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Implementation of Relational Database in the STEAM-Problem Based Learning Model in Algorithm and Programming

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***Abstract*— Currently, digital technology is developing in all fields. The development of this technology certainly has a significant impact on the world of education. A suitable learning model is needed, especially in the Algorithm and Programming course, to face global challenges in the Industrial Revolution 4.0. Students are expected to have skills that include critical and creative thinking in solving problems, communication, and collaboration with the support of technology. The STEAM-Problem Based Learning model can be used in the Algorithm and Programming learning process with seven syntaxes: preparation and knowledge identification; problem identification; plan solution; create and test products; communicate; evaluation and feedback and giving rewards. All activities carried out in the learning process by lecturers and students can be stored in a database. This research attempts to determine the validity of the STEAM-Problem Based Learning database design, which will be implemented in the Algorithm and Programming course. The data analysis technique used is validity analysis, which is based on assessing the data obtained through a questionnaire or a questionnaire using a Likert scale. Data was processed using Aiken's V validity coefficient formula to test the expert's judgment. Assessment indicators include correctness, consistency, relevance, completeness, and minimality. The results of the study show that the validity test on the STEAM-Problem Based Learning database design is valid, so it is feasible to implement it in algorithm and programming learning.**

***Keywords*— Database; relational database; STEAM; problem-based learning.**

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I. INTRODUCTION

Problem-based learning is a learning model popularly applied in the world of education, including in Indonesia, apart from the project-based learning model. These two learning models have something in common: prioritize activity, while the difference lies in the products produced. The problem-based learning method prioritizes critical thinking products, while project-based learning prioritizes products in the form of completed projects based on competency. Through problem-based learning methods, it has been found that students' thinking skills have improved in many Asian countries, including Indonesia [1]. Critical thinking skills are fundamental skills in solving problems [2]. These skills are essential for students to find the source of the problem and the right solution for it. Critical thinking skills can be instilled in various disciplines. Lecturers are essential in designing and developing learning programs that empower these skills. Creative thinking skills are related to applying a new approach to solving a problem to make an innovation.

Problem-based learning developed rapidly using digital devices during the COVID-19 pandemic and is still in most countries, especially in the medical field [3]. Along with technological developments, there has been a change in the characteristics of students into a generation that is more open-minded, inclusive and understands technological developments, so a problem-based learning model is needed that is in line with technological developments and maximizes the power of critical thinking [4], [5]. The quality of humans in a country is determined by the implementation of good education, which indicates the development of thought patterns ethics and human behavior in society. Industry 4.0 has attracted significant interest from companies, governments, and individuals as a new concept of industrial, future computer, and social systems [6]. In the present-day context, the ongoing expansion of technology and the development of new products amplify the importance of innovation and creativity across multiple fields [7].

The US-based Partnership for 21st Century Skills (P21) identifies critical thinking, creative thinking, communication, and collaboration skills as competencies needed in the 21st century. These competencies are known as 4C competencies. The application of the 4C learning model can affect student learning outcomes. To create innovation, students need new and original ideas, knowledge, and skills in planning and making solutions for more creative problem-solving. The rapid advancement of technology has positively impacted various industries, including the industrial sector and different service sectors. The education sector has particularly benefited [8], [9]. Learning engagements in programming learning activities are critical to developing students' higher-order thinking skills [10]. Students' creative thinking skills such as their willingness to solve problems can be exemplified. Problem-based learning demonstrates a degree of academic accomplishment and enhances problem-solving capabilities. The application of the problem-based learning model is very practical in algorithms and programming supported by mathematics as a basic science in computing, which is needed to build an algorithm and program [11]. Collaboration is a vital skill in the modern era, and there's growing attention towards utilizing computer-supported collaborative learning to cultivate the necessary competencies for 21st-century students. However, there remains a shortage of strategies for facilitating collaboration among learners in specific subject areas. With the growing emphasis on collaborative problem-solving (CPS) abilities, there has been a rising interest in investigating methods to evaluate these skills using digital technologies in recent years [12], [13], [14]. CPS is recognized as a crucial skill for the 21st century. Success in CPS relies on possessing CPS skills and having positive attitudes toward collaboration, known as collaboration dispositions [15].

To face the Industrial Revolution 4.0, the Informatics and Computer Higher Education Association (APTIKOM) in 2019 has socialized the development of the OBE-based IQF curriculum in Informatics and Computer Science. Based on eight topic domains in Informatics Engineering, one of them is Algorithm and Programming, which requires students to think creatively and innovatively. Programming is an essential skill for computer science learners and a widely visible skill employed across many fields worldwide. Nevertheless, it's frequently observed that students typically exhibit low interest and confidence in coding [16]. Computer programming can improve the problem-solving skills of students of all ages. Reflective judgment and computational skills related to problem-solving should be included in the training program as part of learning applied programming at various levels. Programming is important in Science, Technology, Engineering, Art, and Mathematics (STEAM) education. However, programming concepts and syntax are characterized by their high level of abstraction [17].

In Industry 4.0, data models and standards are essential elements given the ever-increasing amount and variety of data [18]. Implementing Science, Technology, Engineering, Arts, and Mathematics (STEAM) in teaching and learning allows teachers to integrate culture, architecture, environment, technology, and math [19]. The development of the STEAM-Problem-Based Learning model needs a system that can monitor student learning progress. For this reason, a database is needed to store data permanently, such as data on students, lecturers, course materials, grades obtained from attendance, exercises, quizzes, assignments, and tests carried out. In this system, lecturers can see student learning progress anytime and anywhere.

II. Materials and Methods

A. Literature Review

In this section, theoretical concepts related to research will be explained. An effective learning model is needed in learning algorithms and programming. The Problem-Based Learning model can train students' skills to solve problems so that students' reasoning will be developed. Therefore, problem-based learning has the potential to solve the weaknesses of the traditional approach. To see the experience of students in problem-based learning, it is generally shown that students are happier and more satisfied to gain experience with the problem-based learning model than with conventional learning programs. Problem-based learning is learning based on actual problems and situations in everyday life to encourage students to learn and involve students optimally. Problem-Based Learning is an effective model for increasing interaction between students and lecturers with students [20].

Today, education is initiating another revolutionary shift in modernity. The fourth industrial revolution was shaped by global decentralization, increased acceptance of interdisciplinary innovation, and rapid adoption of innovation across society. Components strongly support learning processes that grow rapidly and are self-reinforcing in iterative development, supporting sustainable change throughout society. An education system in a state of chaos is trying to balance the needs of the past and preparing students for the future. Recognizing the need for change, there has been an increasing focus on integrated, cross-cutting approaches in Science, Technology, Engineering, and Mathematics (STEM). While the terminology may be debated, the basic premise and rationale for STEM education has always been to integrate the transdisciplinary understanding of the four subject areas to encompass a more holistic view of community development. STEM-specific skills are higher than soft skills in scoring [21]. The focus of STEM or STEAM should be on preparing students for a future that includes related knowledge and skills integrated into the arts and humanities. In education, STEAM means there is a need to consider how to design learning experiences and environments. The STEAM model can develop students' ability to think creatively and critically.

The primary skills that are highly valued by students in the literature concerning modern learning consist of learning objectives related to the development of problem-solving, collaboration, and students' soft skills. Problem-solving is a confluence of critical thinking processes aimed at investigating and interpreting information. Meaningful interpretation and problem solutions emerge from student inquiry, which revolves around more profound reflective practice to engage students' critical thinking skills fully. Consequently, the STEAM curriculum is designed to enrich students' problem-solving skills through involvement in higher-order thinking practices that aim to conceptualize the basic principles of problem-solving. The STEAM with rich art elements can activate in-depth discussions, and students' emotional experiences may be stimulated by the art elements so that lecturers can further increase students' interest in the material in Algorithms and Programming [22].

STEAM is an interdisciplinary pedagogical approach integrated as a multidisciplinary learning model that explicitly aims to develop creative thinking skills and collaboration across disciplines [23]. The collaborative orientation of STEM and STEAM problem solving is envisioned to encourage the development of teamwork through solving group challenges. Solving objective problems that arise from collaborative efforts. Students are instructed in developing collaborative problem-solving that focuses on how each student's role contributes to completing tasks in the group as a whole. As a result, students learn to collaborate with various students with different interests, abilities, and backgrounds. Individual learners' diverse collaborative problem-solving efforts strive to achieve learning objectives by contributing to developing a creative atmosphere for student learning and engagement in practice.

The STEAM-Problem-Based Learning model is a learning model that is designed attractively so that the implementation of learning can run effectively. This model is a learning approach that emphasizes the relationship of science, technology, engineering, art, and mathematics (STEAM) knowledge and skills to solve problems. The development of the STEAM-Problem Based Learning model is hoped to make the learning process fun, effective, and efficient, providing opportunities for students to receive new information, apply, analyze, and even assess that information. Students can build their knowledge, describe abstract things into concrete, and get meaningful learning experiences from what they learn. Thus, it is expected to improve student learning achievement, metacognition, communication skills, problem-solving abilities, and students' critical thinking. Integrating STEAM activities into education might be an efficient strategy for cultivating creativity [24]. STEAM-Problem-Based Learning provides a series of problem-solving activities in real-world contexts combined with science, technology, engineering, art, and mathematics so that students will be assisted in more creative thinking processes in facing every challenge. STEAM-Problem-Based Learning also provides students with interesting, broad, and meaningful learning experiences. Overall, communication skills have been emphasized throughout the literature as important for developing problem-solving skills with active learning approaches, especially metacognitive and collaborative skills [25].

In the current era of information technology, programming has become a significant activity. Programming is the heart of computer science [26]. The program can run on several devices built in a process that becomes a work pattern of the program, namely the algorithm. The algorithm is the heart of computers or informatics. The term algorithm refers to many branches of computer science. Using algorithmic techniques is essential for solving many significant problems in the life sciences. Developing good and correct algorithms can monitor and control the system being built [27]. Algorithms can be made to solve problems that exist in the real world optimally. The development of real-world optimization challenges and their effective resolution using algorithms has instigated many research investigations [28].

The relational model has been the dominant approach in the computer industry for storing and retrieving data since the 1980s [29]. For decades, relational databases have been at the heart of many information systems [30]. Currently, a significant quantity of data on the Internet is stored using relational databases [31]. Relational database management systems are used to explore the hidden and real relationships among data. One can obtain the required information scattered across tables using user-defined queries [32]. Relational schema can store and organize metadata items [33]. The relational model is based on the mathematical concept of relationships and is represented in tabular form. A relational schema comprises a collection of relation schemas. Each relation schema defines the relation's name, attribute names, and the domain of each attribute. The connections between relations are implied through key propagation from one relation schema to another in the case of one-to-one and one-to-many relationships or through distinct relation schemas for many-to-many relationships. As a result, a relational schema can depict entity or relation types. The construction of a relational schema involves the inclusion of tuples in each relation. One or more attributes form the key (primary key) of each relation, and the value of the critical attribute determines the uniqueness of each tuple. Tables represent relationships, with attributes referred to as columns and tuples as rows. A table may specify a foreign key, which comprises one or more columns referencing the primary key of another table for key propagation [34].

The extensive adoption of the relational storage paradigm may result from its dominance in the field of Database Management Systems (DBMS), which is attributed to its simplicity and developers' extensive experience [35].

B. Research Method

The database design in the development of the STEAM-Problem-Based Learning model goes through several stages, as shown in Fig. 1.

1) Stage 1, Data collection and analysis: The process of identifying and analyzing data requirements. To determine the needs of a database system, first know the parts of the information system that will interact with the STEAM-Problem Based Learning database system, including existing users and new users and their applications. Activities in data collection and analysis:

- Determine user groups and areas of application.
- Review of existing documentation.
- Analysis of the operating environment and data processing.
- Questionnaires and interviews.

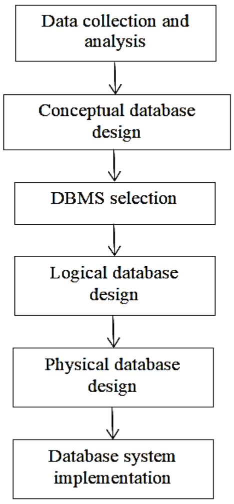

Fig. 1 Stage of database design

The data obtained is in the form of lecturer data, lecture material data, student data, attendance data, lecture data in the form of individual and group assignments, quizzes, exercises, tests, and assessment data given by the lecturer. The data obtained is in the form of lecturer data, lecture material data, student data, attendance data, lecture data in the form of individual and group assignments, quizzes, exercises, tests, and assessment data given by the lecturer.

2) Stage 2, Conceptual database design: At this stage, a conceptual scheme for a database in a specific DBMS will be obtained using a high-level data model in the form of an ER model. Based on the data collected, data modeling is made in a conceptual scheme described using the MySQL database application. The data is stored in a database and grouped into 20 tables. In cases where information is stored across several tables, these tables are linked by foreign keys that implicitly represent and establish connections between objects and their attributes [36]. In designing this model through a normalization process [37], as Fig. 2. Each normalization stage indicates a higher level of conformity to the established database design standards. Increasing the data normalization level will result in more tables with fewer columns [38]. A potential area for future exploration is enhancing operations across entity models, explicitly focusing on matching operations designed to identify duplicate or asynchronously stored data [39].

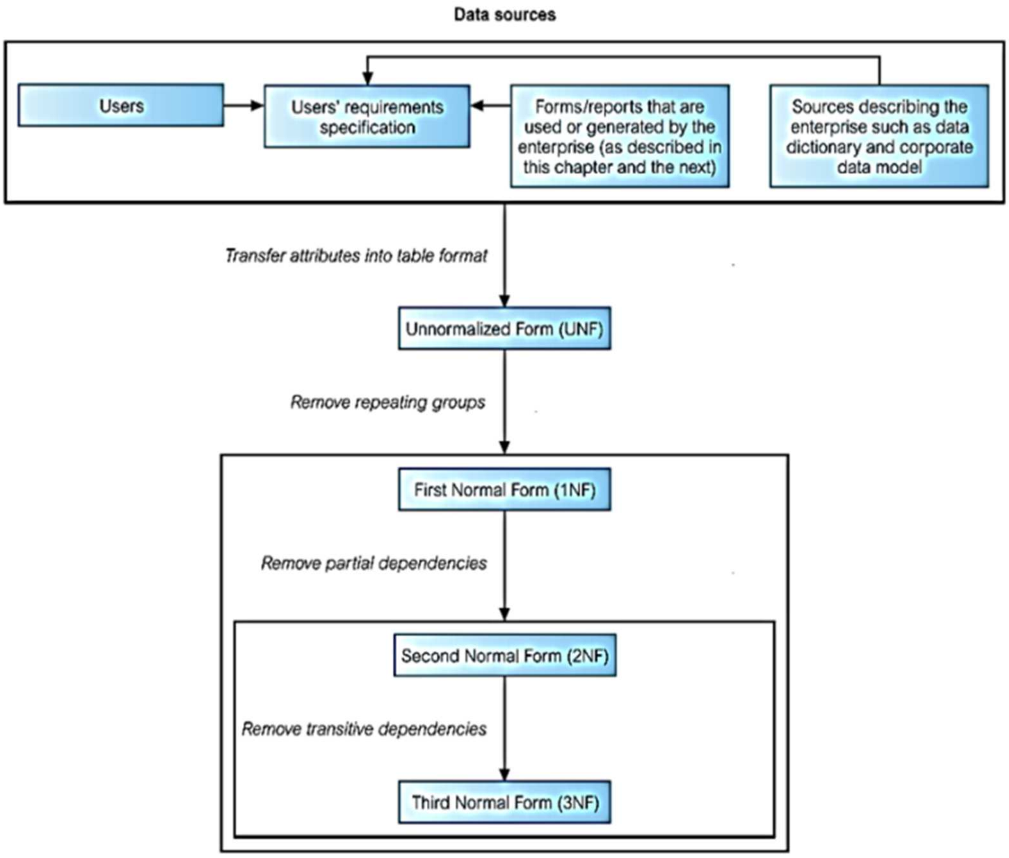

Fig. 2 Diagrammatic illustration of the process of normalization

3) Stage 3, DBMS Selection: Database selection is determined by technical, economic, and organizational political factors. The technical factor is the existence of a DBMS in carrying out its duties by using a relational DBMS type, storage structure, and access paths that support the DBMS, users, and others. Economic and organizational factors that influence each other in the selection of DBMS include a). The data structure, that is, the data stored in the database, follows a relational structure, so the relational type of the DBMS must be considered, b). Personnel who are familiar with a system and staff programmers in an organization who are familiar with a DBMS can reduce training costs and learning time, c). The availability of system user services where user service facilities is needed to help solve some system problems.

4) Stage 4, Logical database design (data model mapping): The next stage is to create a conceptual scheme and an external scheme on the data model of the selected DBMS. This stage is carried out by mapping the conceptual and external schemes generated in stage 2. At this stage, the conceptual scheme is transformed from the high-level data model used in stage 2 into the data model of the data model of the selected DBMS in stage 3. The mapping can be processed in 2 levels:

- System-independent mapping

It is mapping into the DBMS data model without considering the characteristics or unique things that apply to the DBMS implementation of the data model.

- Schema customization to specific DBMS

Set up the schema generated in step 1 to adapt to a specific future implementation of a data model used in the selected DBMS. The output of this step uses DDL (Data Definition Language) commands in the selected DBMS language that determines conceptual and external scheme levels of the database system. In some cases, however, DDL statements include physical design parameters, so a complete DDL must wait until the physical database design phase is complete. This phase can be initiated after selecting a data model implementation while waiting for the specific DBMS to be chosen. For example, if you use several relational DBMSs but have not decided on a central relation. The design of external schematics for specific applications is often completed during this process.

5) Stage 5, Physical database design: Physical database design is selecting storage structures and access paths in database files to achieve the best performance in various applications. During this phase, specifications for the stored database are designed for physical storage structures, record assignments, and access paths. Related to the internal scheme (in terms of 3 levels of DBMS architecture). Some guidelines for choosing a physical database design:

- Response time

The elapsed time of a database transaction submitted to execute a response. The primary influence on the response time is under the DBMS's control: database access time for data items pointed to by a transaction. Response time is also affected by factors that are not controlled by the DBMS, such as operating system scheduling or communication delays.

- Space utility

The amount of storage space used by database files and access point structures.

- Transaction throughput

The average number of transactions that can be processed per minute by the database system is a critical parameter of the transaction system. The result of this phase is the initial determination of the storage structure and access path for database files.

6) Stage 6, Database system implementation: After the logical and physical design is complete, we can implement the database system. The commands in the DDL and SDL (Storage Definition Language) of the selected DBMS are compiled and used to create the database scheme and (empty) files. Now, the database is loaded (unified) with the data. If data must be converted from a previous computer system, routine changes may be required to reformat the data for inclusion in the new database. Application programmers must now execute database transactions. Specifications are conceptually tested and linked to program code with commands from embedded DML that have been written and tested. Once the transactions are ready and the data has been entered into the database, the design and implementation stages are completed. Then the operational phase of the database system begins.

To test the validity of the database design implemented in the STEAM-Problem-Based Learning model, it is necessary to carry out a validity analysis. Validity analysis is based on the results of assessing the data obtained through a questionnaire or a Likert scale. Data processing was carried out using the Aiken V validity coefficient formula, which was used to test the expert's assessment (rater). Based on the expert judgment of people for each item, several items represent the construct being measured. Aiken developed the Aiken V formula to calculate the Content Validity Coefficient. Assessment scores ranged from 1 to 5. Score 1 indicates a very bad score and 5 indicates vice versa. Index coefficient values range from 0 to 1.00. Aiken's V formula follows [40].

$$V = \frac{\sum S}{[n(c-1)]} \quad (1)$$

Information:
V = Appraiser agreement index
S = The score determined by the appraiser is reduced by the lowest score/value in the category
n = The number of raters
c = The number of categories

The predicate of the V value based on Aiken's V formula can be described in Table I.

TABLE I
AIKEN'S VALIDITY CRITERIA

Aiken index	Criteria
0.667 -1.00	Valid
< 0.667	Invalid

III. RESULT AND DISCUSSION

After analyzing and designing the STEAM-Problem Based Learning model development model through the normalization process, a database consisting of 19 tables is obtained, which is free from data redundancy and inconsistency so that the desired data can be obtained whenever needed. Relationships between tables can be described in an entity relationship diagram, as shown in Fig. 3.

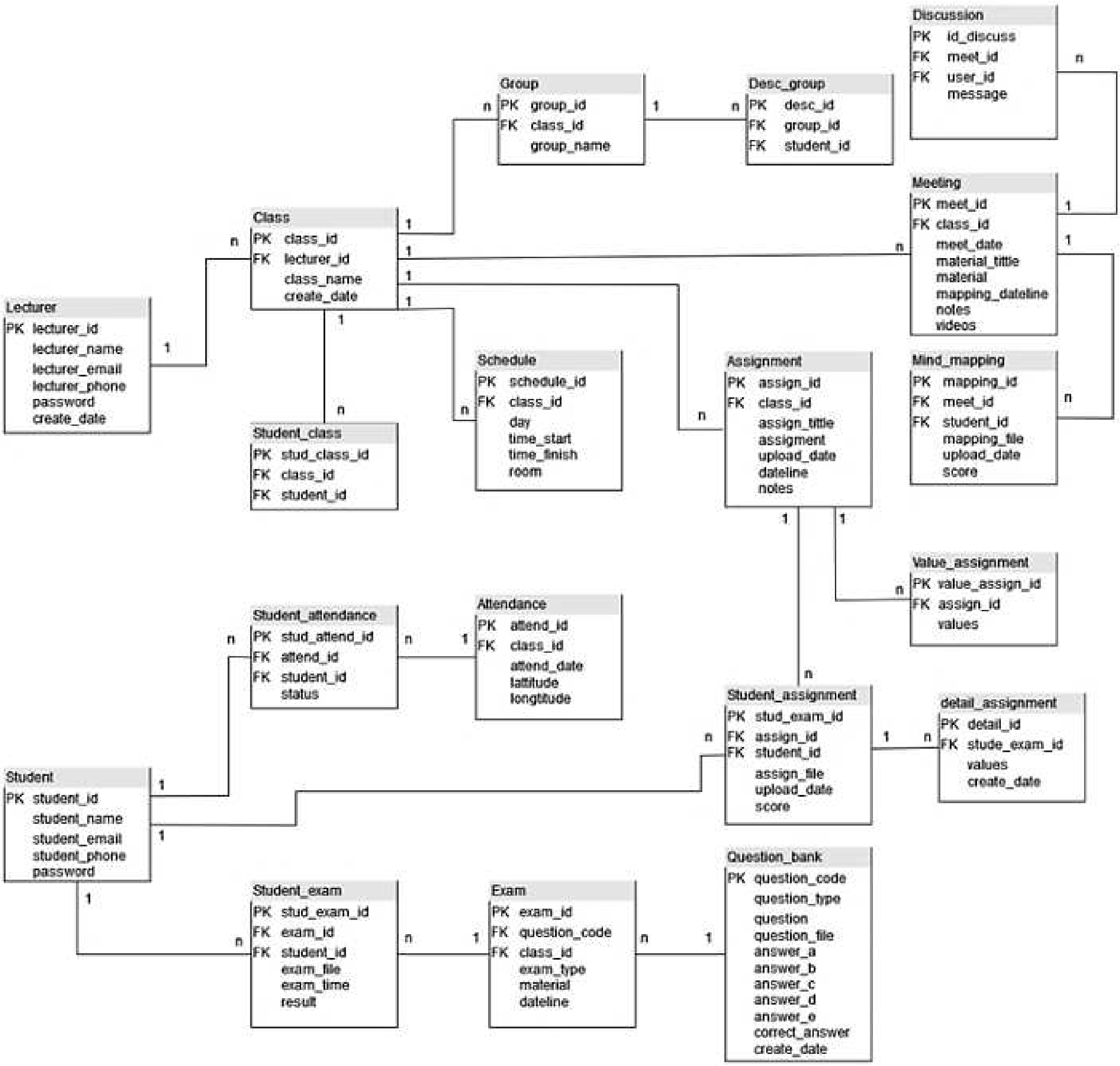

Fig. 3 ER Diagram of STEAM-Problem Based Learning model

Based on Fig. 3, the function of each table can be described in Table II. Digitized organization processes often surround interaction with relational databases [41]. A database in a large organization will require many tables that store a large amount of data, and the tables are interconnected through the critical fields of each linked table.

TABLE II
DATABASE DESIGN DETAIL

No	Table Name	Function
1	Lecturer	saves lecturer data that is used to log into the system
2	Student	store student data that is used to log into the system
3	Class	store class data taught by the lecturer
4	Student_Class	store class data followed by students
5	Schedule	save lecture schedule data based on existing classes
6	Meeting	store lecture meeting data such as meeting material, meeting time
7	Attendance	store lecture meeting attendance data such as location points, dates, and classes
8	Student_Attendance	store student attendance data per meeting
9	Mind_mapping	storing data mind mapping material at each meeting by students
10	Assignment	save assignment data from the lecturer
11	Student_Assignment	store student assignment data given by the lecturer
12	Detail_Assignment	store assessment data from student assignments based on the completion steps of the task assessment

No	Table Name	Function
13	Value_Assignment	store assessment data for each step on student assignments given by the lecturer
14	Group	stores group data created through the results of ranking test scores by the system
15	Desc_Group	Store data for all group members
16	Question_Bank	saves the question data that the lecturer will use to conduct the test
17	Exam	save the test answer data given by the lecturer
18	Student_exam	Store data on the results of student exams that have been done
19	Discussion	storing data on the results of conversations between students and lecturers at each meeting held

To measure the quality of the resulting database schema design results, use a validity test with several criteria, namely correctness, consistency, relevance, completeness, and minimality, as shown in Table III, Fig. 4, and Table IV.

TABLE III
RESULT OF STEAM-PBL MODEL SCHEMA QUALITY ASPECT ANALYSIS

Criteria	Description	Analysis Result
Correctness	is a technical aspect, whether all elements are modeled correctly according to the needs and limitations of the system. This aspect can be used to measure all schemas using expertise by reviewing the depth of knowledge in all technical aspects.	The STEAM-PBL database schema has a limitation that can filter data entry into tables so that the data entered is correct.
Consistency	It is a technical aspect whether all aspects in the model are free from contradictions. Consistency and correctness aspects are fundamental to measuring whether users accept the schema or not. Measurement is done using technical expertise by analyzing the consistency of each technical aspect in the model and comparing it with the following technical aspect.	The STEAM-PBL database schema does not have redundancy data, which results in an enormous potential for consistency.
Relevance	It is a technical aspect to determine whether the schema is acceptable to the user. Measurement is done using technical expertise to determine all relevant aspects and compare them with the schema.	The STEAM-PBL database schema contains schemas that are relevant to other schemas.
Completeness	Whether the schema is complete concerning the requirements, this aspect is essential to know whether the schema is acceptable to users or not. Measurements can be made from the elements of coverage and level of detail.	The STEAM-PBL schema database contains many schemas that are relevant to other schemas.
Minimality	Whether the schema is modeled compactly and without repetition. This aspect is important because the conceptual schema must be precise. Measurements are made using engineering expertise to check whether aspects are modeled repetitively.	The STEAM-PBL database schema does not have schema repetition, making programming easier.

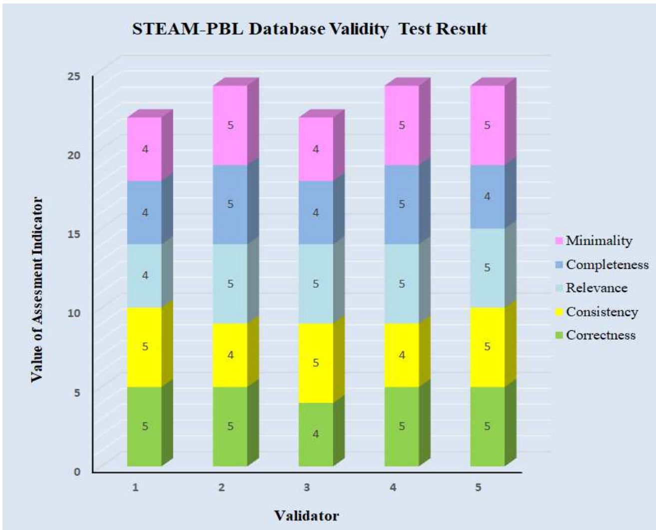

Fig. 4 STEAM-Problem-Based Learning Database Validity Test Results

TABLE IV
RESULT OF STEAM-PBL MODEL SCHEMA QUALITY ASPECT ANALYSIS

Criteria	Aiken's V Value	Category
Correctness	0,95	Valid
Consistency	0,90	Valid
Relevance	0,95	Valid
Completeness	0,85	Valid
Minimality	0,90	Valid
Average	0,91	**Valid**

Based on the STEAM-Problem Based Learning model database design results, this consists of a database with 20 tables. This database can store data in learning Algorithm and Programming courses, which consist of lecturer data, students who take Algorithm and Programming courses, lecture materials, assignments both individually and in groups, and the value of each stage of problem-solving up to the final grade. The system can divide groups, and group leaders based on the ranking results of the test scores given at the end of each lesson. Lecturers can monitor student learning outcomes at anytime and anywhere. For each assignment given to students, lecturers can provide direct assessments, and students can see the results of their learning whenever needed.

Before implementing the STEAM-Problem Based Learning database schema, a Focus Group Discussion (FGD) process was carried out with experts. This expert is an expert in the field of Database, which is determined based on his experience and competence.

The results of the validity test of the STEAM-Problem Based Learning database schema, according to the validator, are Valid with an Aiken's V value of 0.91. Aiken's calculation results range from 0 to 1, and the validation results getting closer to number 1 can be interpreted as having a high coefficient so that the STEAM-Problem Based Learning database schema is feasible to implement in Algorithm and Programming learning

IV. Conclusion

Based on the research results, it is known that the STEAM-Problem Based Learning relational database design is declared valid in Algorithms and Programming in storing lecturer and student activity data during the learning process. This is very important to improve students' ability to think critically and be creative in problem-solving, communication, and collaboration, which is much needed in the Industrial Revolution 4.0 so that the results of this database design are feasible to be implemented in STEAM-Problem Based Learning applications.

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