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Empowering future mathematics educators: Designing e-IBCA learning model to enhance decision-making skills

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Abstract

Decision-making skills must be trained in future mathematics educators because 21st-century skills have become a core component of teaching students. There is a need to develop new learning models to enhance students' decision-making abilities effectively. The decision-making skills of mathematics teacher candidates can be developed by giving them problem HOTS. The learning model designed is e-IBCA, which is short for electronic, with the syntax (1) Identifying the problem, (2) Building an idea, (3) Clarifying the idea, and (4) Assessing the reasonableness of the idea. This Research and Development study uses the model by Dick et al. (2015), which has four stages: planning, development, implementation, and evaluation, with revisions carried out continuously at each step. The research results show that teaching and student characteristics were analyzed at the planning stage. The development stage carried out the design of e-IBCA learning models, instruments, and learning tools with valid results. At the implementation stage, trials have yielded practical, effective results. At the evaluation stage, the e-IBCA learning model is feasible and can be used to develop future mathematics teachers' decision-making abilities. These findings suggest that the e-IBCA learning model can equip future mathematics teachers with 21st-century skills.

Keywords:
Decision making, e-IBCA, Learning model, Mathematics teacher

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1. INTRODUCTION

We are now facing Industrial Revolution 4.0 and Society 5.0, a period where humans are expected to solve various challenges and problems by utilizing multiple innovations. This encourages everyone to adapt quickly and precisely, which requires thinking process abilities (Koh et al., 2015) such as decision-making (Facione & Facione, 2008; Wahono et al., 2025). Decision-making is a thinking process carried out by someone to choose something from a variety of things to choose from alternative solutions, situations or strategies with agreed conditions (Dauer et al., 2022; Wang & Ruhe, 2007). Through a thinking process, which can begin with the stage of generating ideas, then clarifying the clarity of each concept that is had, and then continuing with evaluating or assessing the reasonableness of the concept to choose the best idea (Lunenburg, 2010; Murtafiah et al., 2020; Swartz et al., 1998). Decision-making is an essential part of the thinking process to find solutions to unexpected problems. These problems can be included in HOTS (Higher Order Thinking Skills) type cases/issues/questions at the educational level.

Universities that produce teacher candidates in line with the demands of the times must strive to create graduates with professional competence, as expected by the independent curriculum. In an era like today, to become an experienced teacher, a teacher must have decision-making skills to integrate these abilities into learning activities and to promote an environment that enables the physical and psychological development of the students (Unciti & Palau, 2023). This indicates that to become a teacher, you must have the ability to think processes, namely, good decision-making. Previous research showed that only 3.1% (1 out of 32) prospective teacher students demonstrated proficient decision-making (Murtafiah et al., 2019). This condition indicates that there is only one student who can generate ideas for designing media for learning, clarify ideas for designing media for learning that are adapted to the student's conditions and the characteristics of the learning material, and the ability to assess the reasonableness of ideas based on aspects of validity, practicality and effectiveness. Another study found that 64.29% of student teachers still failed to solve mathematical problems (Murtafiah et al., 2021). A more in-depth study of one student in the group revealed that he was able to formulate the problem into a mathematical model but was unable to apply the appropriate method to solve the problem, indicating a weak ability to develop ideas. He was able to justify his chosen idea, but there were errors in the steps and mathematical concepts he used. As a result, he lacked confidence in assessing the reasonableness of his idea. This demonstrates the prospective teacher's still weak decision-making ability when solving mathematical problems.

For this reason, the ability of professional teachers is still a big battle for universities that want to produce professional teachers following current conditions, because it has been found that only a small number of prospective teacher students have good decision-making abilities. The consequences of inadequate decision-making impact student learning outcomes. Teachers with poor decision-making skills tend to fail to meet diverse learning needs (Graham et al., 2021; Pozas et al., 2019), struggle with adaptive learning, leading to lessons not going according to plan (Lupiáñez et al., 2024; Park & Datnow, 2017), and exhibit lower teaching self-efficacy (Jerrim et al., 2025; Leijen et al., 2024). Furthermore, students' ability to solve HOTS-type questions remains low. Research shows that HOTS encompasses critical thinking, problem-solving, and decision-making as interrelated competencies (Khadka et al., 2025). However, prospective teachers often struggle to develop and implement HOTS-based learning (Sarkawi et al., 2023; Zhou et al., 2023). Studies show that many prospective teachers have limited HOTS problem-solving skills (Purnomo et al., 2024). This creates a cyclical problem; teachers who cannot effectively engage in higher-order thinking struggle to facilitate it in their students (Kim, 2025). Giannetto and Vincent (2002) documented poor performance on HOTS assessments among secondary school students, while Lukitasari et al. (2018) found that prospective teachers at a private university in East Java demonstrated low ability to solve HOTS problems, problems that inherently require the same decision-making processes that teachers should model and facilitate.

Based on the problems above, the solution that can be implemented is to develop a new learning model to improve students' ability to make decisions. The learning model developed in this research is the e-IBCA learning model which is based on the decision-making thinking process stage (Swartz et al., 1998). This model consists of 4 learning syntaxes, namely (1) Identifying the problem, (2) Building an idea, (3) Clarifying the idea, and (4) Assessing the reasonableness of the idea. The philosophical foundation related to this model is based on constructivist learning theory, cognitive theory, social cognitive theory, and mental information processing theory. Constructivist learning theory broadly concerns students constructing new knowledge based on past experiences (Ausubel, 1968; Bruner, 1977; Ncube & Luneta, 2025). Cognitive theory focuses on learning through the stages of a person's development (Supratman, 2013), while social-cognitive ideas are learning that occurs through social interaction (DeVries, 2008; Shvarts & Abrahamson, 2023; Vygotsky, 1978). Cognitive information processing theory concerns a person's learning through information analysis (Díaz-Chang & Arredondo, 2024; Gagne et al., 2005). The theoretical foundation for each phase is presented in Figure 1.

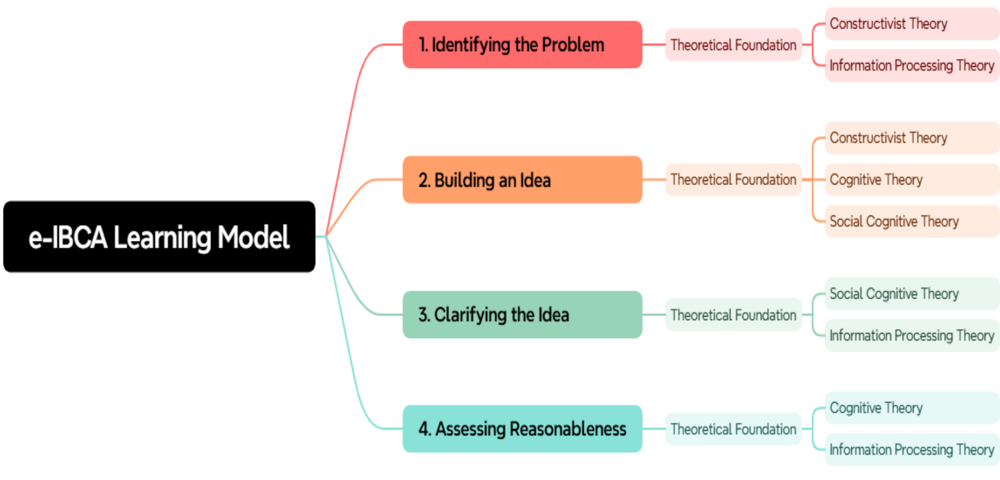

Figure 1. Theoretical Foundation of the IBCA Learning Model

Although the learning model developed aims to improve decision-making abilities, this learning model indirectly supports improving critical and creative thinking abilities. This is because decision-making, creative, and critical thinking skills are interrelated in making reasonable, binding judgments (Haritas & Harini, 2025; Swartz et al., 1998). Critical and creative thinking skills are applied when someone makes decisions. Decision-making is often equated with critical thinking and problem-solving by thinking logically and selectively (Herodotou et al., 2019). The decision-making learning model uses several steps, which include (1) information gathering, (2) formulating the problem, (3) identification of alternatives, (4) problem-solving, and (5) formulating conclusions (Wang & Ruhe, 2007). This learning model is designed for students to improve student learning outcomes. This learning model also needs to provide certain types of problems used in implementing the learning model. On the other hand, decision-making skills in mathematics learning will be very appropriate if they are related to solving a case as an HOTS-type problem. Therefore, designing a learning model with stages or syntax is needed to develop decision-making abilities in solving HOTS-type questions.

This model is designed for implementation in both offline and online learning environments to support effective instruction, hence the name e-IBCA learning model, with stages as in Figure 1, electronically based. This online learning focuses on using ICT as a digital learning medium without boundaries of space and time, and is a solution to the problems of the Industrial Revolution 4.0. ICT in learning influences students' critical thinking abilities (Robertson & Mullen, 2017), an integral part of decision-making in solving HOTS questions. The increasing development of student teachers' decision-making abilities, when given a case/problem to support the implementation of independent learning, will also improve the quality of graduates who play an essential role in preparing future professional teachers who can face various challenges.

2. METHOD

2.1. Design Research

This research and development study uses four stages, namely planning, development, implementation, and evaluation and revision, which are carried out continuously at each stage throughout the development cycle (Dick et al., 2015). This development cycle model can be visualized in Figure 2. The selection of this model is based on considerations: (1) the existence of four basic elements that are important for developing learning, namely objectives, learning strategies or models, determining learning materials, and assessment; (2) model accuracy This is for determining procedural elements, (3) the theoretical fundamentals are in line with the modern, constructivist learning perspective which is oriented towards students' learning goals and needs, (4) all steps are sequential and integrated from developing measurement tools, developing learning strategies, and developing teaching materials.

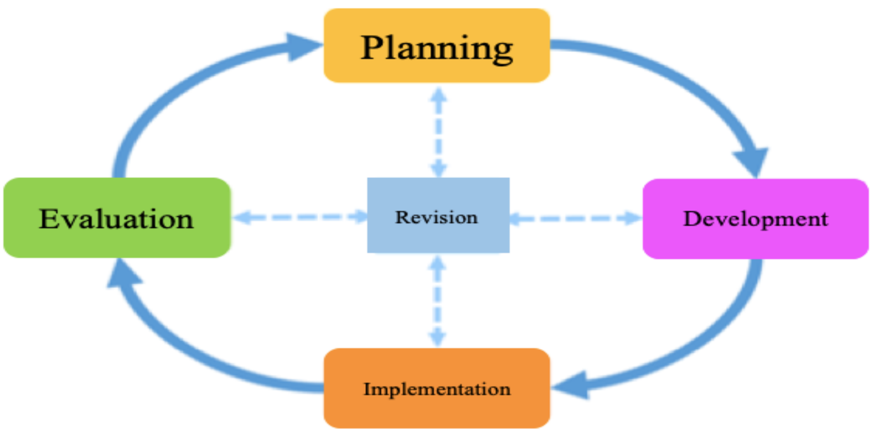

Figure 2. Teaching development model

2.2. Procedure of Research

Based on development research activities, which include four stages: planning, development, implementation, and evaluation, a more detailed research procedure can be drawn, as shown in Figure 3.

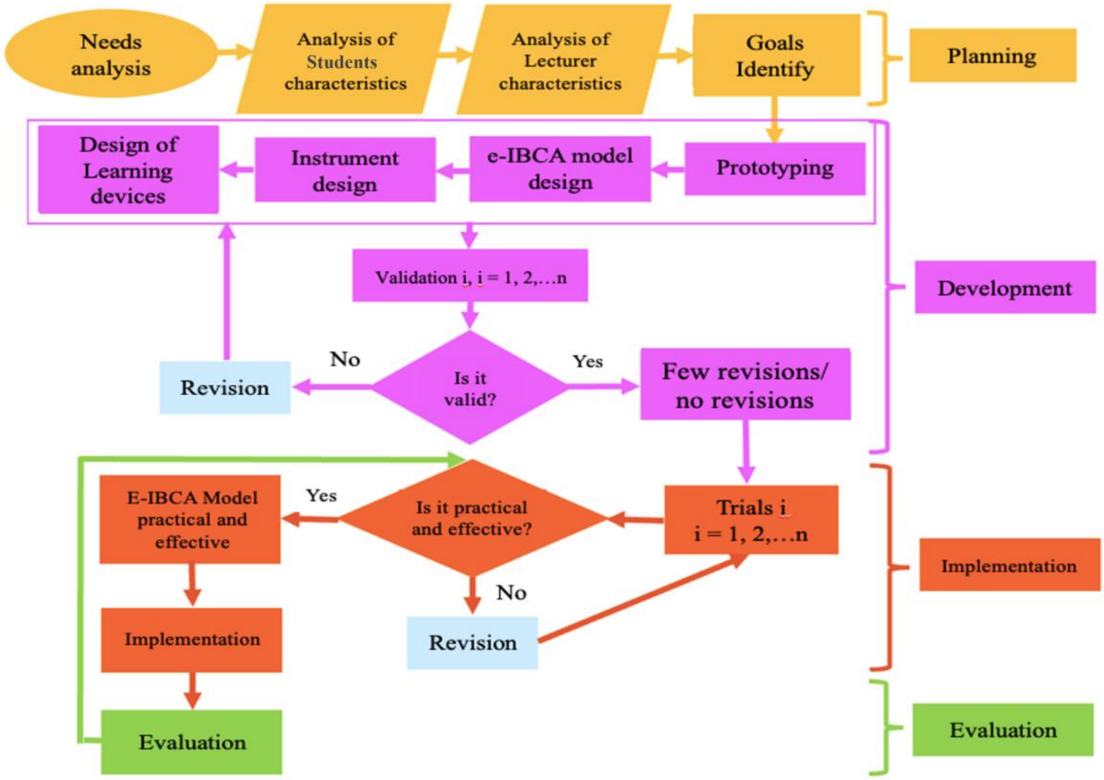

Figure 3. Flowchart e-IBCA Learning Model

2.2.1. Planning Stage

This planning stage includes needs analysis and identifying goals. Needs analysis includes student characteristics and lecturer characteristics. The final goal at the planning stage includes identifying teaching objectives. This objective is used to determine the achievements of learning activities. The subjects used in the research stage were students of the mathematics education study program at PGRI Madiun University and Jember University, namely 63 students and 13 lecturers, who were taken using simple random sampling. Student participants (n=63) comprised 22 males and 41 females, with ages ranging from 19 to 22 years. They were distributed across years 1 to 4 in mathematics education. The distribution across institutions was Universitas PGRI Madiun (n=24) and Universitas Jember (n=39). Lecturer participants (n=13) included 4 males and 9 females, with teaching experience ranging from 5 to 20 years. The institutional distribution was Universitas PGRI Madiun (n=5) and Universitas Jember (n=8).

The instrument needed at this stage is a needs-response questionnaire for learning mathematical problem-solving. The needs response questionnaire was developed based on five indicators, namely 1) perceptions of lecturers and students regarding problem-solving, 2) giving problem-solving questions to students by lecturers, 3) students' problem-solving abilities according to lecturers, 4) difficulties faced by students in solving problems, and 5) availability of learning devices owned by lecturers. This response questionnaire was given to selected subjects using Google Forms. Researchers chose this platform to conduct online surveys because of its ease of use, as subjects can fill in student and lecturer responses anywhere and anytime. The data analysis technique required in this research is a quantitative descriptive.

2.2.2. Development Stage

The development stage requires a prototype of the e-IBCA model and learning tools (learning plans, student worksheets, and assessment sheets). At this stage, a Focus Group Discussion (FGD) was carried out on the e-IBCA model. The FGD aims to obtain input from 5 validators on the prototype of the e-IBCA model being developed. The validators consisted of three learning model development experts and two mathematics learning media experts, all purposively selected based on their expertise and scholarly contributions. The learning model development experts (n=3) included one Professor of Mathematics Education (Validator 1) with a successful record of creating and implementing mathematics learning models, and two experienced researchers (Validator 2, Validator 3) with proven expertise in developing learning tools published in reputable journals. All three hold doctoral degrees with expertise in instructional design, learning theory, and model validation. The mathematics learning media experts (n=2) comprised two validators (Validator 4, Validator 5) who hold doctoral degrees in Mathematics Education and specialize in mathematics learning media development. Their expertise is evidenced through publications in reputable international journals and the successful development of innovative learning media for mathematics education. This expert panel ensured comprehensive validation of the e-IBCA model's theoretical foundation, pedagogical design, and media implementation.

At this stage, the instrument needed is a validation sheet. This instrument aims to validate or assess research products such as model books and learning tools (learning plans, student activity sheets, and decision-making assessment sheets). The model book validation sheet consists of 7 indicators/aspects, namely 1) supporting theory, 2) syntax, 3) social system, 4) reaction principle, 5) supporting system, 6) instructional impact and accompaniment, and 7) learning implementation. The validation sheet for this learning tool consists of 3 indicators/aspects, namely 1) format, 2) content, and 3) language, with six questions. The data analysis technique required in this research is a quantitative descriptive. The data analysis technique used at the development stage is quantitative descriptive by determining the average of each validator's assessment (Hasyim et al., 2024; Meilantifa & Budiarto, 2018). The average is then compared with the validity criteria in Table 1 (Hariadi et al., 2021).

Table 1. Validity criteria

Interval Score	Validity Criteria	Information
$3.30 < V \leq 4.00$	Very Valid	It can be used without modification
$2.30 < V \leq 3.30$	Valid	It can be used for minor modification
$1.80 < V \leq 2.30$	Less Valid	It can be used for major modification
$1.00 < V \leq 1.80$	Invalid	It cannot be used, and more consultation is needed

2.2.3. Implementation Stage

At the implementation stage, e-IBCA product trials were carried out. Model testing was carried out three times, namely small-scale trials, medium-scale trials, and wide-scale trials. The small-scale trial involved 20 students and two lecturers from the mathematics education study program at PGRI Madiun University. The selection of Universitas PGRI Madiun is a follow-up to a preliminary study conducted by researchers, which is a private university that still needs a lot of innovation in overcoming the problem of students' low ability to solve problems (Murtafiah et al., 2021). The selection of 20 5th-semester students was taken randomly from one class and two parallel classes because both classes had equal abilities. The two selected lecturers are lecturers in the class teaching mathematical problem-solving courses. This single-site approach to limited testing follows the principles of design-based research (McKenney & Reeves, 2013; Plomp & Nieveen, 2013), which recommend intensive, focused testing to thoroughly examine implementation before broader validation. This allows for close monitoring, direct support for faculty, and greater control over the initial implementation.

The medium-scale trial involved 22 students, two mathematics education lecturers at Universitas PGRI Madiun, and 21 students, two mathematics education lecturers at Universitas Jember. The selection of 2 universities and subjects for this medium-scale trial was based on the results of an analysis of student and lecturer needs at the planning stage (Murtafiah et al., 2022). PGRI Madiun University is a private university, while Jember University is a state university in Indonesia. The selection of 22 students at Universitas PGRI Madiun was taken from 1 class from 2 parallel courses, where this class had not been used in small-scale trials. The two lecturers selected were lecturers in courses who taught mathematical problem-solving in that class, and not lecturers who were used as subjects in small-scale trials. The selection of 21 students at the University of Jember was taken from 1 class randomly from 4 parallel classes that had equal abilities. The two selected lecturers are the lecturers in the class who teach problem-solving courses.

The wide-scale trial phase involved 132 students and 12 lecturers at six universities (Universitas Nusantara PGRI Kediri, Universitas Veteran Bangun Nusantara Sukoharjo, Universitas Pendidikan Mandalika, Universitas PGRI Delta Sidoarjo, Universitas PGRI Kalimantan, dan Universitas Hamzanwadi). The six universities were chosen because they had students in mathematics education study programs and were selected randomly in 4 provinces out of 38 provinces in Indonesia. These four provinces were selected because they were considered to represent the diversity of characteristics of mathematics education study program students in Indonesia in solving mathematical problems. The instruments needed at this stage are decision-making assessment sheets and student and lecturer response questionnaires. The decision-making assessment sheet is used to measure students' decision-making abilities. This assessment sheet consists of 3 indicators: building ideas, clarifying ideas, and assessing the reasonableness of problem-solving ideas. The student response questionnaire was developed based on five indicators, namely 1) material components, learning atmosphere, and the way the lecturer teaches; 2) students' ability to understand the worksheet and the problems presented; 3) appearance (writing, illustrations/drawings, image layout) on the worksheet and the problems presented; 4) student interest in participating in learning using the e-IBCA model; and 5) response in improving student decision making abilities.

Student and lecturer responses are analysed to see the practicability of the e-IBCA model. The response data analysis used is quantitative descriptive. The response data was analysed based on the percentage of students and lecturers' overall answers through positive statements with a Likert scale (Hasyim et al., 2024). Furthermore, it is included in the very good category if it reaches 81% -100%. If 61% - 80% is included in good, 41% - 60% is included in good enough, 21% - 40% is not good, and 0% -20% is included in bad (Wahyuni et al., 2020).

Analysis of students' achievement of decision-making abilities is used to see the effectiveness of the e-IBCA model. The data analysis used is quantitative and qualitative descriptive. Because, at this stage, the aim is to determine the effectiveness of the e-IBCA learning model in terms of students' decision-making abilities, data on this ability were obtained from the trial until implementation. To see its effectiveness, data analysis uses N-Gain (Aziz et al., 2021) and the interpretation of the N-gain value criteria (Trisniawati et al., 2019). The effect uses Cohen's *d* formulation (Goulet-Pelletier & Cousineau, 2018; Lakens, 2013; Maher et al., 2013). Analysis of the results of the interpretation of the effect size criteria (Cohen et al., 2002) is ignored ($0.00 \leq ES < 0.20$), small ($0.20 \leq ES < 0.50$), fair ($0.50 \leq ES < 0.80$), large ($0.80 \leq ES < 1.30$), very large ($ES \geq 1.30$).

2.2.4. Evaluation and Revision Stage

A feasibility analysis of the e-IBCA model was carried out at the evaluation stage. The instruments needed at this stage are model feasibility indicators of validity, practicality, and effectiveness. Validity is measured by analyzing the results of the validator assessment at the development stage. Practicality is measured by analyzing the results of student response questionnaires at the implementation stage. Effectiveness is measured by analyzing the achievement of students' decision-making abilities at the implementation stage. The revision stage is carried out continuously at every stage throughout the development cycle. For example, after the planning stage, goal setting is revised. After the development stage is a revision of the tools in the learning plan and student worksheets. After the trial, the assessment sheet was revised. After the implementation stage, the assessment sheet is revised.

In this study, we acknowledge that formal ethics approval was not obtained prior to data collection, which is a limitation of this study. However, we adhered to ethical principles of educational research by obtaining voluntary consent from all participants, ensuring data anonymity and confidentiality, allowing participants to withdraw at any time, and using the data solely for research purposes.

3. RESULTS AND DISCUSSION

3.1. Results

Research into the development of the e-IBCA learning model was carried out in stages: planning, development, implementation, and evaluation. The results and discussion of each stage of this development research are described as follows.

3.1.1. Planning Stage

The needs analysis was performed at the planning stage. The research on lecturers' needs focuses on lecturers' perceptions of students' abilities and difficulties in solving cases, and the availability of problem-solving learning tools owned by lecturers. The analysis of the needs for developing this learning model has been carried out by researchers, with the results described as follows (Murtafiah et al., 2022). Many prospective mathematics teachers still have difficulty in finding problem-solving ideas. They are not precise in choosing strategies and procedures for solving. This causes prospective mathematics teachers to be less able to solve mathematical problems well. Other results show that many lecturers have not allowed prospective mathematics teachers to express, clarify, and assess solution ideas. In addition, there are no learning tools that are explicitly designed so that prospective mathematics teachers become good problem solvers. From this planning stage, the results obtained indicate the need to develop a decision-making-based learning model to train prospective mathematics teacher students in solving problems.

3.1.2. Development Stage

Research instruments, learning models, and tools are designed at this development stage. At this stage, validation was performed by five experts in the field of mathematics education. The research instruments designed include five validation instruments, namely (1) learning model validation instrument, (2) lesson plan validation instrument, (3) student worksheet validation instrument, (4) decision making ability assessment validation instrument, (5) lecturer response questionnaire validation instrument, and students, with validation results as shown in Table 2.

Table 2. Validity criteria

Instruments	**Score Each Aspect**									**Average**	**Criteria**
	Validator 1			**Validator 2**			**Validator 3**				
	Format	**Content**	**Language**	**Format**	**Content**	**Language**	**Format**	**Content**	**Language**		
Learning model validation instrument	4	4	4	4	4	4	4	4	4	4.00	Very Valid
Lesson plan validation instrument	4	3.7	4	4	4	4	4	3.7	4	3.93	Very Valid
Student worksheet validation instrument	4	4	3	4	3.6	4	4	4	4	3.84	Very Valid
Decision-making ability assessment validation instrument	4	4	3	4	4	4	4	4	4	3.89	Very Valid

Instruments	Score Each Aspect									Average	Criteria
	Validator 1			Validator 2			Validator 3				
	Format	Content	Language	Format	Content	Language	Format	Content	Language		
Student response questionnaire validation instrument	4	3.6	4	4	4	3	4	4	4	3.84	Very Valid

The next step is to develop a learning model by designing an e-IBCA learning model book to improve students' decision-making abilities. The learning model book is designed to include four chapters and appendices. The structure of the model book consists of a cover, foreword, and table of contents. Chapter 1: Rationale for the e-IBCA learning model, Chapter 2: theory underlying the e-IBCA learning model, Chapter 3: e-IBCA learning model, Chapter 4: instructions for using the learning model, bibliography and appendices. The learning model designed is e-IBCA with syntax as shown in Figure 4.

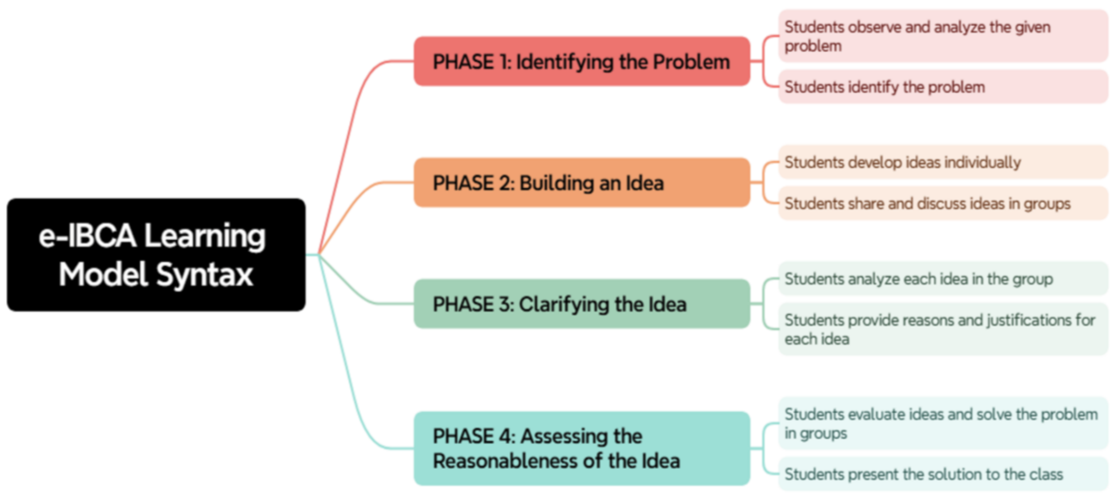

Figure 4. e-IBCA learning model syntax

The validation results of the e-IBCA learning model are presented in Table 3. The results of the validation of the learning model by the five validators show that, on average, each aspect assessed falls into the very valid criteria.

Table 3. Learning model validation result

Aspect	Score Each Aspect					Average	Criteria
	Validator 1	Validator 2	Validator 3	Validator 4	Validator 5		
Supporting theory	4	4	4	4	4	4	Very Valid
Syntax	3.25	4	3.5	3.5	4	3.65	Very Valid
Social system	3.33	4	3.5	3.5	4	3.67	Very Valid

Aspect	Score Each Aspect					Average	Criteria
	Validator 1	Validator 2	Validator 3	Validator 4	Validator 5		
Reaction principle	4	3.83	3.92	4	3.92	3.93	Very Valid
Support system	3.29	3.86	3.57	3.71	4	3.69	Very Valid
Instructional impact and accompanying impact	4	4	4	4	4	4	Very Valid
Learning implementation	3.43	3.86	3.29	3.86	4	3.69	Very Valid

The subsequent development is the design of learning tools. This design was developed by developing lesson plans, student worksheets, and decision-making ability evaluation tools for testing/implementing the e-IBCA learning model. The validation results of the developed learning devices fall into the very valid criteria and can be seen in Table 4.

Table 4. Learning tools validation result

Instruments	Score Each Aspect															Average	Criteria
	Validator 1			Validator 2			Validator 3			Validator 4			Validator 5				
	Format	Content	Language	Format	Content	Language	Format	Content	Language	Format	Content	Language	Format	Content	Language		
Lesson plan	4	4	4	3	4	4	4	3	4	3	4	4	4	4	4	3,8	Very Valid
Student worksheet	4	4	4	4	3	4	4	4	4	4	4	4	4	4	4	3,93	Very Valid
Assessment of decision-making	4	3	4	4	4	4	4	4	4	4	4	4	3	4	3	3,8	Very Valid

3.1.3. Implementation Stage

At this implementation stage, trials were conducted at two universities and implemented at six universities. The results of lecturer and student responses and student learning achievements in solving HOTS cases/problems/questions during testing and implementation are presented below. Trials were carried out at Universitas PGRI Madiun and Universitas Jember in differential equations and microteaching courses. Implementation was conducted at Universitas Nusantara PGRI Kediri (UNP Kediri), Universitas Veteran Bangun Nusantara Sukoharjo (UNIVET), Universitas Pendidikan Mandalika, Universitas PGRI Delta Sidoarjo, Universitas PGRI Kalimantan, and Universitas Hamzanwadi in the subjects of Learning Media Production, Basic Statistics, Introduction to Mathematics, Integral Calculus, Linear Programming, and History of Mathematics. The e-IBCA learning model is implemented offline and online using ICT (e-learning and online evaluation applications).

The results of the analysis of lecturer and student responses to the implementation of the e-IBCA learning model in medium and wide-scale trials are presented in Table 5.

Table 5. Response results to the e-IBCA learning model

Aspect	Medium-scale trial	Wide-scale trial	Average	Category
Clarity of learning steps	88.33%	88.38%	88.36%	Very Good
Learning atmosphere	83.33%	88.03%	85.68%	Very Good
Use of supporting media	83.75%	84.95%	84.35%	Very Good
Knowledge, attitudes, and skills training	85.33%	87.39%	86.36%	Very Good
Average	85.19%	87.19%	86.19%	Very Good

Table 5 shows that lecturers and students responded with an average of 85.19% in the medium-scale trial and 87.19% in the wide-scale trial. In addition, the overall response average was 86.19%. This indicates that the e-IBCA learning model developed is practical with an outstanding category, which means that this model can be applied to learning in several different courses, both mathematics and education.

The effectiveness of the e-IBCA learning model is assessed following the findings of tests performed using the instrument. The average level of growth (N-Gain) and the pre-test and post-test are then used to determine these findings. Tables 6 and 7 provide data on the average pre-test, post-test and N-Gain scores from the two universities for the small group trial and six universities for the big group trial.

Table 6. Mean scores from Universitas PGRI Madiun and Universitas Jember for the pre-test, post-test and N-Gain

Description	Universitas PGRI Madiun		Universitas Jember	
	Pre-Test	Post-Test	Pre-Test	Post-Test
Lowest value	28	64	46	61
Highest score	80	93	91	95
Average value	60.91	82.68	65.10	82.05
Number of students	22	22	21	21
Average N-Gain	0.57		0.52	
The Average N-Gain is 2 Universities	0.54			
Category	Medium			

Table 6 shows that the average post-test score is higher than the pre-test score at Universitas PGRI Madiun and Universitas Jember. The average N-Gain in Universitas PGRI Madiun is 0.57 in the medium category. Meanwhile, the average N-Gain in Universitas Jember is 0.52 in the medium category. The average N-Gain in those two universities is 0.54 in the medium category.

Table 7. Mean scores from Universitas PGRI Delta Sidoarjo, UNP Kediri, UNIVET, Universitas PGRI Kalimantan, Universitas Pendidikan Mandalika and Universitas Hamzanwadi for the pre-test, post-test and N-Gain

Description	Universitas PGRI Delta Sidoarjo		UNP Kediri		UNIVET		Universitas PGRI Kalimantan		Universitas Pendidikan Mandalika		Universitas Hamzanwadi	
	Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test
Lowest value	45	55	51	78	52	72	41	77	50	75	40	80
Highest score	81	90	72	95	83	98	81	90	80	95	84	98

Description	Universitas PGRI Delta Sidoarjo		UNP Kediri		UNIVET		Universitas PGRI Kalimantan		Universitas Pendidikan Mandalika		Universitas Hamzanwadi	
	Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test
Average value	64.58	81.32	62.33	86.5	64.30	83.80	58.25	80.50	65.77	86.51	65.35	88.47
Number of students	19	19	12	12	20	20	12	12	35	35	34	34
Average N-Gain	0.49		0.63		0.55		0.48		0.56		0.64	
The Average N-Gain is six universities	0.56											
Category	Medium											

Table 7 shows that the average post-test score is higher than the pre-test score in Universitas PGRI Delta Sidoarjo, UNP Kediri, UNIVET, Universitas PGRI Kalimantan, Universitas Pendidikan Mandalika, and Universitas Hamzanwadi. The average N-Gain in Universitas PGRI Delta Sidoarjo is 0.49 in the medium category. The average N-Gain in UNP Kediri is 0.63 in the medium category. The average N-Gain in UNIVET is 0.55 in the medium category. The average N-Gain in Universitas PGRI Kalimantan is 0.48 in the medium category. The average N-Gain in Universitas Pendidikan Mandalika is 0.56 in the medium category. Meanwhile, the average N-Gain in Universitas Hamzanwadi is 0.64 in the medium category. The average N-Gain in those six universities is 0.56 in the medium category.

The effect of the e-IBCA learning model was also used in Cohen's *d* formulation. The average level of growth (N-Gain) and the pre-test and post-test are then utilised to determine these findings. Tables 8 and 9 provide data on the average pre-test, post-test and Cohen's *d* formulation scores from the two universities for small group trials and six universities for big group trials.

Table 8. Mean scores from Universitas PGRI Madiun and Universitas Jember for the pre-test, post-test and Cohen's *d* formulation

Description	Universitas PGRI Madiun		Universitas Jember	
	Pre-Test	Post-Test	Pre-Test	Post-Test
Lowest value	28	64	46	61
Highest score	80	93	91	95
Average value	60.91	82.68	65.10	82.05
Number of students	22	22	21	21
Average Cohen	0.90		0.95	
The Average Cohen is two universities	0.92			
Category	Large			

Table 8 shows that the result of Cohen's *d* formulation in Universitas PGRI Madiun is 0.90, which is in a large category. Meanwhile, the result of Cohen's *d* formulation in Universitas Jember is 0.95, which is in a large category.

Table 9. Mean Scores from Universitas PGRI Delta Sidoarjo, UNP Kediri, UNIVET, Universitas PGRI Kalimantan, Universitas Pendidikan Mandalika and Universitas Hamzanwadi for the pre-test, post-test and Cohen's *d* formulation

Description	Universitas PGRI Delta Sidoarjo		UNP Kediri		UNIVET		Universitas PGRI Kalimantan		Universitas Pendidikan Mandalika		Universitas Hamzanwadi	
	Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test
Lowest value	45	55	51	78	52	72	41	77	50	75	40	80
Highest score	81	90	72	95	83	98	81	90	80	95	84	98
Average value	64.58	81.32	62.33	86.5	64.30	83.80	58.25	80.50	65.77	86.51	65.35	88.47
Number of students	19	19	12	12	20	20	12	12	35	35	34	34
Average Cohen	0.94		0.95		0.95		0.91		0.88		0.90	
The Average Cohen is six universities	0.92											
Category	Large											

Table 9 shows that the result of Cohen's *d* formulation for Universitas PGRI Delta Sidoarjo is 0.94, which is in a large category. The result of Cohen's *d* formulation UNP Kediri is 0.95 in the large category. The result of Cohen's *d* formulation UNIVET is 0.95 in a large category. The result of Cohen's *d* formulation for Universitas PGRI Kalimantan is 0.91 in a large category. The result of Cohen's *d* formulation for Universitas Pendidikan Mandalika is 0.88 in a large category. Meanwhile, the result of Cohen's *d* formulation, Universitas Hamzanwadi is 0.90 in the large category. The average Cohen's *d* formulation in six universities is 0.92 in a large category.

3.1.4. Evaluation Stage

Data is obtained at the implementation stage. This evaluation stage also analyzes the feasibility of the e-IBCA learning model and finds out whether this model can develop and teach prospective mathematics teachers' decision-making abilities—feasibility analysis of the e-IBCA learning model in Figure 5.

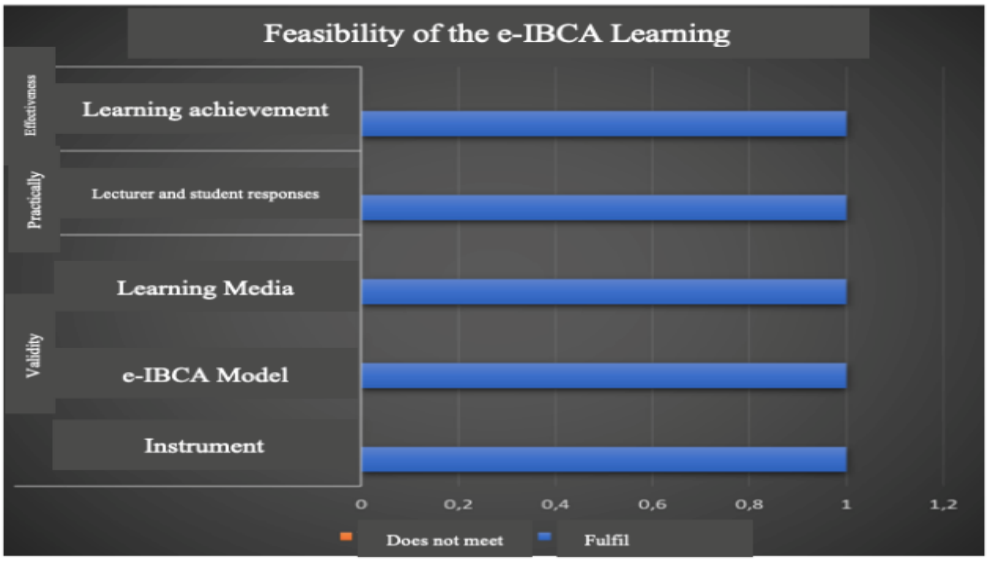

Figure 5. Feasibility of the e-IBCA learning model

Figure 5 shows that at the instrument development stage, learning models and learning tools meet the validity criteria, while at the implementation stage, they meet practicality and effectiveness. The ideas set by students are shown in Figure 6.

a) What ideas do you have to help teachers with the problem above? Identify possible sources to help resolve the above problem/to prepare the material well, the teacher must prepare/arrange learning methods, prepare learning materials in accordance with the learning program plan. So, to be able to solve the problem above, you can research the material first before starting. Examples that we can follow, include looking for reference internet, social media or interviewing other people who have experience.

a. What methods can possibly be used to complete that differential equations!
- By using exact differential equations
- By using separate variable differential equations

PT Galah Bonar produces Sasirangan clothes for men and women, 1 Sasirangan clothes for men needs 1,5 m^2 of fabric and 2 rolls thread. Then, 1 Sasirangan clothes for women needs 2 m^2 of fabric and 3 rolls thread. Sasirangan men selling for Rp. 200.000 and women's Sasirangan for Rp. 300.000. If there have 30 m^2 of fabric and 60 rolls thread, how many Sasirangan clothes can be produces to get maximum profit.

a) What ideas do you have to solve the problem above? Write down possible pros/media to help explain the solution to the problem above!
- Train
- Pyramid

Write down statistical ideas that the analyst might be able to use so that the policies adopted can be fair to all employees according to their length of service.
- Using average
- Using standard deviation
- Data variations

Figure 6. Building solution ideas

Figure 6 shows that students build ideas by mentioning 1 to 3 pictures or ways to solve problems/cases according to the material in the course. At the clarifying stage, students clarify the ideas by stating explanations regarding their idea selection, as shown in Figure 7.

b. Write down the reasons for using the method in point a.

1. Because the problem is $M(x, y)dx + N(x, y)dy = 0$
2. Because the problem is $g(x)dx + h(y)dy = 0$

b) Give an explanation or reason regarding the ideas mentioned above! And develop strategy to solve the problem!

Regarding the ideas that have been proposed. It is important to first understand what problem we want to solve, so that it is easy to understand the available problems, because by looking for references first, information related t the problem can be resolved easily.

b) Give an explanation or reason regarding the solution idea you have!

The reasons, because Sasirangan is a traditional from South Kalimantan, so that it will be more traditional from South Kalimantan, and the questions we make can be decided using simplex method so that we can find out how many traditional clothes it is made within the limits of supply.

b) Give an explanation or reason regarding the props/media ideas mentioned above!
- The train stops at a station carrying new passengers (new bacteria) to continue their journey to the next station.
- Pyramid begins at 100 as it goes down doubles the previous value.

Provide an explanation regarding the ideas presented in point (2). Write down the advantages and disadvantages (if any) if the idea is implemented!
- Using average, you can find out the average of the data. But must require accuracy in calculating data.
- Looking for the standard deviation produces the standard deviation value, which is fixed and well defined but is not based on providing specific information in the data.
- Looking for data variations can find out how far apart a collection of data is from the average, the disadvantages is that requires time for analysis the varians.

Figure 7. Clarifying ideas

Figure 7 shows that students clarify the possible solution by stating the reasons for selecting the concepts for solving differential equation problems. At the Assessing the Reasonableness of Ideas stage, students assess the reasonableness of ideas regarding solving differential equations, as shown in Figure 8.

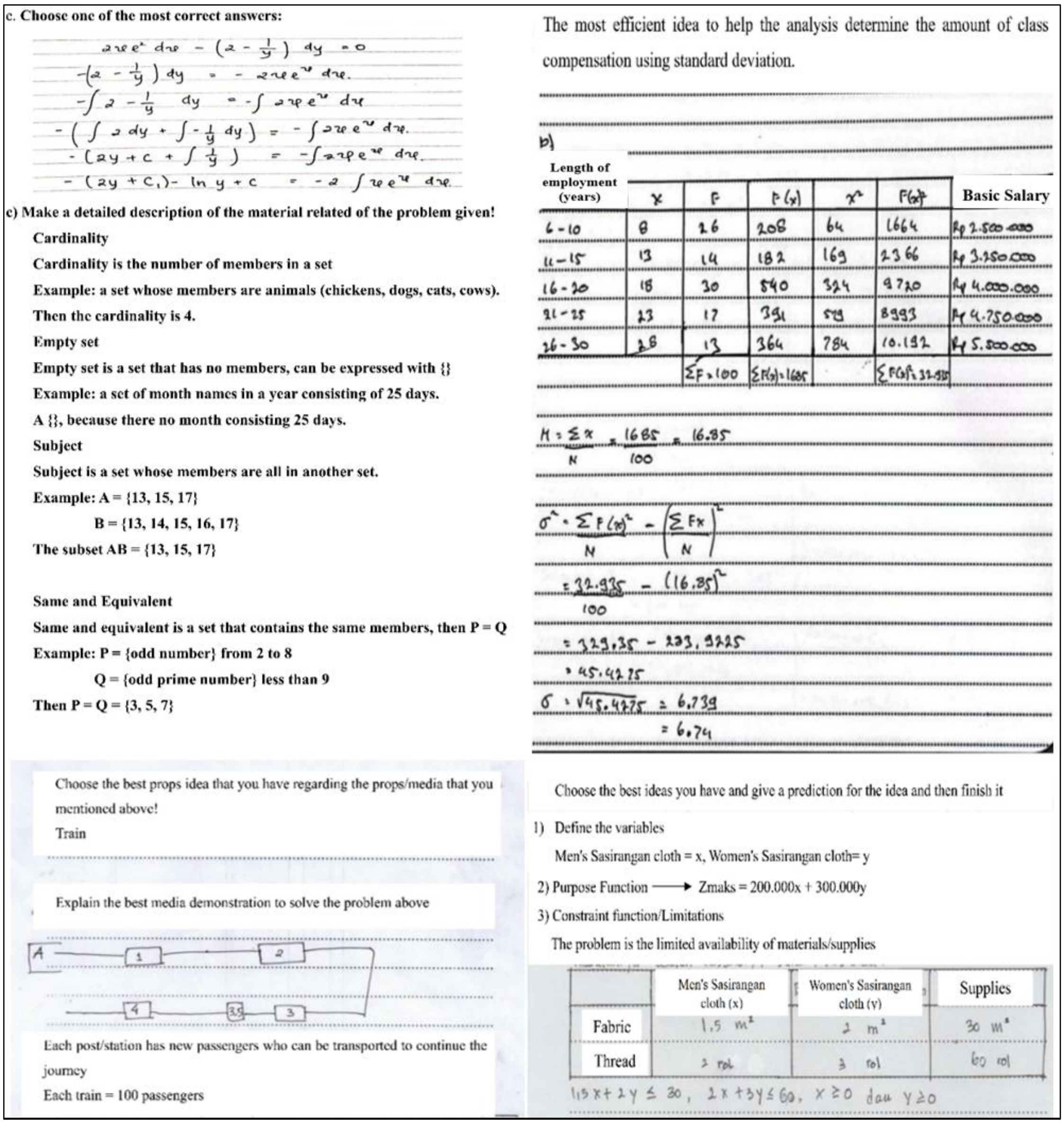

Figure 8. Assessing the reasonableness of ideas

The student shows the idea selected by the student to solve the problem. Students assess the reasonableness of ideas in solving problems/cases by selecting 1 of several theories that have been clarified. In implementing the reasonableness of this idea, students made predictions based on logical explanations.

3.2. Discussion

The planning stage is identified following the analysis of the learning model requirements. In mathematics learning, a problem is a mathematical question or problem for which the process of finding a solution is not immediately apparent but requires thinking, analysis, and challenges (Bell, 1978; Wahyuni et al., 2020). Problems are tasks that need to be completed using non-routine procedures (Cai & Lester, 2010; Murtafiah et al., 2024; Siswono et al., 2017; Widodo et al., 2024). Problem-solving abilities should be taught to teacher candidates, as it is part of professional teachers' necessary pedagogical content abilities

(Lestari et al., 2019; Murtafiah & Lukitasari, 2019). Therefore, lecturers should often provide HOTS questions in learning activities to develop student problem-solving skills (Sa'dijah et al., 2021).

The results also show that students' ability to communicate problem-solving needs to be developed (Kana, 2015). Previous research also states that student creativity still needs to improve in solving problems (Murtafiah et al., 2023). Difficulties are also experienced by students at the problem-solving stage, especially in understanding, planning, and implementing strategies (Yapatang & Polyiem, 2022). Educators are expected to design learning processes that facilitate students' learning and application of effective learning (Ndia et al., 2020). Implementing effective learning models allows students to obtain better grades, highlighting the importance of educators designing relevant learning models (Reigeluth & Carr-Chellman, 2009). In learning, the lecturer was correct because he gave HOTS questions to students. After all, problems were used as a starting point in education so that students were used to developing their thinking abilities (Samo et al., 2018). So, it is necessary to equip students with decision-making skills to solve problems. The thinking process in making decisions regarding solution ideas is very important so that students can obtain a reasonable solution because it goes through a series of decision-making steps (Randahl, 2016). Therefore, it is essential to design or develop learning models to teach decision-making, namely the e-IBCA learning model, to improve the decision-making abilities of teacher candidates. e-IBCA is short for electronic, with the syntax consisting of (1) Identifying the problem, (2) Building an idea, (3) Clarifying the idea, and (4) Assessing the reasonableness of the idea.

To create this learning model, development needs to be carried out, which includes (1) instrument development, (2) development of learning models and (3) development of learning tools. The research instruments are designed to validate or assess products such as model books and learning tools (learning plans, student activity sheets, and decision-making assessment sheets). The results of instrument development, development of learning models, and development of learning tools validation show that it is very valid, which means it is ready for research. This is because determining the average of each assessment given by the validators is more than 3 (Hasyim et al., 2024; Meilantifa & Budiarto, 2018), which is then included in the validity criteria (Hariadi et al., 2021). The model book validation sheet consists of 7 indicators/aspects, namely 1) supporting theory, 2) syntax, 3) social system, 4) reaction principle, 5) supporting system, 6) instructional impact and accompaniment, and 7) learning implementation. Researchers design the learning model for online, offline, and blended learning. The stage starts with identifying problems because it is the first step to building knowledge in thinking (Bacraharya, 2010; Reiter-Palmon & Robinson, 2009). Next, the stage of creating ideas is designed where students can generate many ideas in various categories, and having new ideas is very supportive for solving problems (Rahman, 2017). The ideas built are then clarified at the clarifying ideas stage because students analyze ideas and compare them, which is convergent thinking to choose the optimal solution to a problem (Barak, 2009; Treffinger & Isaksen, 2013). Then, it ends with the assessing reasonableness ideas stage, a critical thinking activity that can help students make careful assessments to make the right decisions (Hidayat et al., 2025; Mahanal et al., 2019; Zubaidah et al., 2018).

In the implementation stage, the results of this research indicate the practicality of a product resulting from its development. The e-IBCA learning model developed is practical because it received positive responses from students (Hasyim et al., 2024; Rohaeti et al., 2019). This indicates that the e-IBCA learning model developed is practical with a very good category, which has been proven that this learning model can be applied to several different courses in mathematics education. The average N-Gain in small and big group trials are in the medium category, which indicates that the e-IBCA learning model developed is effective. The effect of the implementation of the e-IBCA learning model is in a large category (Goulet-Pelletier & Cousineau, 2018; Lakens, 2013; Maher et al., 2013). This means that it can greatly improve students' decision-making skills (Cohen et al., 2002). Additionally, the e-IBCA learning model can have a positive impact and improve students' learning achievements across all courses in offline or online learning. This learning model which can be implemented both online and offline, also supports case study-based learning to solve everyday problems (Hidayat et al., 2022; Hidayat et al., 2023).

Thus, the evaluation stage showed that the e-IBCA learning model is feasible as it meets the validity, suitability, and efficacy requirements. Next, the student's achievements in decision-making abilities in solving cases in several courses are presented. The process begins with the stage of building an idea for a solution. This indicates that students can generate ideas by listing several ideas (Hasan et al., 2025; van Merriënboer, 2013). Students state their views based on their experience and knowledge (Borko et al., 2008; Murtafiah et al., 2020). The clarification done by students aligns with the opinion that clarifying ideas includes giving reasons and expressing assumptions about the statements presented (Swartz et al., 1998; Vieira et al., 2011). In implementing the reasonableness of this idea, students made predictions based on logical explanations (Lestari et al., 2018; Syamsuddin et al., 2020). This follows the fact that in assessing the reasonableness of an idea, a person must have confidence in what he has chosen by referring to the logical reasons put forward, which also shows the student's communication skills (Hidayat & Aripin, 2023; Murtafiah & Lukitasari, 2019; Ningsih et al., 2023; Ristiana et al., 2025). The decisions made by students are based on their basic knowledge. Apart from expertise, this decision-making is also based on experiences in learning mathematics (Sa'dijah et al., 2021).

4. CONCLUSION

This research shows that a needs analysis was carried out for lecturers and students at the planning stage, and objectives were identified. At the development stage, research instruments, learning models, and learning tools were designed with an average validation score in very valid criteria. At the implementation stage, trials were conducted at two universities and implemented at six universities, with the lecturers and students giving positive responses in very good category, which means that the e-learning model IBCA meets practicality. The student's achievement results with the average N-Gain in medium category and the average Cohen's *d* formulation in large category, which shows that the learning model is effective. Thus, the e-IBCA learning model is feasible and can enhance the decision-making abilities of mathematics teacher candidates.

This study is limited to the development and implementation of the e-IBCA learning model within selected mathematics education courses at partner institutions. Trials were conducted at Universitas PGRI Madiun and Universitas Jember, while broader implementation occurred at six additional universities across diverse subjects. The model was applied in both offline and online settings using ICT tools; however, the study does not explore long-term learning outcomes, cross-disciplinary applications, or contextual variables such as institutional infrastructure, pedagogical approaches, and learner diversity, which may constrain the generalizability of the results. Despite these limitations, the study demonstrates a positive impact by enhancing decision-making skills among prospective mathematics educators, indicating the model's potential to support more reflective and adaptive teaching practices in the digital era. It is recommended that future research expand the model’s application across disciplines, investigate long-term impacts, and adapt it to diverse educational contexts in combination with various ICT-based media to optimize its broader educational benefits and ensure its relevance in increasingly digital learning environments.

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Declarations

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