sciendo

Research on Education and Media
Vol. 16, N. 2, Year 2024
ISSN: 2037-0830 – DOI: 10.2478/rem-2024-0011

Artificial intelligence prediction model for educational knowledge representation through learning performance

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Abstract

Precision education derives teaching and learning opportunities by customizing predictive rules in educational methods. Innovative educational research faces new challenges and affords state-of-the-art methods to trace knowledge between the teaching and learning ecosystem. Individual intelligence can only be captured through knowledge level representation, i.e., learning performance that sheds light on learners' knowledge and ability to apply skills after course learning in the education process. Emerging Artificial Intelligence (AI) predicts future learning performance in the higher education system. This research aims to implement an AI application using a supervised learning model to predict students' learning abilities, which are developed by the end of course study. The authors examine learners' performance skills using Bloom's classifiers. This study aims to develop more innovative ways to represent learners' knowledge level by implementing AI models in learning performance. This prediction model assists both teacher and learner in understanding learners' knowledge abilities, and this study can find out the current status of learners' knowledge.

Keywords: *Learning outcome, Skill level, Blooms' Taxonomy, Artificial Intelligence, Learning performance.*

Introduction

Artificial Intelligence (AI) has become an enormous pillar in sustainable education development. Innovative teaching and learning are highly demandable aspects of education. AI applications can make interactive lesson plans that foster creative skills through technology-driven educational processes. AI focuses on technology-oriented human performance and brings about technology-humanity conditions between technology and humans. To enhance human perspectives and contexts, Yang et al. (2021) addressed a study on advanced AI research in educational practice. Advanced AI has the potential to improve human performance and make them even better in various services and activities. A study by Schiff (2021) discussed the impact of AI on education is called Artificial Intelligence in Education (AIEd). The author suggests that AI applications are efficient in supporting pedagogy, curriculum, educational training, and other necessary tools used in education. AI technology enables teachers and students to interact very closely. AIEd supports radical changes in student–teacher relationships through distance education and advocates for students' learning experience through high-quality education access. Educational quality depends significantly on the quality of student–teacher relationships.

Besides, the authors have recommended potential benefits of AI in higher education and depicted the effectiveness in assessment, enhancing technology in teaching–learning applications to support higher education (Bates et al., 2020). AI applications are merged with other subjects to conduct educational performance. The prediction model is prioritized to evaluate student performance through an educational domain. According to Ane et al. (2020), the education ecosystem needs dynamic technological achievements and paradigmatic developments to access technological services that significantly meet IoT-based challenges. AI technology has added new extensive dimensions to overcome the challenges of existing traditional chalkboard education.

In fact, AI applications have gained more significant attention in various important fields, such as agriculture, medicine, education, circular economy, energy, and smart home applications. AI plays a pivotal role in increasing learning output as it can remove cognitive problems of learning and promote lower-cost schooling because AI not only adds new learning tools but also combines traditional classrooms with new technology-based learning tools. AI applications have

prominent effects on a multi-factors educational domain. Another study by Chen et al. (2020) evaluated AIEd applications and developments in educational factors, mentioning that institutional landscapes are affected by technological developments, and the methods of teaching and learning are frequently changing. Interactive technologies have transformed traditional classrooms into online versions named "virtual classrooms." These technologies help students to understand global educational challenges. A similar research by Chen et al. (2020) concluded the relationship to indicate AIEd, data mining, computer and learning analysis, and research findings that suggest AI technology with educational theories. The study further clarified AIEd research and deep-learning technologies in the educational process.

Furthermore, AI has potential applications in simulation-based learning and has become salient in a learning context. AI has made systematic mapping and built socio-interactions through teaching, learning, and technological simulations (Dai & Ke, 2022). The study reviewed six mapping categories and three thematic trends within the learning frame. Su & Yang (2022) proposed AI applications in educational products and services, called AI literacy, and the authors claimed AI literary dimensions in education, that is, knowing, applying, evaluating, and creating AI in educational settings.

Laupichler et al. (2022) presented a framework XAI-ED method to produce decisions in the system and a design to study and develop AI tools. Furthermore, their article promoted emerging viewpoints such as fairness, accountability, transparency, and ethics in educational systems implemented by AI decision algorithms. The study also explained personalized teaching to improve effective and diverse learning systems. Online education, including AI technology (Du et al., 2023), helps teaching strategies to understand learning features. The online learning algorithm is designed with a neural network model to decide task complexity, data availability, and resource computation. The model determined the optimal topology to achieve crucial learning output.

He (2023) introduced an intelligent model built by machine learning techniques, ensuring the integrity of data privacy and finding standardized, private, and secured solutions for preschool and educational institutes. Thus, sensor devices provide a tracking system for education and training purpose, monitoring system without intervals. In addition, these smart devices reduce the consuming data analysis process in educational networks.

Therefore, the authors explored survey articles related to AI applications in the education system. This research study aims to develop an AI prediction model to represent learners' knowledge levels based on their learning performance. Learning performance is classified using Bloom's learning classifiers, and each classification is indexed with a knowledge level using a prediction algorithm. AI prediction model manipulates the learners' learning data to provide innovative solutions that identify each learner's knowledge level including actual knowledge status. Our study tries to develop an AI prediction model that predicts learners' knowledge abilities by analyzing their performance data. This article has main four sections including an "Introduction" section that explains AI-based simulation in education, AI learning algorithm, and technology-oriented teaching and learning process; the "Materials and Methods" section specifies the relationship between "AI and Education," "AI Drives the Education System," "A Definition of Knowledge," "AI Application on Learning Performance," "Blooms Classifiers for Learning Performance," "Data Collection," and "Experiment Model;" and then, "Result and Discussion" section presents the output of the experimented model and result discussion. Lastly, the "conclusion" section shows research findings in educational practice, its limitations, and future applications of research.

1. Materials and Methods

1.1. Artificial Intelligence and Education

AI adds value to the economy of computer science applications. The modern way of human living is significantly influenced by AI. The most challenging aspect now is defining the standard parameters of AI that can come up with computer advances technology, that is, machine learning, fuzzy logic, deep learning, computation algorithm, data analysis, data mining, neural network, and quantum theory. The primary questions asked are: What is AI? And why does it resemble human intelligence? —The answers are entitled from several cited research works, but due to space limitations, very few speeches are picked for this section. One is that computers can only calculate but calculate speed super-fast and huge frequency of numbers than humans. Other explains that humans have the power of natural intelligence that computers do not (Cope et al., 2020).

AI is dramatically transforming information while technological movements aim to gain the latest and super achievements. Its theories have successfully been applied to break complex computational issues into easier forms that enable humans to perform efficient calculations in real scenarios (Zhang et al., 2014). Turing (1950) discovered a relationship between the "question and answer" method similar to the teaching and learning approach. This marked the beginning of AI in computer science and much earlier it proposed "yes," suggesting that machines can take a pattern of human behavior satisfactorily. In a practical context, a digitally programmed computer may ask a question like a human and can provide an answer faster than a human. The article by Bozkurt et al. (2021) tries to draw human–non-human communication relations and Al practice, with predictive opportunities or solutions for suitable problems.

Intelligence is classified into two ways (Harari, 2021), consciousness intelligence which feels objects and resolves particular issues and another which only clears up problems with no consciousness like computers. Computers have artificial intelligence, that is, computers are nonconscious and able to solve problems. Artificial Intelligence (AI) is a

replica version of human intellectual skill (Aishwarya et al., 2020), and an expert system preciously does the performance that is outreached by humans. The above discussion brings the concept that AI has the potential to act as an educational guide using computer programming.

1.2. AI Drives the Education System

AI has emerged as a striking feature in education systems, especially in the field of AIEd as discussed in the "Introduction" section. Teaching and learning encompass both teachers and learners engaging within an automated expert educational model. Higher education has significantly emphasized AI opportunities in large research criteria. Researchers (Richter et al., 2019) suggested that AI can perform cognitive tasks, performed by computers. AI mixed with other technology forms an umbrella technology to perform problem-solving systems in education. In the article by Batchelor and Petersen (2019), the authors highlight the prominent requirement for knowledge-based decision-making solutions developed by AI algorithms and also predict that by 2027, in educational technology, robots will take part in teachers' sites.

AI allows teachers to outline professional judgment to boost learning opportunities. As AI functions like an intelligent machine, computer systems can perform cognitive tasks. AI is interrelated to human psychology in learning problem-solving. The article by Pokrivcakova (2019) reviewed foreign language education and suggested using an AI-powered expert system to solve issues in this field. The educational economy has been significantly impacted by pedagogical learning approaches, which shaped new and different teaching tools for learners. Pedagogical learning focuses on learning outcomes, while teaching emphasizes course design goals and the necessity of learners to understand long-term vision, especially in higher education.

Most education systems begin to follow the pedagogical learning system, and educational researchers recommend exploring AI opportunities in higher education systems. The data-driven educational algorithm implements AI-based learning practices for effective education. AI helps to identify learning gaps by huge data analysis and provides accurate data-driven solutions for the pedagogical education system. Similar to the industrial revolution, that is, industry 1.0, industry 2.0, industry 3.0, and industry 4.0 (Ane and Yasmin, 2019), an educational revolution is grouped into education 1.0, education 2.0, education 3.0, and education 4.0 (Cope & Kalantzis, 2019). Education 1.0 is associated with traditional education, whereas only knowledge is transmitted from teachers to students. In contrast, education 2.0 focuses on knowledge representation using computer-based educational policy. Keser & Semerci (2019) characterized the other two educational technologies, education 3.0 and education 4.0. Education 3.0 is based on digital technology, allowing learners to share and access knowledge using web technology, while education 4.0 adjusts to IoT applications, robotic mechanisms, AI, cloud technology, etc. In education 4.0 for effective learning, AI is proposed to evaluate learners' outcome-based performance to improve academic success (Chen et al., 2020). As a result, modern learning systems eagerly conduct AI solutions for knowledge representation medium in each education site.

1.3. Definition of Knowledge

Knowledge is a meaningful concept that defines fact-objects of anything. Sometimes, knowledge means a vital relationship among familiar concepts. It is represented by skill achievements. When a learner knows specific problems, they have the necessary skills with additional experience in certain regions to map out. Knowledge has two main features: one is unstructured learning or self-learned by an individual, which cannot be implemented logically and is called tacit knowledge; the other is transferable skills acquired through either training or practicing. Definitions of knowledge are shown in Figure 1 and 2.

1.4. AI Application on Learning Performance

Academic learning objectives are outcomes used to define learners' academic performance. Sometimes, learning objectives play as focal points for performance indicators, enabling teachers to estimate the outline of students' learning journey by assuming learning outcomes at the end of the course program. Learners have the opportunity to be informed of the learning expectations and goals they are expected to achieve at the end of the course or lesson in both theoretical- and practical-oriented lessons.

An instructor sets learning objectives in the education process to improve both declarative and procedural knowledge. Learners gain knowledge about facts by studying lessons, but knowing when and how to apply this knowledge to subjects is quite a distinct skill to acquire. This article presents an AI solution to identify each learner's knowledge and weaknesses, referred to as their knowledge status. The results of knowledge representation will be explained later in the "Result and Discussion" section.

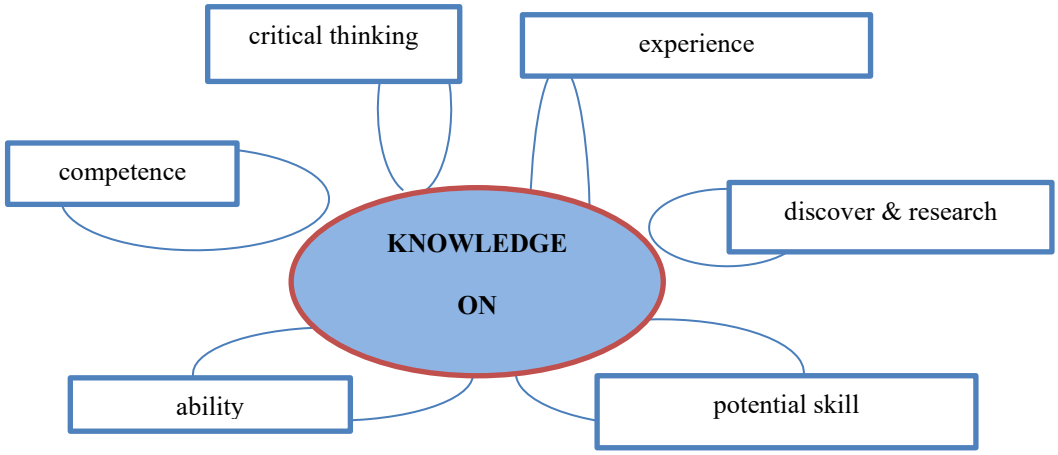

Figure 1. Knowledge definition and knowledge features.

Both skills are driven by AI solutions in educational practice. AI applications track down outcome-based learning in knowledge acquisition. Smart education, enhanced with AI application, has a long-term visionary impact on pedagogical learning.

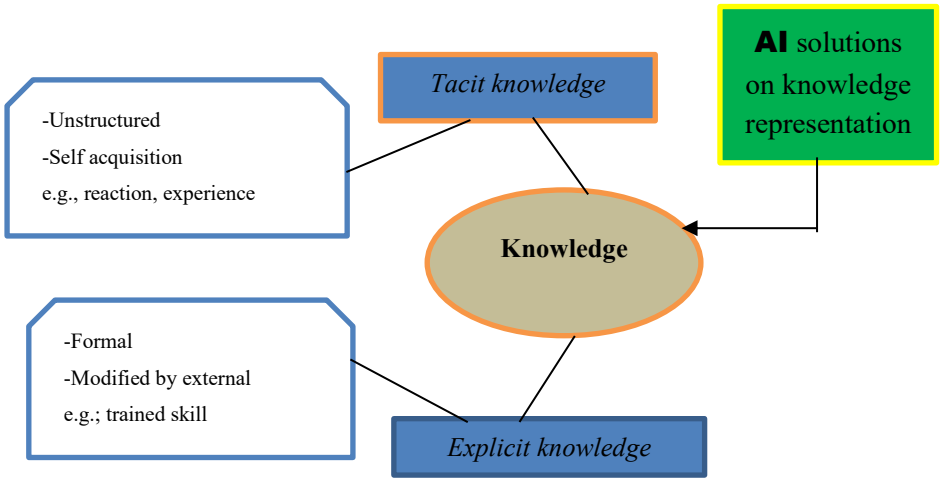

Figure 2. Knowledge classification with AI solutions for knowledge representation.

1.5. Bloom's Classifier for Learning Performance

Different learning objectives from Bloom's Taxonomy classification are designed by instructors to accurately measure learners' intellectual levels. These range from lower-order skills to higher-order skills, such as remembering, understanding, applying, analyzing, evaluating, and creating (Shabatura, 2022). Each state depends on the previous domain of cognitive skills, enabling learners to recall, process, analyze, apply, and perform quickly.

In collaboration with higher-order thinking, learning prototypes are closely connected with learning outcomes (Hyder and Bhamani, 2016). Here, the authors will define knowledge levels following Bloom's knowledge theory, as shown in (Figure 3). Learners start with low-order skills, such as initially recalling information by "remembering knowledge," then explaining the facts by "understanding knowledge," and later, being able to apply the learned idea on an application basis by "applying knowledge." Advanced learners progress to high-order skills, such as completing lab work by "analyzing knowledge," then making decisions by "evaluating knowledge," and later, discovering new formulas by "creating knowledge."

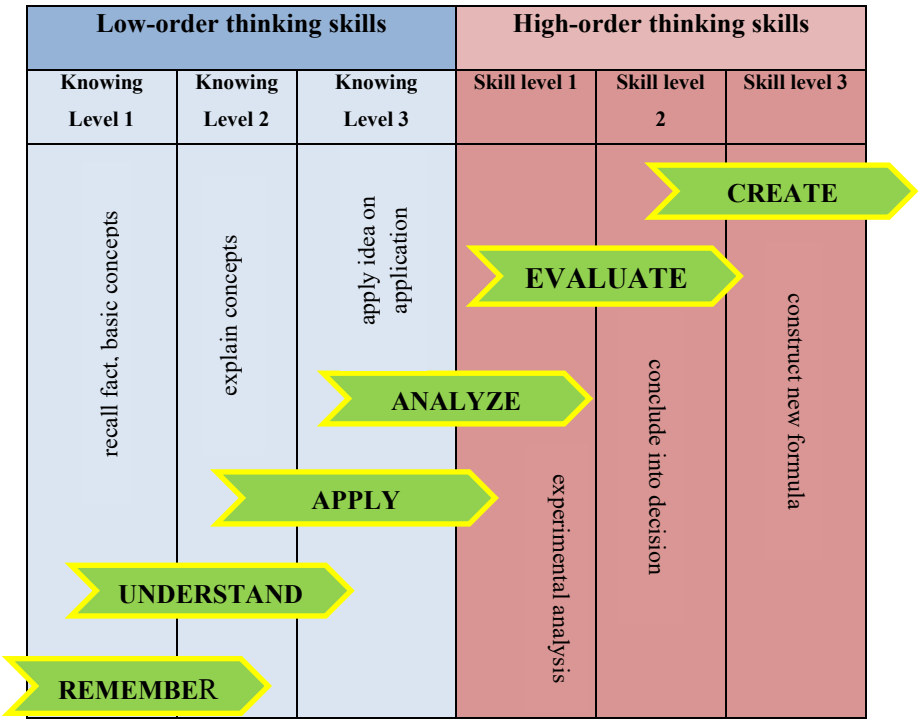

Figure 3. Knowledge level.

1.6. Learning Performance to Knowledge Assessment

Learning performance helps the learners gain positive reinforcement in their application, work effectively with others in the field, and feel motivated to engage with deep learning factors (Seda and Zahitjan, 2016). Individual motivation has a significant impact on creativity planning.

The authors focus on precision education in university teaching and learning as the education requirements for their research. Precision education is defined, since a unique learning strategy may not be a preference for global education improvement, as the need to represent a data-driven instructional set that facilitates learners' learners' education system (White, 1986). A study by Minn (2022) suggested a knowledge assessment technique for an adaptive learning ecosystem based on static and dynamic learning data. Bayesian Knowledge Tracing (BKT) was proposed to track knowledge levels and various KT models were discussed before (Dai et al., 2021). For this research purpose, the authors encourage accepting learning performance scores to predict learners' knowledge levels and academic performance skills during assessment.

1.7. Data Collection

AI applications may become an alternative supportive tool in education. To ensure quality education in higher studies, the number of teachers should be increased to provide adequate care for each student. AI is appreciated for its potential to assist teachers in tutoring and evaluating assessments (Watson, 2023; Ane & Nepa, 2021), aiming to reduce the inadequate curriculum gap.

For the research experiment, we selected data from 50 students out of a total enrollment of 60 students each term. Our observations were focused on these 50 students to train the AI prediction model. The test dataset requires 30 sample data, with the remaining data used for the training dataset. Each data point is classified into performance activity features and arranged into performance classifiers as described in Figure 3. The experiment dataset includes three kinds of classifiers. These classifier variables represent detailed student records with categorical values. The three main classifier variables are (i) classifier level 1 on analyze performance (C1A), classifier level 2 on evaluate performance (C2E), and classifier level 3 on creating performance (C3C) types of variables. The experiment aims to build a prediction model specifically designed for higher-order thinking skills.

1.8. Linear Regression Prediction Model

The article (Hamsa et al., 2016) proposed a prediction model to improve learners' academic results using a decision tree approach. Statistical decision theory, discussed by Jones (1998), follows the Bayesian framework, demonstrating that academic decisions can benefit from a wider range of options derived from observed data values using a prediction model.

Additionally, Snelson & Ghahramani (2005) suggested a predictive presentation for academic performance to outline future academic reports based on data from an unknown, new academic set.

This study applied an AI prediction algorithm using a linear regression model of students' datasets. AI contributes more than the rule-based statistical approaches, particularly for larger datasets, to conclude model results. AI excels in handling diverse datasets with multiple variables, whereas classical statistical models make a simple prediction analysis on smaller datasets. In establishing clear relationships among multi-variable learning outcomes within larger datasets, AI-supervised learning algorithms are preferred for predicting learners' performance. Each student's performance activity depends on multiple dependent variables according to classifiers. Only relying on rule-based classification to predict model analysis does not accurately identify knowledge levels. This study instead preferred a multivariable linear regression model using AI concepts. In the experiment, the total number of observations is denoted by n. In a linear regression model, there are two main types of variables: an independent variable that is manipulated and a dependent variable that is measured and manipulated by the independent variable. The equations denote model variables specifying x as the independent variable value and y as the predicted dependent variable value. The linear regression model expression for the experiment design is shown in Equations (1–4).

$$y_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n. \qquad (1)$$

Equation (1) defines the total students' input values as independent variables x1, x2, x3, ..., xn, where n is the number of observations. β0 represents the intercept value on the regression line in axis and β1, β2..... βn are the coefficients for each data point of independent variables (IV) and yi is the dependent variable (DV) in the input dataset model to prepare the estimated output.

The linear regression model to calculate the Mean Absolute Error (MAE) is given in Equation (2).

$$\mathrm{MAE} = \frac{1}{n}\sum_{i=1}^{n-1} |y - y_n|. \quad (2)$$

Equation (2) represents the model error, where the prediction outcome is divided by the total number of observation data points (n). To calculate residuals, Equation (2) is used in the prediction model. For each data point, the predicted response values are compared with the actual values to identify any mismatches, and then, the experiment model needs to analyze these residual values. Residual determines the prediction models' appropriateness on modeling data points. Residual values are measured to evaluate the model by analyzing the differences between predicted and actual variable data values. To plot the regression line perfectly in the linear regression model, the authors applied a hypothesis value, as shown in Equation (3).

$$H_0(x_i) = \theta_0 + \theta_1 * x_{i.} \quad (3)$$

And the regression coefficient value is shown in Equation (4).

$$\beta = \frac{n\sum xy - (\sum x)(\sum y)}{n\sum x^2 - (\sum x^2)}. \qquad (4)$$

Experiment steps are documented, and the authors completed the program coding design in R Studio. The model examines and analyzes the test data points, and hence, it is required to apply functions and build functions that are programed into R Studio. The model defined lnr as a linear regression model variable to hold information as a value of the regression function, such as lnr = Linear Regression(). The training model code uses variables like x-train, x-test, y-train, y-test, test-size, and train-size to execute the program. To predict new observations, the prediction model applies instructions and code to trace knowledge levels through learning performance activities using the formula yprediction = lnr.predict (x-test), where y is the new predicted output value of an unknown observation, which is formed by calling the predict function on the set of independent variables (IV). The model iteratively executes predicted yprediction variable values for each new data point.

2. Result and Discussion

2.1. Experimented Performance Prediction Result

The prediction model accepts the input data as data points. Then, the designed AI model manipulates these data values to produce predicted outcomes by analyzing processed data values. The AI model experiment has examined IV variables to estimate the values of DV variables, which are predicted in Table 1. Programming is designed to upload code on three learning classifiers according to Bloom's higher-order thinking skills. The results show clear prediction outcomes, with

the table splitting the output into two parts: one showing the actual dependent (DV) variable and the other showing the model's estimated dependent (DV) variables.

The AI prediction model depicts learning performance output (Table 1) and knowledge prediction result (Figure 4).

Table 1. Model prediction learning performance.

Learning activity score	Actual performance values			Predicted performance values		
Classifier	**C1A**	**C2E**	**C3C**	**C1A**	**C2E**	**C3C**
Score-28	1	1	1	1	1	1
Score-25	1	1	1	**0**	1	**0**
Score-20	1	0	1	1	0	1
Score-18	1	1	1	**0**	1	1
Score-15	1	1	0	1	1	**0**

Table 1 represents students' learning performance at the end of the course. The score is a feature of the independent variable and is mapped with three dependent variables: "analyze," "evaluate," and "create" higher-order knowledge levels. Learning activity score-28 plotted output as the model predicts the actual output. Students with an activity score-28 obtained satisfactory results on all three knowledge levels. However, for score-25, there are differences between the actual and predicted performance output (marked as red). The model does not identify the actual values for the "analyze" and "create" classifiers. In another case, the model performed well at activity score-20 and activity score-15, where both classifier value levels are correctly examined. Activity score-18 shows that students have excellent knowledge in three performance classifiers, but the model picks poor performance in the "analyze" classifier.

2.2. Experimented Knowledge Prediction Result

The AI prediction model functions and counts the value of knowledge level output. Total data points include 50 students' data. The AI-supervised model draws a summary of knowledge acquired by each student, which is listed in Figure 4. Table 1 shows two types of output, including actual and predicted performance results. More clear output can be observed from Figure 4, which presents how several students are engaged in the knowledge group. The knowledge group has four categories of data boundaries: good, better,better-best, and best. The graphical results outline that the AI model predicts results among the total students. The least portion of students achieved good knowledge in the "Evaluate knowledge" group, while the majority portion of students learned better to best knowledge in the group. The fourth portion of students have better knowledge in the "Create knowledge" group. Among the three knowledge groups, students are not performing well in "Creativity knowledge" acquisition.

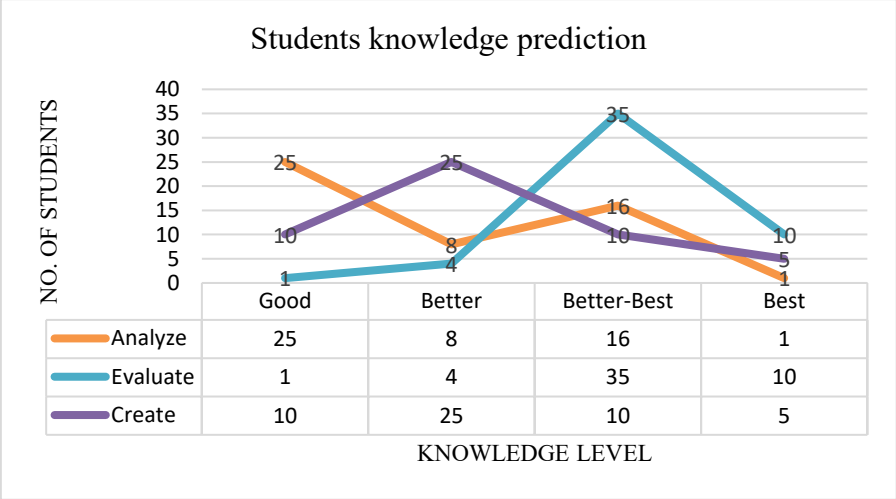

Figure 4. AI prediction of knowledge level.

Tables 1 and Figure 4 represent the prediction model output in both cases. Table 1 shows learning performance on the activity score model predicting the output, while Figure 4 defines how many students achieved good, better, and best knowledge in three higher-order thinking skills. Figure 5 briefs out the AI application procedure to predict learning performance and knowledge level status.

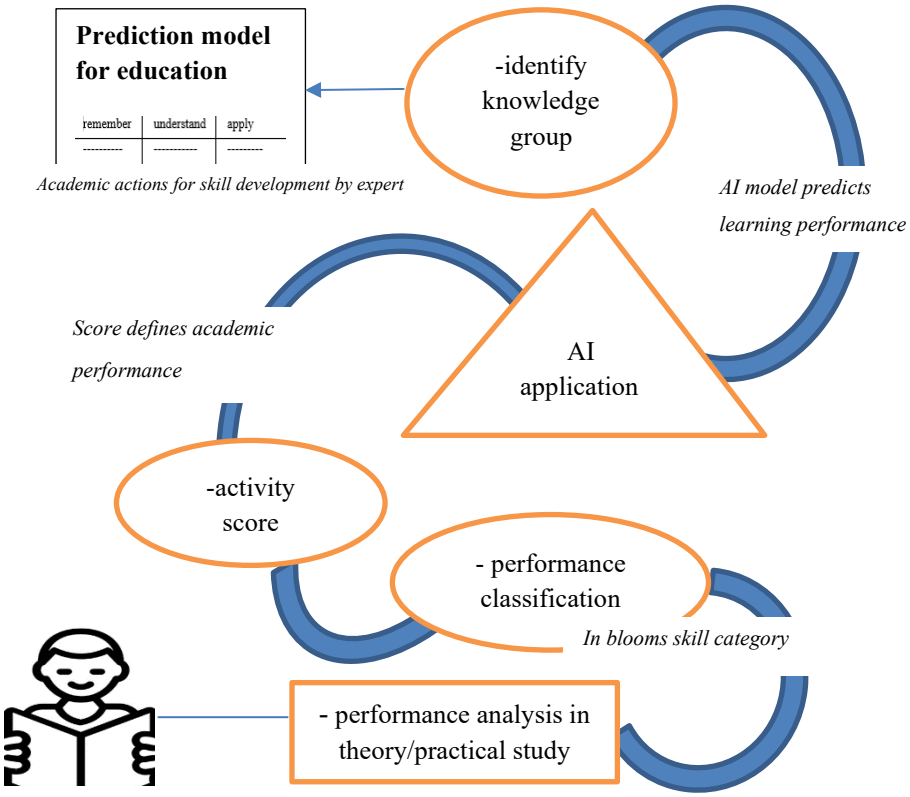

Figure 5. AI prediction model for educational knowledge level

3. Conclusion

AI has the potential ability to reshape the world's educational learning procedures with more intelligent ideas. Teaching and learning approaches are increasingly integrating significant technological applications in practical educational management. In the field of educational research, AI technological applications are in demand to enhance robustness of all educational domains and their capabilities.

This article focuses on AI applications to represent students' knowledge levels using three classifiers: analyze, evaluate, and create based on data boundary values (good, better, better-best, and best). The prediction model introduced here aims to identify students' knowledge status by analyzing their performance capabilities. The AI model picked only one learner out of 50 who achieved the best in analyze knowledge and good in evaluate knowledge, while 35 learners also showed improvement in evaluate knowledge.

The developed AI prediction model will help both teachers and learners achieve learning goals and problem-solving solutions. Researchers are designing AI-based models to detect learners' knowledge status so that teachers can easily identify learners' knowledge weaknesses and strengths, enabling them to promptly adapt learning patterns. Our research experiments have a few limitations; we only applied three learning classifiers to manipulate learners' data. In future research, we plan to expand our research work to evaluate large institutional datasets with more learning classifiers and develop a learning model based on pedagogy learning outcomes.

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