approach, making up the experimental group, and those taught using the conventional lecture method making up the control group. The sample selection technique used in this study was random sampling, and the type of research was quasi-experimental with a nonequivalent control group design. The data obtained were analyzed using parametric statistics with a t-test, and all data analyses were performed using SPSS version 16.0. The subjects studied were mathematics students from 4 high schools located in Bali, Nusa Tenggara Timur (NTT) and Nusa Tenggara Barat (NTB) provinces, the schools involved in the study were: Baturiti Public high school 1 in Bali and Haharu Public high school in NTT, whose students composed of the experimental class. The control class consisted of students from Klungkung Public High School 1 in Bali and Mataram Public High School 2 in NTB. This means that the classes were divided into two groups: the experimental group consisted of 41 students (18 males and 23 females), and the control group consisted of 41 students (24 males and 17 females). The control group studied mathematics using the lecture method, whereas the experimental group was taught using the STEM approach. The study concluded that the experimental group learned well based on the assessment, compared to the control group. The results of the data analysis revealed that there was a significant difference in higher-order thinking skills between students taught using the STEM approach and those who attended conventional classes taught using the lecture method.