EFFECTIVE USE OF ARTIFICIAL INTELLIGENCE METHODS FOR THE IMPLEMENTATION OF PREREQUISITES IN CURRICULUMS

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Abstract

Prerequisites play a critical role in the construction of a curriculum for courses where student success heavily relies on previously acquired knowledge or skills. The application of artificial intelligence (AI) methods for the implementation of prerequisites in curriculums can significantly enhance the efficiency and effectiveness of educational planning. The article argues that association rules can be effectively applied in the implementation of prerequisites in the curriculum.

Keywords: curriculums, program schema, prerequisites, artificial intelligence, association rules.

I. Introduction

The curriculum in academic education refers to the structured set of courses, learning experiences, and assessments designed to provide students with the knowledge, skills, and competencies required to achieve educational objectives. It is a comprehensive plan that outlines what students are expected to learn, how they will learn it, and how their learning will be assessed. Curriculum is usually plotted against Bachelor of Science (B.Sc.) program.

A Bachelor of Science (B.Sc.) program typically includes a mix of core courses, major-specific courses, electives, labs, and possibly a capstone project or thesis. A program schema for a Bachelor of Science (B.Sc.) typically includes the structure and organization of courses that a student needs to complete to earn the degree.

Prerequisites in a Bachelor of Science (B.Sc.) program schema are essential for several reasons, as they establish a foundation of knowledge and skills necessary for students to succeed in their academic and professional endeavors. By leveraging AI methods, educational institutions can create more effective and personalized learning experiences, ensuring that students are well-prepared for advanced coursework and ultimately improving their academic success. Association rules can be very useful for determining the implementation of prerequisites in educational curriculums.

II. Program schema and prerequisites

A Bachelor of Science program schema typically consists of various components designed to provide a comprehensive education in the sciences. Here's a general outline of what a B.Sc. program

schema might look like [1]:

1. Core Courses (CC)

These are mandatory courses that provide foundational knowledge in the chosen field of study.

2. Major-Specific Courses (MSC)

These courses provide specialized knowledge in the chosen field of study. Here are examples for different majors

Courses specific to the student's major that provide in-depth knowledge and specialized skills.

3. Electives Courses (EC)

Students can choose electives based on their interests, which can be within or outside their major. Electives allow students to explore other disciplines or deepen their knowledge in their field of study.

Table 1 shows a fragment of the program scheme for the Bachelor of Science in Information Technology.

Table 1

Fourth Semester				
S.No.	Course type	Course Title	Prerequisite	Credit Hours
1	CC	Probability & Statistics	None	3
2	MSC	Database Systems	IT Fundamentals	7
3	MSC	Computer Networks	Computer architecture	8
4	CC	Discrete mathematics	None	3
5	CC	Business and academic communication in English - IV	Business and academic communication in English - III	3
6	EC	IT Elective I	None	6

Prerequisites play a critical role in the construction of a curriculum for courses where student success heavily relies on previously acquired knowledge or skills. Here are some key reasons why prerequisites are important:

- Ensuring Readiness: Prerequisites help ensure that students have the necessary background knowledge and skills to grasp the new material. This readiness is crucial for courses that build on complex concepts introduced in earlier coursework.
- Maintaining Academic Standards: By requiring students to complete certain courses before advancing, institutions can maintain a high standard of education and ensure that students are adequately prepared for the challenges of more advanced material.
- Improving Success Rates: Students who meet the prerequisite requirements are more likely to succeed in subsequent courses. They are better equipped to understand and engage with the material, which can lead to higher grades and retention rates.
- Streamlining Learning: Prerequisites help create a logical progression through a curriculum, allowing for a more structured and coherent learning experience. This structure helps students build on their knowledge systematically.
- Preventing Overwhelm: Courses without prerequisites might result in students feeling overwhelmed by material for which they are not prepared, potentially leading to frustration, disengagement, and higher dropout rates.
- Efficient Use of Resources: Prerequisites help instructors plan their courses more effectively, as they can assume a certain level of knowledge among their students. This allows for more efficient use of class time and resources.

Prerequisites are essential in curriculum design to ensure that students are adequately

prepared, which in turn enhances their chances of success and maintains the integrity and quality of the educational program.

Here are the key points explaining the importance of prerequisites:

1. Foundation of Knowledge

- Building Blocks: Prerequisites ensure that students have the basic understanding and foundational knowledge required for advanced courses. Without this foundation, students may struggle with complex concepts and techniques.
- Sequential Learning: Many subjects, especially in science and mathematics, build upon previously acquired knowledge. Prerequisites ensure that students progress through their education in a logical and effective sequence.

2. Academic Preparedness

- Readiness for Advanced Material: Prerequisites verify that students are academically prepared for the challenges of more advanced courses, reducing the likelihood of failure or the need for remedial instruction.
- Enhanced Learning Experience: When students enter a course with the necessary background, the entire class can engage more deeply with the material, leading to a richer and more productive learning experience.

3. Efficient Use of Resources

- Optimal Use of Faculty Time: Ensuring students meet prerequisites allows instructors to focus on teaching advanced material rather than re-teaching basic concepts.
- Classroom Dynamics: Classes can proceed at the intended pace without having to accommodate students who are not adequately prepared, leading to a more efficient and effective use of instructional time.

4. Student Success and Retention

- Higher Success Rates: Students who meet prerequisites are more likely to succeed in their courses, which can improve overall retention and graduation rates.
- Confidence and Motivation: When students feel prepared and capable of handling course material, their confidence and motivation increase, positively impacting their academic performance and engagement.

5. Professional and Academic Standards

- Maintaining Standards: Prerequisites help maintain high academic standards within the program, ensuring that graduates possess the knowledge and skills expected by employers and graduate schools.
- Accreditation Requirements: Many academic programs have accreditation standards that require adherence to specific prerequisite structures to ensure the quality and rigor of the education provided.

6. Interdisciplinary Integration

- Cohesive Knowledge Base: For programs that integrate multiple disciplines, prerequisites ensure that students have the necessary background in all relevant areas, facilitating better interdisciplinary understanding and collaboration.
- Preparation for Capstone Projects: Prerequisites ensure students are adequately prepared for capstone projects or theses, which often require integrating knowledge from various courses and disciplines.

7. Time Management and Planning

- Efficient Course Planning: Understanding prerequisites helps students plan their course schedules effectively, ensuring they meet all necessary requirements in a timely manner without delaying their graduation.
- Avoiding Overload: Properly structured prerequisites help prevent students from enrolling in courses they are not ready for, which can lead to academic overload and burnout.

8. Career Readiness

- Skill Competency: Prerequisites ensure that students develop essential skills progressively, making them more competent and competitive in their chosen careers.
- Preparation for Professional Exams: For fields requiring certification or licensure, prerequisites prepare students for professional exams by ensuring they have covered all necessary material.

Prerequisites in a B.Sc. program schema are crucial for ensuring that students are adequately prepared, facilitating effective learning, maintaining academic standards, and ultimately contributing to student success and readiness for professional and academic challenges.

III. The application of AI methods for the implementation of prerequisites in curriculums

The application of AI methods for the implementation of prerequisites in curriculums can significantly enhance the efficiency and effectiveness of educational planning. Here are several ways AI can be applied [2]:

- Data Analysis and Predictive Analytics:
- Student Performance Prediction: AI algorithms can analyze historical student performance data to predict which prerequisites are most strongly correlated with success in advanced courses. This can help in identifying essential prerequisite courses.
- Early Warning Systems: AI can identify students who are likely to struggle in a course based on their performance in prerequisite courses, allowing for early interventions.
- Personalized Learning Paths:
- Adaptive Learning Systems: AI-driven platforms can create personalized learning paths based on individual student performance, strengths, and weaknesses. These systems can dynamically adjust prerequisites for each student, ensuring they receive the preparation they need.
- Recommendation Engines: Similar to how e-commerce sites recommend products, AI can recommend courses that students should take next based on their academic history and performance in prerequisite courses.
- Curriculum Development and Optimization:
- Curriculum Mapping: AI can assist in mapping out the entire curriculum, identifying gaps, redundancies, and optimal prerequisite structures. This ensures a more streamlined and efficient curriculum.
- Scenario Analysis: AI can simulate different curriculum structures and prerequisite requirements to determine the most effective configurations for student success.
- Natural Language Processing (NLP) and Text Mining:
- Prerequisite Identification: NLP techniques can analyze course descriptions, syllabi, and other educational materials to automatically identify and recommend prerequisites for new or existing courses.
- Curriculum Alignment: Text mining can help ensure that the content of prerequisite courses aligns well with the requirements of subsequent courses.
- Automated Advising Systems:
- Virtual Advisors: AI-powered chatbots and virtual advisors can provide students with guidance on course selection, ensuring they understand and fulfill prerequisite requirements.
- Degree Planning Tools: AI-driven tools can help students plan their entire academic journey, taking into account prerequisites, course availability, and personal preferences.
- Assessment and Feedback:
- Intelligent Tutoring Systems: These systems can assess students' knowledge and skills in

real-time, providing immediate feedback and identifying areas where prerequisite knowledge may be lacking.

Formative Assessments: AI can design and administer formative assessments to gauge students' readiness for advanced courses, ensuring they have mastered prerequisite content.

IV. Association rules for the Implementation of Prerequisites in curriculums

Association rules, a concept widely used in data mining, can be effectively applied to the implementation of prerequisites in curriculums. These rules can help in identifying patterns and relationships between different courses, thereby aiding in the design of prerequisite structures. Here's how association rules can be utilized:

- Identifying Strong Course Relationships:

- Mining Historical Data: By analyzing historical enrollment and performance data, association rules can help identify strong relationships between courses. For example, if a significant number of students who succeed in Course A also succeed in Course B, it might suggest that Course A could be a good prerequisite for Course B.

- Support and Confidence Metrics: Use metrics such as support (the frequency with which items appear together) and confidence (the likelihood of item B appearing in transactions containing item A) to determine the strength of associations between courses.

- Developing Prerequisite Structures:

- Frequent Itemsets: Identify sets of courses that frequently appear together in successful student records. These sets can suggest natural groupings of prerequisites and subsequent courses.

- Rule Generation: Generate rules that can guide the creation of prerequisite structures. For example, a rule like {Course A, Course B}→{Course C} might indicate that students who complete Courses A and B are well-prepared for Course C.

- Enhancing Student Advising:

- Personalized Recommendations: Use association rules to provide personalized course recommendations to students. If a student has successfully completed certain courses, the system can recommend the next courses based on association rules mined from data of similar students.

- Path Analysis: Analyze the paths of successful students to recommend optimal course sequences for current students, ensuring they meet prerequisite requirements efficiently.

- Improving Course Success Rates:

- Predictive Analytics: Use association rules to predict potential challenges students might face in certain courses based on their performance in prerequisite courses. Interventions can then be designed to support at-risk students.

Early Detection: Detect early signs of struggle in prerequisite courses and provide additional support to ensure students are adequately prepared for advanced courses.

V. Example Workflow for Implementing Association Rules

Data Collection: Gather historical data on student enrollments, grades, and course sequences.

Data Preprocessing: Clean and preprocess the data to ensure it is suitable for mining. This might involve removing incomplete records and normalizing grades.

Frequent Itemset Mining: Use algorithms like Apriori or FP-Growth to find frequent itemsets in the data.

Rule Generation: Generate association rules from the frequent itemsets, focusing on rules with high support and confidence.

Rule Evaluation: Evaluate the generated rules to ensure they make logical and educational

sense. Discard any rules that do not provide valuable insights.

Implementation: Implement the validated rules into the curriculum design process, updating prerequisite structures and advising systems accordingly.

Monitoring and Adjustment: Continuously monitor student performance and feedback, adjusting the rules and prerequisites as needed to ensure optimal outcomes.

By using association rules, educational institutions can create data-driven prerequisite structures that enhance student preparedness and success.

VI. Association Rule Learning

Association rule learning is a type of unsupervised learning technique that checks for the dependency of one data item on another data item and maps accordingly so that it can be more profitable. It tries to find some interesting relations or associations among the variables of dataset. It is based on different rules to discover the interesting relations between variables in the database. Association rule learning works on the concept of If and Else Statement, such as if A then B. Here the If element is called antecedent, and then statement is called as Consequent. These types of relationships where we can find out some association or relation between two items is known as single cardinality. It is all about creating rules, and if the number of items increases, then cardinality also increases accordingly. So, to measure the associations between thousands of data items, there are several metrics. These metrics are given below: *Support; Confidence; Lift*. Let's understand each of them [3].

Support is the frequency of A or how frequently an item appears in the dataset. It is defined as the fraction of the transaction T that contains the itemset X. If there are X datasets, then for transactions T, it can be written as:

$$Supp(T) = \frac{Freq(X)}{T} \tag{1}$$

Confidence indicates how often the rule has been found to be true. Or how often the items X and Y occur together in the dataset when the occurrence of X is already given. It is the ratio of the transaction that contains X and Y to the number of records that contain X.

$$Confidence(T) = \frac{Freq(X,Y)}{Freq(X)} \tag{2}$$

Lift, is the strength of any rule, which can be defined as below formula

$$Lift(T) = \frac{Supp(X,Y)}{Supp(X) \times Supp(Y)} \tag{3}$$

It is the ratio of the observed support measure and expected support if X and Y are independent of each other. It has three possible values:

- If Lift= 1: The probability of occurrence of antecedent and consequent is independent of each other.
- Lift>1: It determines the degree to which the two itemsets are dependent to each other.

Lift<1: It tells us that one item is a substitute for other items, which means one item has a negative effect on another.

VII. Problem Statement

When we study, we have a standard list of subjects that we learn. Each student has a different list of electives, depending on their needs and preferences. Students can choose from a variety of subjects. These electives can help enhance learning in several ways. If there is a pair of subjects X and Y that are often studied together [4]:

Both X and Y can be placed on the same syllabus so that students who study one subject are encouraged to study the other.

Although we know that certain subjects are often studied together, the question arises: how can we detect these associations?

Association rules can also be used in academic education. For example, they can determine the required sequence of subjects (prerequisites) included in the curriculum and help students successfully earn credits.

VIII. Apriori Algorithm

The algorithm was first proposed in 1994 by Rakesh Agrawal and Ramakrishnan Srikant. Apriori algorithm finds the most frequent itemsets or elements in a transaction database and identifies association rules [5] between the items just like the above-mentioned example.

The model: data

- $I = \{i_1, i_2, \ldots, i_m\}$: a set of items
- Transaction t: t a set of items, and $t \subseteq I$.
- Transaction dataset T: a set of transactions $T = \{t_1, t, \ldots, t_n\}$

To construct association rules between elements or items, the algorithm considers 3 important factors which are, support, confidence and lift.

The support of item X is defined as the ratio between the number of transactions containing the item X by the total number of transactions expressed in formula (1). Support indicates how popular an itemset is, as measured by the proportion of transactions in which an itemset appears. In Table 2 below, the support of {IT Fundamentals} is 4 out of 8, or 50%. Itemsets can also contain multiple items. For instance, the support of {IT Fundamentals, Computer Networks, Database Systems} is 2 out of 8, or 25%. If you find that test results outside of a certain ratio have a significant impact on your success, you may want to consider using that ratio as a support threshold. You can then define itemsets with support values above this threshold as significant itemsets.

Table 2

Transactions (successful exam of students)	Items (subjects)
Transaction 1	“IT Fundamentals”, “Computer Networks”, “Database Systems”, “IT Elective”
Transaction 2	“IT Fundamentals”, “Computer Networks” , “Database Systems”
Transaction 3	“IT Fundamentals”, “Computer Networks”
Transaction 4	“IT Fundamentals”, “Discrete mathematics”
Transaction 5	**“**Computer architecture”, “Computer Networks”, “Database Systems”, IT Elective”
Transaction 6	**“**Computer architecture”,, “Computer Networks”, “Database Systems”
Transaction 7	**“**Computer architecture”,, “Computer Networks”
Transaction 8	**“**Computer architecture”, “Discrete mathematics”

This is measured by the proportion of transactions with item X, in which item Y also appears. The confidence between two items X and Y, in a transaction is defined as the total number of transactions containing both items X and Y divided by the total number of transactions containing X (formula (2)). Confidence says how likely item Y is purchased when item X is purchased, expressed as {X→Y}. This is measured by the proportion of transactions with item X, in which item Y also appears. In Table 2, the confidence of {IT Fundamentals →Computer Networks} is 3 out of 4, or 75%.

One drawback of the confidence measure is that it might misrepresent the importance of an association. This is because it only accounts for how popular "IT Fundamentals"s are, but not "Computer Networks"s. If "Computer Networks"s are also very popular in general, there will be a higher chance that a transaction containing "IT Fundamentals"s will also contain "Computer Networks"s, thus inflating the confidence measure. To account for the base popularity of both constituent items, we use a third measure called lift.

Lift is the ratio between the confidence and support. Lift says how likely item Y is purchased when item X is purchased, while controlling for how popular item Y is.

$$Lift(X \rightarrow \mathrm{Y}) = \frac{Supp(X,Y)}{Supp(X) \times Supp(Y)}$$

In Table 2, the lift of {IT Fundamentals→Computer Networks} is 1 which implies no association between items. A lift value greater than 1 means that item Y is likely to be bought if item X is bought, while a value less than 1 means that item Y is unlikely to be bought if item X is bought. (*here, X represents "IT Fundamentals" and Y represents "Computer Networks"*).

IX. Summary

In summary, prerequisites are essential in curriculum design to ensure that students are adequately prepared, which in turn enhances their chances of success and maintains the integrity and quality of the educational program. By using association rules, educational institutions can create data-driven prerequisite structures that enhance student preparedness and success. By leveraging these AI method, educational institutions can create more effective and personalized learning experiences, ensuring that students are well-prepared for advanced coursework and ultimately improving their academic success.

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