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ACADEMIC RESILIENCE AND SCIENCE ACADEMIC EMOTION IN NUMERATION UNDER ONLINE LEARNING: PREDICTIVE CAPACITY OF AN ARTIFICIAL NEURAL NETWORK

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ABSTRACT

The main objective of this study is to predict student academic resilience based on academic emotions in studying numeration and science under online learning. Many researchers have analyzed student academic resilience and online learning. Unfortunately, only a few similar research topics focus on numeration and science. 191 students at a university in Central Java Province have been randomly selected as research samples. Academic resilience is classified into three groups: low, medium, and high. The academic emotions were measured using three indicators: class-related emotions, learning-related emotions, and test emotions. This study uses an artificial neural network (ANN) to obtain predictive values. The results indicate that the level of academic resilience and academic emotion in numeration and science under online learning is in the medium category. The results also show that the relative error provides a fairly small percentage, namely 19.7% at the training stage and 25% at the testing stage. This refers to the prediction results having a good level of accuracy. Predictive estimation results also indicate that class-related emotions are predicted to be the aspect that has the most crucial impact on students' academic resilience, in which the normalized importance value is 100.0%. It is followed by the aspect of learning-related emotions (65.0%) and test emotions (24.3%). The implication is that the aspect of class-related emotions should get better attention from lecturers and students so that students can increase their chances of getting a good level of academic resilience in numeration and science.

Keywords: academic resilience; artificial neural network; numeration; online learning; science emotion

INTRODUCTION

Mathematics and science continue to be unappealing to high school and university students. This may cause Indonesian students' math and science literacy scores to be very low (OECD, 2019). Several studies report how Indonesian students deal with various difficulties in understanding concepts in mathematics and science (Mahmudah et al., 2020; Mulbar & Bahri, 2021; Permanasari et al., 2021; Utomo & Syarifah, 2021). Mathematics and science have a symbiotic relationship of mutualism that cannot be separated from one another. The two have a very close and mutually beneficial relationship (Oppermann et al., 2021; Rodin, 2021). Moreover, along with the development of science and technology, the relationship between the two sciences is increasingly visible. Furthermore, it is undeniable that mathematics and science have contributed significantly to various life fields.

Based on initial observations made by researchers on online learning, it was found that most students were less motivated to follow and

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study mathematics and science materials given by lecturers. They were also less active in carrying out the tasks, both individual and group assignments. The difficulty understanding the math and science material caused the students not only to be less interested in participating in the online learning process but also, they tended to have less focus. The results of these initial observations were in line with research published by experts who reported that students tended to be less interested in math and science material (Fong et al., 2021; Levy et al., 2021; Starr & Simpkins, 2021; Thompson, 2021). Moreover, if learning mathematics and science are done with an online system, then it will have more challenges.

The online learning system can run well if students can stay focused on learning well (Pantu et al., 2021; Psotka, 2022). There are several difficulties with online distance learning for students, which raises questions about their academic resilience (Yu & Huang, 2022). The importance of networking and collaboration in terms of technological advancement, preparedness for other dangerous risks, and most importantly, security issues may help universities work together to overcome challenges during online learning, increasing the resilience of students and teachers in higher education institutions (Kibria & Abedin, 2022). Student academic resilience becomes very important in online learning systems. Academic resilience and online learning satisfaction can influence students' readiness to learn independently. The level of student academic resilience is also positively related to learning readiness, where a higher level can increase online learning readiness, which in turn increases students' online learning satisfaction (Kumalasari & Akmal, 2021).

Academic resilience refers to academically strong students who can maintain the motivation to excel and have good academic performance despite facing various stressful events and conditions that may decrease their performance in school. Five things affect students' academic resilience: self-efficacy, planning, control, low anxiety, and persistence (Martin & Marsh, 2006). Academic resilience is essential to be explored because it can reduce academic stress. Students with good academic resilience can turn threats into opportunities to grow and develop for good change (Masten et al., 2021). A report stated that students' academic resilience was able to become a moderator in reducing the effects of academic stress on online learning satisfaction (Kumalasari & Akmal, 2021).

Many studies report students' academic resilience in online learning (de los Reyes et al., 2021; Grande et al., 2021; Wang et al., 2022). One study reports on how international students at Malaysian universities maintain academic resilience in online learning during the COVID-19 pandemic (Singh, 2021). Several studies on the same topic also have been conducted on Indonesian students (Pantu et al., 2021; Permatasari et al., 2021). Another study reported that increasing students' academic self-efficacy increased academic flow (Pantu et al., 2021). This is closely related to academic stress, which is also related to students' academic emotions. Both students' academic self-efficacy and students' academic emotions can affect students' academic performance. The low interaction between lecturers and students can produce various obstacles affecting their psychology. Academic resilience as a psychological skill can overcome student stress and stimulate satisfaction during the online learning period (Kumalasari & Akmal, 2021). Thus, students' academic resilience and emotions in learning mathematics and science must be analyzed more comprehensively.

However, only some studies related to academic resilience are based on the academic emotions of science under online learning focused on numeration and science for university students. Both of them are known to have difficulty and complexity. Previously, most research only looked at factors related to student academic resilience during a pandemic, rarely analyzing their predictions. Moreover, studies that analyze its predictive capacity based on the academic emotion of science are very difficult to find. In addition, online learning is increasingly putting pressure on students to understand numeration and science material. Then, students increasingly need help understanding various concepts in mathematics and science through online learning. Moreover, according to a report, Indonesian students lack science achievement in the science learning process (Mahmudah et al., 2018; Utomo & Syarifah, 2021). The difficulties of mathematics and science, the lack of interest, and low motivation can cause the student even more depressed and affect the students' academic resilience. Hence, it is necessary to maintain the students' academic resilience to be constantly motivated and active in learning mathematics and science because they will be able to maintain academic achievement even though they are in less-than-ideal academic situations.

This study aims to predict student academic resilience during online learning by implementing an artificial neural network (ANN) with a multilayer perceptron based on five indicators;

self-efficacy, planning, control, low anxiety, and persistence. This model's strength is its ability to study the representation in the used data and to relate it to the output variable for prediction (Netsanet et al., 2022). In other words, neural networks can study mapping. They can learn any mapping function and have proven to be mathematically universal approximation algorithms. The predictive ability of neural networks is the outcome of the hierarchical or multi-layered structure of the network (Wang et al., 2022).

This research aims to analyze the predictive capacity of students' academic resilience based on the science academic emotions under online learning. It focuses on student resilience in numeration and science courses because both courses are almost available in all majors at the university. Both of them are considered as necessary competencies of college graduates. In addition, the initial observations made by the researcher also found that some students intentionally took specific majors to avoid mathematics or science class. This research is expected to provide a more comprehensive understanding that can be used as a benchmark for various stakeholders, such as students, lecturers, and academics on campus, to maintain academic resilience when academic situations are not ideal or change immediately. Students' academic resilience needs to be maintained because it will impact their academic performance, which is closely related to the quality of learning.

METHODS

To obtain adaptive predictive results on student academic resilience during the online learning period, this study applies a quantitative approach by conducting a survey (Sugiyono, 2013; Creswell & Creswell, 2018). This research at UIN K.H. Abdurrahman Wahid Pekalongan in Central Java, Indonesia. The technique for data collection is carried out by purposive sampling, which is based on considering the researcher as well as the relevance of the research. The consideration used in this study is that the sample selection is targeted at those who have been enrolled currently or have completed mathematics and science courses. This is undertaken to obtain the data relevant to the study's primary purpose. Sample data was obtained by distributing questionnaires to 191 samples that have completed or are currently joining the mathematics and science courses.

Before distributing the instrument to the respondents, the validity and reliability tests are carried out first. This phase ensures that the instrument used is valid and reliable then the results of research conclusions can be accounted for. The validity test results indicate that all statement items are said to be valid based on a significance level of 0.05, where the calculated r-value is greater than the r-table value = 0.14. Meanwhile, the reliability test also indicates that Cronbach's alpha value is more than 0.60, which means the research instrument is reliable

The instrument of academic resilience measurement uses a questionnaire adapted from Martin and Marsh, which includes five aspects: self-efficacy, control, planning, low anxiety, and persistence (Martin & Marsh, 2006). The questionnaire was prepared using a Likert scale with four alternative answers: strongly agree, agree, disagree, and strongly disagree. The academic resilience measurement instrument consists of 26 statement items. The self-efficacy variable consists of 7 statement items, the control variable includes 5 statements, the planning variable consists of 4 statements, the low anxiety variable contains 5 statements, and the persistence variable includes 5 statements.

The instrument for measuring emotions in academic science uses the Achievement Emotions Questionnaire (AEQ) scale, which consists of 24 question items with three indicators measured, namely Class-related emotions (X1), Learning-related emotions (X2), and Test emotions (X3) (Pekrun et al., 2011). The indicators of classroom and learning emotions assess boredom, hopelessness, anger, anxiety, enjoyment, pride, hope, and shame. While the emotional component of the test also assessed the same things as classroom and learning emotions, boredom was replaced with relief. For the three emotional components, the items are ordered in three ways, namely before (before), during (during), and after (after) doing class/learning and evaluation/test. The AEQ instrument was made using a Likert scale with four alternative answer choices (Strongly Agree, Agree, Disagree, and Strongly Disagree).

This study implements a multilayer perceptron network on an artificial neural network (ANN) to obtain predictive results of student academic resilience in science and mathematics courses during online learning. ANN is the backbone of deep learning algorithms, which is a sub-field of machine learning. ANN is related to information processing, which is inspired by the way biological nervous systems, such as the brain is for processing information. The key element of this model is the new structure of the information processing system, which consists of a large number of highly interconnected processing elements (neurons) that work together to solve a particular problem. A perceptron is a neural network with only one neuron, and it can only understand the linear relationship between a given input and output data. However, with Multilayer Perceptron, the horizon can be expanded so that neural networks can have many layers of neurons to study more complex patterns. This is because the Multilayer Perceptron procedure produces a predictive model for one or more dependent variables based on the values of the independent variable (predictor).

To obtain the optimal solution, two numbers of hidden layers were used in this research, while the activation function used is the hyperbolic tangent function. The hidden layer in ANN refers to the layer between the input and output layers, where the artificial neuron takes a set of weighted inputs and produces output through an activation function. When the dimensions and data features used are more complex than the number of hidden layers should be high to get the optimal solution. The dependent variable is the student's academic resilience, which is categorized into three groups (low = 1; moderate = 2; and high = 3). The independent variables are the academic emotions of science students, which consist of three dimensions, namely class-related emotions (X1), learning-related emotions (X2), and test emotions (X3). The nominal status chosen is gender. Regarding the partition of the total cases used, this study instructed the network to use 70% for the platinum phase and 30% for the test phase. However, the network will automatically and randomly adjust the percentage. The result of network adjustment, in the end, gave 66.5% (127 cases) in the training phase and 33.5% (64 cases) in the testing phase.

RESULTS AND DISCUSSION

In this study, an artificial neural network (ANN) was used to create predictive capacity on students' science emotions based on their academic resilience during the online learning period due to the COVID-19 pandemic. The general description of respondents can be described as follows. The average age of the respondents is 22 years, with the youngest age being 19 years and the oldest respondent being 24 years old. The majority of them are in the 6th semester of college.

In general, students' academic resilience is in the medium category. Figure 1 below illustrates the proportion of students' academic resilience levels in mathematics and science courses.

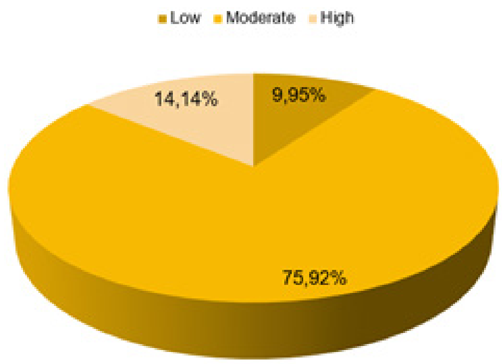

Figure 1. Student Academic Resilience

Figure 1 shows that most students have moderate academic resilience in mathematics and science, as many as 145 students (75.92%). Meanwhile, 19 students had low academic resilience (9.95%), and 27 students had high academic resilience (14.14%). These results indicate that the resilience of respondents in this study has moderate academic resilience. Hence, it can be said that they are projected to have moderate achievements even though good conditions or backgrounds do not support them. This is in line with previous research, which stated that academic resilience refers to students' capacity to have maximum achievements during unfavorable conditions (Ye et al., 2021).

Meanwhile, Figure 2 shows the emotional level of students' academics. Academic emotions are related to the ability of students to control emotions in stressful or unpleasant situations. It is also related to the student's ability to manage stress to maintain their academic achievement.

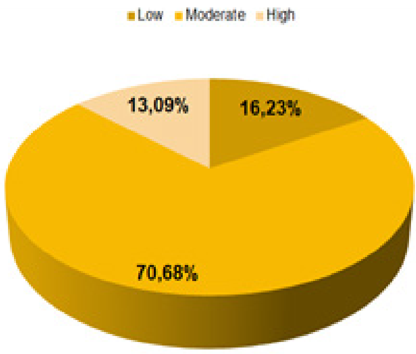

Figure 2. Student Academic Emotions

Based on Figure 2, most respondents have moderate academic emotions, which more than 70% are in this category. Students who have low and high academic emotions are 16.23% and 13.09%, respectively. These results indicate that the respondents' academic emotions are projected to be in the moderate category even though good conditions do not support them. High academic stress can affect student life, including academic achievement (Flores et al., 2022). Moreover, when high academic stress with effects in the form of physical disorders, then it will be a bad influence on the students. To reduce the impact of stress, it is necessary to be able to control emotions in stressful or unpleasant situations. The ability to manage stress will allow the students to maintain their academic performance.

The lack of student motivation in mathematics and science courses impacts their persistence in understanding the material provided. The difficulties students face can also disrupt their mental health, especially in the online learning model (Fatimah & Mahmudah, 2020). Although the COVID-19 pandemic has been increasingly controlled, some universities are still implementing online learning systems, both full online learning and blended learning. Psychologically, it takes work for students to adapt. A report states that the most common symptom of depression and anxiety during online learning is dissatisfaction with academic performance, which tends to decrease (Bolatov et al., 2021). Other studies report that academic stress negatively affects satisfaction with online learning (Tan et al., 2021).

An ANN is a mathematical nonparametric model consisting of a set of interconnected processing units called "neurons", which are adaptive and trainable. The ANN design in this study is an ANN with three layers, which include one input layer, two hidden layers, and one output layer, as shown in Figure 3.

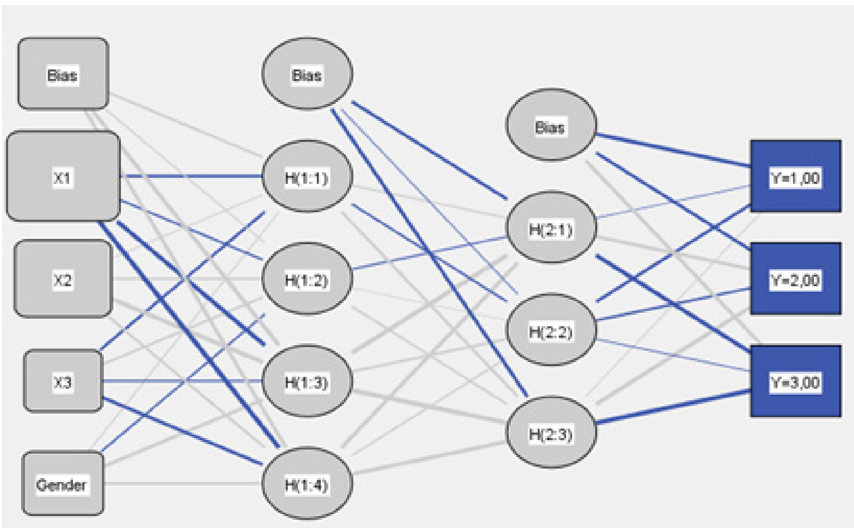

Figure 3. ANN Design for Predicting Student Academic Resilience

Figure 3 shows an ANN consisting of four units of input layers that function as covariates, namely class-related emotions (X1), learning-related emotions (X2), test emotions (X3), and gender. The number of hidden layers is 2, while the number of units in hidden layer 1 is 4 layers, and the number of units in hidden layer 2 is 3. Then, the output layer is one dependent variable, namely academic resilience with the number of units equal to three. This study uses an activation function in the form of a sigmoid function in both the hidden and output layers. This function is defined by $\gamma(c)=1/(1+e^{(-c)})$, which takes a real-valued argument and converts it to a range (0, 1). Then, the error function in the output layer is a sum of squares.

Figure 3 also shows that two lines represent synaptic weight in a neural network, which refers to the strength or amplitude of the connection between two nodes. Synaptic weight displays an estimated coefficient that shows the relationship between units in a certain layer and units in the next layer. Synaptic weights are based on training samples even if the active data set is partitioned into training, test, and storage data. The thick blue synaptic weight line indicates "negative impact" or synaptic weight < 0. Conversely, the gray line refers to "positive impact" or synaptic weight > 0, which indicates the weight diverges considerably from 0. Based on Figure 3, X1 (class-related emotions) has the most synaptic weight, indicating the coefficient estimate. Also, it can be seen that test emotions (X3) have more coefficient estimates than learning-related emotions (X2). If all weights are initialized to zero, the derivative will remain the same for each weight. Furthermore, Figure 3 also shows that the output layer comprises three nodes, representing three categories of student academic resilience: low, medium, and high. In the meantime, the boxes called bias are designed to correct systematic errors in the predictions.

Table 1 indicates the relative error or percentage of incorrect predictions based on the neural network design and procedures used.

Table 1. Results of ANN Prediction Analysis

Categories	Training phase	Testing phase
Sum of squares error	19.65	13.01
Percent incorrect predictions	19.7%	25.0%
Percent correct predictions	80.3%	75.0%

The error is the sum-of-squares error because the activation function at the output layer is sigmoid. The relative error or percentage of incorrect predictions depends on the dependent variable's measurement level. If all dependent variables are categorical, then the average percentage of incorrect predictions will be displayed. The relative error or percentage of incorrect predictions is also shown for the individual dependent variables. Table 1 indicates that the percentage of prediction errors is 19.7% in the training phase and 25% in the testing phase. This also implies that 80.3% of the prediction analysis results are correct at the training phase and 75% at the testing phase. These numbers show prediction results with a good level of accuracy. Hence, it is safe to conclude that the estimation of the neural network in this study is appropriate.

Table 2 shows the importance of each predictor variable in predictive analysis using a predetermined ANN design and its normalized magnitude.

Tabel 2. Independent Variable Importance

Variables	Importance	Normalized Importance
Class-related emotions (X1)	0.455	100.0%
Learning-related emotions (X2)	0.296	65.0%
Test emotions (X3)	0.111	24.3%
Gender	0.138	30.2%

Table 2 indicates the sensitivity analysis, which calculates the importance of each predictor in determining the artificial neural network (ANN). All independent variables are represented by percentage numbers that indicate their importance in influencing output, especially the level of academic resilience of students under online learning. The analysis is based on a combined training and testing sample. It should be noted that computational sensitivity analysis is expensive and takes a relatively long time if there are many predictors or cases. Table 2 shows that the gender predictor variable has an essential contribution to the predictive analysis of student academic resilience based on the academic emotions of science in online learning, which is 30.2%. According to the findings of the study, female students not only have a higher level of academic resilience than male students, but they also have a higher level of academic emotion. As a result, it is not surprising that they have greater endurance in maintaining academic performance on numeracy and science materials under learning online. This discovery is consistent with a study finding that student gender is a significant predictor of quality of life and academic resilience (Berdida & Grande, 2021). Another study with a similar report finds a statistically significant difference in ASE (academic self-efficacy) based on gender, with female students outperforming male students (Warshawski, 2022). These findings could be attributed to women's superior social-emotional development and concern for others. Besides being known to be more diligent in doing the tasks assigned by the lecturer, female students also have better relationships and communication with fellow students and lecturers.

Furthermore, Table 2 shows that class-related emotions have been identified as the most crucial variable in suggesting if students have low, medium, or high academic resilience based on science academic emotion under online learning. The predictive analysis results also imply that class-related emotions affect academic resilience more than learning-related emotions and test emotions. In another way, compared to the other two indicators in science academic emotions, test emotions have the least effect on students' academic resilience levels. Likewise, if students want to know how to increase the likelihood they will have high academic resilience, they would also focus on their class-related emotions. Regardless, the other two variables, learning-related emotions and test emotions, should be considered because they also have an impact.

Therefore, the matters related to the aspect of class-related emotions need more attention from lecturers and students so that students' academic resilience when learning time can use the Non-Face to Face (NF2F) method. For example, by creating online math and science classes, students can enjoy the classes so that they feel comfortable, do not give up easily, and do not get bored quickly. In addition, it is also necessary to create a math and science classroom environment that can increase students' confidence when taking online math and science classes. Class environments that should be avoided by lecturers and students in online math and science courses include classes that can make students 1) feel angry after taking online math and science classes, 2) feel uncomfortable when learning math and science online, 3) feel less confident in math and science classes, and 4) feel bored and hopeless when math and science classes are online.

Meanwhile, related to aspects of learning-related emotions (X2), the lecturers can create mathematics and science learning under online learning that can make students: 1) feel enjoy and happy when they get new science knowledge, 2) feel optimistic about science learning that they will learn, and 3) feel proud after participating in online science learning. Thus, online science learning is attempted not to make students: 1) feel tense and nervous during science learning, 2) feel embarrassed because they cannot absorb science material well, 3) feel hopeless when thinking about learning science, and 4) feel very bored when online science learning is running.

Furthermore, in the aspect of test emotions (X3), the lecturers can create an evaluation system for mathematics and science courses that can make students: 1) feel challenged and fun when taking tests/exams for mathematics and science subjects under online learning, 2) have high expectations for students mathematic and science abilities, and 3) feel happy and proud when taking science exams/tests. On the other hand, the lecturers should not create student evaluation schemes for mathematics and science courses online that make students: 1) feel annoyed after taking a science exam, 2) feel panicked when writing science exam answers, 3) feel less confident with the existence of science exams/tests, and 4) feeling hopeless that they have taken the science exams/tests well.

Many previous studies have found a strong relationship between academic emotion and academic resilience, which is also interconnected to students' academic performance (Romano et al., 2021; Yang et al., 2022). Academic emotions were significantly related to student motivation and academic achievement, as well as personality and class antecedents. The findings suggested that educational psychology should address the range of emotions experienced by students in schools and universities to recognize emotional diversity in academic settings (Putwain et al., 2020). Among other emotions, a study discovered a strong association between cognitive assessment and class-related emotions. The report also identified a significant relationship between students' competence, value appraisal, and emotional experiences in the classroom. In the interaction between cognitive, emotional, and academic achievement assessments related to classroom situations, the emotion of hopelessness played an important role (Peixoto et al., 2017). Another study discovered many emotions associated with the classroom environment, such as enjoyment, boredom, and anxiety. The study reported that anxiety was the most crucial emotion for student learning achievement, especially in mathematics (Putwain et al., 2020).

Then, students with higher numeracy skills are more likely to successfully solve math and science problems (Faulkner et al., 2021; Peters & Shoots-Reinhard, 2022; Svensson et al., 2022). According to one study, students with lower numerical self-efficacy had more learning disabilities during the COVID-19 pandemic (Svensson et al., 2022). The report also mentioned that students with higher objective numeracy skills were more prone to learning problems. The report also discovered that students with higher numeracy abilities performed better academically but also felt worse when faced with unexpected difficulties (Svensson et al., 2022). A study focused on the effects of two common emotions, pleasure and boredom, on students' math performance. According to the study, both emotions were found to mediate the effect of cognitive assessment on math performance, which was closely related to math success (Tze et al., 2021).

Anxiety, one of the most common emotions experienced by students, will be heightened when they encounter math and science materials. This is because both subjects are less popular, are known to be stiff and boring, and are more challenging to understand. Anxiety about mathematics and science materials is closely related to unpleasant feelings resulting from unstable emotions characterized by worry and anxiety, interfering with concentration when learning mathematics or other numbers-related subjects, such as scientific materials. Lower self-concept about mathematical ability predicts higher math boredom. Consequently, these emotions are connected to math achievement. Thus, the more students believe emotions are malleable, the more likely they will regulate them and enjoy math anxiety or boredom.

CONCLUSION

This study provides an overview of the predictive value of student academic resilience in numeration and science courses based on academic emotions under online learning. Mathematics and science are subjects that do not interest students when learning face-to-face. Moreover, when learning is demanded to be carried out online, the student will face more challenges. The results revealed that the level of students' academic emotions and academic resilience were in the moderate category, which implies the students tend to be able to accomplish academic achievement at a moderate level even though the conditions at that time were less than ideal. Predictive results using artificial neural networks indicate predictive results with good estimation accuracy, where the percentage of prediction errors is relatively low. The estimation results also show that the three aspects of academic emotions in science, such as class-related emotions, learning-related emotions, and test emotions, were found to have an important influence in predicting the level of academic resilience of students. The aspect of class-related emotions is known to be the most significant impact and the most important aspect in the predictive capacity of students' academic resilience under online learning. Then, this aspect should get optimal attention from various parties to maintain students' academic resilience, which affects their academic achievement. Further research on the same topic needs to be undertaken using more research subjects and a larger population. Additionally, further research can be seen from the perspective of the design and architecture of different artificial neural networks; for example, in the partition section, different relative numbers and percentages can be used. Custom architecture can implement a different number of hidden layers and activation functions.

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