Biosfer: Jurnal Pendidikan Biologi

Journal homepage: http://journal.unj.ac.id/unj/index.php/biosfer

Is project-based transdisciplinary assessment effective in reducing the Mathematical anxiety of pre-service Biology teacher?

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ARTICLE INFO

Article history
Received: 8 April 2021
Revised: 1 May 2021
Accepted: 14 July 2021

Keywords:
Abbreviated math anxiety scale
Collaborative
Mathematical anxiety
Project-based transdisciplinary
Pre-experimental method

A B S T R A C T

Mathematical anxiety is a constant obstacle experienced by pre-service Biology Teachers in developing their quantitative abilities. Project-based transdisciplinary assessment is one type of transdisciplinary application that has not been widely explored to solve this problem. Project-based transdisciplinary assessment in form of mini-research with the topic "Data Collection on local wisdom in each area". The aim of this study is to determine the impact of implementing project-based transdisciplinary assessment on reducing mathematics anxiety among 23 pre-service biology Teachers. This study used a pre-experimental method with a pre-test and post-test design with one non-randomized group. The pre-test and post-test were carried out using the AMAS (Abbreviated Math Anxiety Scale) questionnaire. Data were analyzed using descriptive statistics and the Wilcoxon signed ranks test. Statistical results of this study show no significant difference in mathematics anxiety before and after the implementation of the project-based transdisciplinary assessment with a z value of-0.163 and a p-value of 0.87. Based on the aspect of mathematics anxiety, there is also no significant difference in mathematics learning anxiety and mathematics evaluation anxiety when compared before and after the implementation of project-based transdisciplinary assessment with each z value = -0.664, p = 0.506 and z = -0.931 and p = 0.352. The implication of this research is the need for a continuous, collaborative and institutional effort in the transdisciplinary application so as to improve the quantitative abilities of pre-service Biology Teachers.

Bermuli, J. E., & Tamba, K. P. (2021). Is project-based transdisciplinary assessment effective in reducing the Mathematical anxiety of pre-service Biology teacher?. *Biosfer: Jurnal Pendidikan Biologi, 14*(2), 238-249. https://doi.org/10.21009/biosferjpb.20556

INTRODUCTION

Mathematics cannot be separated from the field of Biology. Taylor et al.(2020) said that Calculus is a major component in developing the quantitative abilities of undergraduate Biology. Nevertheless, Biology students' have anxiety about mathematics that has been observed in various studies. Mathematical anxiety is experienced by almost everyone across ages, ethnics and disciplines (Batchelor et al., 2017; Birgin et al., 2010; Cargnelutti et al., 2017; Çatlioğlu et al.,2009; Ramirez et al., 2018; Rawa & Yasa, 2019; Rizta & Antari, 2018). The impact of this anxiety is the low desire of biology students to engage in learning activities, deepen their mathematical abilities (quantitative), low persistence when facing difficulties in learning mathematics, and the desire to continue to work in the field of biology (Matthews et al., 2010; Poladian, 2013; Wachsmuth et al., 2017). Previous studies have shown that mathematical anxiety includes increased physiological reactions, negative cognition and substandard performance when mathematical stimuli are presented (Hopko et al., 2003), namely in the form of math tests, number tests and math topics (Hopko et al., 2003; Núñez-Peña et al., 2013; Ramirez et al., 2018; Richardson & Suinn, 1972; Suratmi, Abdullah, & Taufik, 2017). It is based on this stimulus category that measuresment of mathematics anxiety are developed.

The assessment of mathematics anxiety was first carried out by Richardson and Suinn (1972) by developing the Math Anxiety Rating Scale (MARS). After MARS, various shorter scales have been developed, such as the Fennema – Sherman Mathematics Anxiety Scale (MAS), Sandman Anxiety Toward Mathematics Scale (ATMS), Math Anxiety Rating Scale-Revised (MARS-R), and Abbreviated Math Anxiety Rating Scale (sMARS) (Hopko et al., 2003; Primi et al., 2014). However, the psychometric properties of the various rating scales above have not been adequately tested (Hopko, 2003; Núñez-Peña et al., 2013; Primi et al., 2014). For that reason, an approach is needed so that the mathematics anxiety of biology students can be reduced or even eliminated. However, the psychometric properties of the various rating scales above have not been adequately tested (Hopko, 2003; Núñez-Peña et al., 2013; Primi et al., 2014).

Hopko et al. (2003) have developed a shorter (simpler) scale, namely the Abbreviated Math Anxiety Scale (AMAS). AMAS only contains nine statement items on a Likert scale. A high score indicates high math anxiety. AMAS classified the nine items into two factors. The first factor is mathematics learning anxiety, which is related to mathematics learning anxiety (eg listening to a lecture in mathematics class). The second factor is mathematics evaluation anxiety, which is more related to the test situation (for example thinking about the math test questions that will be faced) (Hopko et al., 2003; Primi et al., 2014). Various studies have shown that AMAS has good internal consistency for these two factors (Hopko et al., 2003; Primi et al., 2014; Vahedi & Farrokhi, 2011) and is ideal because it is simple (Carey et al., 2017). AMAS also has good internal consistency for various ages (Primi et al., 2014). For this reason, this study will use AMAS in measuring mathematics anxiety of pre-serviced Biology teachers.

BIO2010: Transforming Undergraduate Education for Future Research Biologists (NRC, 2003) suggests increasing the interdisciplinary between biology and mathematics. BIO2010 states that interdisciplinary will solve two issues, namely perception (in this case math anxiety) and performance (math ability). In fact, BIO2010 suggests that this interdisciplinary should be done from the first year (Matthews et al., 2010; NRC, 2003). This recommendation calls for changes to the curriculum, especially assessment.Recommendations suggest that assessment should be directed at interdisciplinarity by encouraging the use of mathematical skills in understanding biological contexts in both text and project form. Various studies have revealed various forms of assessment in calculus for biology (biocalculus). For example, research was done by Hester et al. (2014) who also developed an assessment that can test understanding of biological concepts and the ability to use mathematical skills in a biological context. In

particular, in the context of calculus, the BioCalculus Assessment has been developed through a modification of the Calculus Concept Inventory (Taylor et al., 2020).

Previous research and development of calculus assessments for biology has not been explored in the form of project-based assessments, in particular, in the form of project-based transdisciplinary assessments in biological calculus. In addition, the research has not yet explored the effect of the integration of the concepts of calculus and biology in the assessment of mathematics anxiety in biology graduate candidates. This is important, because one of the components of mathematics anxiety is mathematics evaluation anxiety (Hopko, 2003; Hopko et al., 2003; Richardson & Suinn, 1972). Project-based transdisciplinary assessment provides direct experience for pre-service Biology Teachers in using calculus concepts in understanding biological phenomena. However, no studies have examined the relationship and its effect on the level of mathematics anxiety of pre-service Biology Teacher.

Interdisciplinary assessment or interdisciplinary assessment is an assessment of a task from two or more disciplines (Shen, Liu, & Shannon, 2014). In line with this, Gao, Li, Shen and Sun(2020) explained that an interdisciplinary approach emphasizes interdisciplinary connections in an activity. Project-based interdisciplinary assessment is an interdisciplinary activity that enables students to integrate knowledge from several disciplines and gain understanding with a longer period of time (Drake & Reid, 2017). Thus, project-based interdisciplinary assessment or project-based interdisciplinary assessment is an activity or task or project carried out by integrating several disciplines, with the aim that students have a complete and comprehensive understanding.

In this research, a project-based transdisciplinary study was carried out in the form of a mini-research with the topic "Data Collection on Local Wisdom in Each Region". In this mini research, pre-service Biology teacher will conduct research on the population, growth and distribution of endemic plants or animals or those most widely used by the surrounding community which is the topic of the Ecology course. This data will be analyzed using the calculus concepts studied in the Calculus for Biology course. This study aims to examine the effect of implementing a project-based transdisciplinary assessment on mathematics anxiety of pre-service Biology Teacher. This means that this study will examine differences in the level of mathematics anxiety of pre-service Biology Teachers after participating in a project-based transdisciplinary assessment. Therefore, the question that guides this research is whether there is a significant difference in the mathematics anxiety level of pre-service Biology Teacher after taking the project-based transdisciplinary assessment?

Mathematics cannot be separated from Biology. Almost all domains in biology must be taught with input and collaboration with mathematics (Hoskinson, 2010). Especially in research, mathematics (quantitative ability) is used to understand biological phenomena and systems (Cohen, 2004). One of the important topics in mathematics that is needed is calculus. Calculus is a major component in developing the quantitative abilities of undergraduate biology (Bressoud, 2015; Bressoud et al., 2013; Taylor et al., 2020). Pre-service Biology teacher who are the subjects of this study have moderate mathematics anxiety for the learning component and high for the assessment of mathematics learning. Mathematics anxiety problems can have a negative impact on students majoring in Biology because it will affect the performance, ability and also the desire of students to explore mathematics (Matthews et al., 2010; Poladian, 2013; Wachsmuth et al., 2017). Therefore, this research is needed to see the effectiveness of implementing project-based Transdisciplinary Assessment in an effort to reduce the level of mathematics anxiety in Biology teacher students. Research that is generally carried out is research for students majoring in Biology. Until now there have not been many studies that discuss mathematics anxiety in Biology Education students who will become pre-service Biology teachers so that this information can be used as a benchmark for further research on mathematics anxiety in pre-service Biology teacher.

METHODS

Research Design

This study was a pre-experimental. The design used was a pretest and posttest with one non-random group (nonrandomized one group pretest-posttest design) (Creswell, 2012). The variables in this study were mathematics anxiety and transdisciplinary assessment. Mathematical anxiety is the dependent variable while transdisciplinary assessment is the independent variable. Internal and external validation of this experimental study confirms the results of the study are the result of a project-based interdisciplinary assessment treatment (Creswell, 2012).

Population and Samples

Respondents in this study were 23 pre-service Biology Teacher class 2019 (5 men, 18 women). The selection of participants was carried out purposively, namely pre- service Biology Teachers who are currently taking calculus courses in the field of biology and ecology. This was done because the transdisciplinary project was carried out in collaboration with the two courses. Before attending Calculus for Biology courses, respondents had completed statistics and essential mathematics courses. This means that in addition to Calculus for Biology, mathematical knowledge and abilities have also been introduced in previous courses.

Instrument

Quantitative data on mathematics anxiety were collected using a mathematics anxiety questionnaire. This questionnaire uses the AMAS (Abbreviated Math Anxiety Scale) (Hopko et al., 2003) as a measure of mathematics anxiety. The original AMAS questionnaire (see Hopko et al., 2003) was translated into Indonesian. The nine items in AMAS are grouped into two aspects of mathematics anxiety, namely mathematics learning anxiety (5 items) and mathematics evaluation anxiety (4 items). AMAS uses a Likert scale with a 5-point scale, from 1 (low anxiety) to 5 (high anxiety). AMAS is used because this instrument is a development and simplification of the previous Mathematical Anxiety instrument (Hopko, 2003; Richardson & Suinn, 1972) which contains 98 items. AMAS contains only nine items. The results of this simplification produce a more valid and reliable Mathematical Anxiety instrument (Hopko et al., 2003). Therefore this study uses AMAS as an instrument to measure Mathematical Anxiety. Table 1 is the indicators and statement items from AMAS.

Table 1
Statement items in the AMAS questionnaire

Aspect	Statement	Item Number
Mathematics learning anxiety	Must use the table at the back of the math book.	1
	Watch or listen to the teacher or lecturer working on the math equations on the board.	3
	Listen to lectures or explanations in math class.	6
	Listening to other students explain math formulas.	7
	Starting a new topic in mathematics learning / lectures.	9
Mathematics Assessment Anxiety	Thinking about the math exam questions that will come 1 (one) day in advance.	2
	Take a class test or math class.	4
	homework assignments were given in the form of difficult questions for the next meeting.	5
	Unexpectedly given a quiz in math class.	8

Before use, the validity and reliability of the mathematics anxiety questionnaire with AMAS were tested. As a result, the Pearson correlation value for each item is in the range of 0.574 to 0.799 and is significant for $\alpha = 0.05$. This value indicates that the validity of the

instrument is acceptable. The Cronbach's Alpha value of 0.877 (greater than 0.5) indicates that the questionnaire has a high level of internal consistency (reliability). Meanwhile, for each factor, it also has a high level of internal consistency, namely the Cronbach's Alpha value for mathematics learning anxiety of 0.92 and for mathematics evaluation anxiety of 0.856.

There are two mathematics anxiety data collected, namely pretest and posttest data. Mathematics anxiety pretest data were collected prior to the implementation of the project-based transdisciplinary assessment. Posttest data were collected after the pre-service Biology Teacher completed the project-based transdisciplinary assessment report. The pretest and posttest data were collected using Microsoft form.

Research Procedure of Project-based Transdisciplinary Assessments

Project-based transdisciplinary assessment is a collaboration of the Calculus course for Biology and the Ecology course. The project-based transdisciplinary assessment becomes the final exam for both courses. The results of the pre-service Biology Teacher's work on the project-based transdisciplinary assessment will be assigned jointly by the two lecturers (researchers). Project-based transdisciplinary assessment in the form of simple research (mini research) with the topic "Data Collection on local wisdom in each area". This simple research was conducted in groups.

The mini research subjects in this transdisciplinary assignment are plants or animals that have become icons in the area or endemic plants or animals or those most widely used by the surrounding community. The data collection on endemic plants or animals is adjusted to the topic of the Ecology subject, namely data collection on local wisdom in the form of plants and animals around their living area. There are eight steps in this mini-research. First, pre-service Biology Teacher divided into 5 groups according to the 5 major islands in Indonesia. Second, a pre-service Biology Teacher has completed a math anxiety pre-test. Third, each group determines the research subject that will be studied, namely the type of animal or plant in the area. Fourth, each group was asked to collect data on their research subject. This mini-research is conducted over 14 weeks, starting from the first week of lecture. Within a period of 14 weeks, pre-service Biology Teachers in groups received guidance from each lecturer. The ecological data obtained is being searched for patterns using the concept of Calculus, for example the group that analyzes the monkey population, looks for the growth function of the population. Fifth, at the 15thmeeting, students and lecturers discussed the research results and also finishing. During the meeting, the two lecturers of Calculus and Ecology comments and input on research data from each group are provided. Sixth, each group makes a report according to its format: (i) background; (ii) review of the theoretical concept of ecology; (iii) a theoretical review of the calculus concepts used; (iv) methodology; (v) data analysis (using Ecological concepts and Calculus) and (vi) conclusions. Seventh, each group should submit the report not more than the 16th meeting. Eighth, the pre-service Biology teacher completes the post-math anxiety test.

The final result of this mini research is that students are able to see the integration between two different disciplines and to study research more creatively and provide a deeper understanding of the concepts of two different subjects. This is in accordance with the research conducted by Drake and Reid (2017) explaining that interdisciplinary assignments start from identifying the big picture of what to be researched, understanding enduring understanding, and the abilities to be achieved in the two courses.

Data Analysis Techniques

Data analysis used descriptive and inferential statistics. Descriptive statistical analysis was conducted to describe the level of mathematics anxiety before (pretest) and after (posttest) the application of project-based transdisciplinary assessment. The description of the level of

mathematics anxiety is also presented based on two factors of mathematics anxiety, namely mathematics learning anxiety and mathematics evaluation anxiety. Analysis with inferential statistics using the Wilcoxon signed ranks test. The analysis was performed using the SPSS 20.0 software rock. In this study, prerequisite tests such as the normality test and the homogeneity test were not carried out because the statistical tests used to answer the research questions were non-parametric statistics which did not require a normality test and a homogeneity test.

RESULTS AND DISCUSSION

In the research conducted, students were given a pre-test and post-test to determine the level of mathematics anxiety of each student. The results of the descriptive analysis of mathematical anxiety levels based on the pre-test and post-test that have been carried out are shown in Table 2.

Table 2
Descriptive level of mathematics anxiety in the pretest and posttest

	Min		Max		Mean		SD	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Mathematics anxiety	15.00	13	38.00	38.00	29.22	29,00	5.53	6.86
Mathematics learning anxiety	6.00	5	19.00	23.00	13.70	14.04	3.31	4.64
Mathematics evaluation anxiety	9.00	8	19.00	20.00	15.52	14.96	2.61	2.70

Tabel 2 explained that the average score of mathematics anxiety in the pre-test was 29.22. Meanwhile, during the post-test, the score of mathematics anxiety was 29.00. This means that mathematics anxiety is very small, which is 0.22 after the Project-based Transdisciplinary Assessment is applied. Meanwhile, based on the mathematics anxiety aspect, the average score of the mathematics learning anxiety aspect in the pre-test was 13.70. Compared with the post-test average of 14.04, there was an increase in mathematics anxiety in the aspect of learning mathematics after the implementation of the Project-based Transdisciplinary Assessment. The increase in the average score for the anxiety aspect of learning mathematics is 0.34. For the aspect of mathematics evaluation anxiety, the mean pre-test score was 15.52 and the post-test score was 14.96. There was a decrease in the average score of mathematics evaluation anxiety by 0.56. Descriptively, these findings indicate that there is a small decrease in the average score of mathematics anxiety and aspects of mathematics evaluation anxiety, while aspects of mathematics learning anxiety is increase.

The results of this study indicate that there is no significant difference in mathematics anxiety experienced by pre-service Biology Teacher after implementation of the Project-based Transdisciplinary Assessment. Indeed, there were changes in the mean score of mathematics anxiety, aspects of mathematics learning anxiety and aspects of mathematics evaluation anxiety, but the differences were very small (respectively, 0.22; 0.34; 0.56). In fact, the anxiety aspect of learning mathematics is getting higher after the implementation of project-based transdisciplinary assessment. The findings show that although there is a decrease in total mathematics anxiety after the implementation of the project-based transdisciplinary assessment, there is no statistically significant difference (decrease). The results of this study are different from literature and previous studies which reveal that applying an interdisciplinary approach will significantly reduce math anxiety (Gross, 2004; Hester et al., 2014; Matthews et al., 2010; NRC, 2003, 2009; Wachsmuth et al., 2017).

The Wilcoxon signed ranks test was performed to determine whether there was a statistically significant difference from pre to post-test for math anxiety as well as for each aspect of anxiety (Table 3). For mathematics anxiety, there was no statistically significant difference between the pre-test and post-test scores (Z = -0.163; p = 0.87> 0.05). Meanwhile,

for the anxiety aspect of learning mathematics, there was also no statistically significant difference between the pre-test and post-test scores (Z = -0.664; p = 0.506> 0.05). Likewise with the aspect of mathematics evaluation anxiety, there was no statistically significant difference between the pre-test score and the post-test score (Z = -0.931; p = 0.352> 0.05). These results indicate that the anxiety experienced by pre-service Biology Teachers about mathematics does not change significantly after the implementation of the Project-based Transdisciplinary Assessment. Likewise for every aspect of anxiety, there was no significant change after the implementation of the Project-based Transdisciplinary Assessment. This result occurs because the level of math anxiety decreased only 0.22 from pre-test to post-test. There was even an increase in mathematics anxiety in the anxiety aspect of learning mathematics from pre-test to post-test of 0.34.

Table 3
Result of Wilcoxon signed ranks test

	***Z*-value**	***p*-value**
Mathematics anxiety	-0.163	0.870
Mathematics learning anxiety	-0.664	0.506
Mathematics evaluation anxiety	-0.931	0.352

Based on the results of the Wilcoxon signed ranks test regarding the significance of the difference between the pre-test and post-test results for mathematics anxiety, the results showed an insignificant decrease (Table 3). This insignificant reduction in math anxiety levels can be due to several reasons. First, previous research has shown that the interdisciplinary approach in biological calculus is a complex and often fundamental failure (Bressoud, 2020). Students experience stress because seeing an interdisciplinary approach makes lectures more difficult, because methods that are not new (unusual) confuse them (Bressoud, 2020). In addition, previous research shows that students are often frustrated because the interdisciplinary approach adds more learning load and requires more initial knowledge (Matthews et al., 2009). Pre-service Biology teachers find this interdisciplinary approach difficult and confusing, because they have to link knowledge and lecture activities in calculus biology courses with ecology courses. It is different from the conventional approach where prospective biology teachers do not need to think about and link the concepts in one course with concepts in other courses.This provides reasons and rationalization for the increase in the anxiety level of mathematics learning after the application of project-based transdisciplinary assessment. However, further research is needed to obtain the perception of prospective pre-service Biology Teachers regarding the application of project-based transdisciplinary assessment. Second, transdisciplinary application requires continuous effort and continuous initiative (Bressoud, 2020).

Previous research has shown that interdisciplinary results only show results when carried out for a long time, for example more than twice (Mayes et al., 2020) and even several years (Matthews et al., 2013). By doing it in a sustainable manner, pre-service Biology Teachers will be more familiar with the approach given. This is also consistent with the findings of this study which indicate that the level of anxiety in the aspects of learning mathematics is higher after the application of project-based transdisciplinary assessment. Third, transdisciplinary application requires collaboration and support from communities and institutions. Various studies have recommended that interdisciplinary implementation requires serious community and institutional support in both curriculum policies and management policies (Eaton, LaMar, & McCarthy, 2020; Eaton, LaMar, & McCarthyc, 2020; Eaton & Highlander, 2017; Gross, 2004; Jungck et al., 2020; Thompson et al., 2013).

Based on the results and analysis of findings, this study contributes to the development of knowledge and research on transdisciplinary application in two ways. First, this study shows that it is necessary to carry out an transdisciplinary assessment continuously and for a long time to reduce mathematics anxiety in pre-service Biology Teachers. The potential for reducing (although not statistically significant) mathematics anxiety by conducting a transdisciplinary assessment exists. Second, the implementation of transdisciplinary assessment needs to be carried out simultaneously with changes in approaches and even curricula in biology education. Therefore, this transdisciplinary assessment is important so that pre-service Biology teacher can use mathematical concepts in analyzing and finding answers to problems in their natural surroundings.Thus, pre-service Biology Teacher do not consider transdisciplinary assessment to be a new learning load. It can be seen that there is a decrease in anxiety (although it is not statistically significant) in the aspect of evaluating mathematics but in the aspect of learning mathematics it is even higher. Therefore, this transdisciplinary assessment is important so that pre-service Biology teacher can use mathematical concepts in analyzing and finding answers to problems in their natural surroundings.

The results of the above research must be viewed in terms of several limitations. First, even though the validation has been carried out, the AMAS instrument used has not undergone modification and contextualization in the conditions of pre-serviceBiology Teachers in Indonesia. Meanwhile, various previous studies have modified and contextualized the country (for example, Milovanović & Branovački, 2020; Núñez-Peña et al., 2013). Second, this study has not explored the responses and perceptions of pre-serviceBiology Teachers to the implementation of the project-based transdisciplinary assessment. Thus, the factors that cause no difference in the level of mathematics anxiety before and after the implementation of the project-based transdisciplinary assessment approach have not been revealed. This can be an issue that further research needs to explore.

CONCLUSION

The conclusion of this study is that although there is a decrease in the mathematics anxiety level of pre-serviceBiology Teachers after the implementation of the project-based transdisciplinary assessment, statistically there is no difference when compared to the anxiety level before and after. Based on the aspect of mathematics anxiety, there is also no significant difference in mathematics learning anxiety and mathematics evaluation anxiety when compared before and after the application of project-based transdisciplinary assessment. The results of this study have implications for further research and Biology Teacher education. Future research needs to explore the responses and perceptions of pre-service Biology Teachers to the implementation of a project-based transdisciplinary assessment. In Biology Teacher education, a continuous, collaborative and institutional effort is needed in transdisciplinary applications so as to improve the quantitative abilities of pre-service Biology Teachers. Based on the results of the above research, it is suggest that the implementation of the transdisciplinary assessment needs to be carried out since the first semester of the biology teacher candidate education program. In addition, transdisciplinary assessments need to be carried out by institutions, not just on specific course initiatives. This is important so that pre-servicebiology teachers do not see this as a new burden in their studies, but as a curriculum that they have to live with. The results of the above research must be seen from several limitations. First, even though the validation has been carried out, the AMAS instrument used has not undergone modification and contextualization in the pre-service conditions of Biology Teachers in Indonesia. Meanwhile, various previous studies have transformed and contextualized the country (eg, Milovanović & Branovački, 2020; Núñez-Peña et al., 2013). Second, this study has not explored the responses and perceptions of pre-service Biology Teachers to the implementation of project-based transdisciplinary assessments. Thus, the

factors that cause no difference in the level of mathematics anxiety before and after the application of the project-based transdisciplinary assessment approach have not been revealed. This could be a problem that requires further research.

ACKNOWLEDGMENT

Thank you to the Pelita Harapan University, for all its support, both in terms of research permits and funding this research. This research is carried out through a performance contract with numbers P-006-FIP/II/2021, February 16th, 2021.

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