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Analyzing Students' Academic Success in Pre-requisite Course Chains: A Case Study in Turkey*

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There are several principles which have been accepted as approaches to successful curriculum development. In spite of the differences in the proposed sequencing of topics, all approaches basically depend on the pre-requisite chains to implement their educational approach in the curriculum development for specifying the order of the subjects. In this research, two pre-requisite chains representing two different curriculum development approaches are taken into consideration in a case study. The first research question considered is whether academic success in a follow-up course is positively related to success attained in the pre-requisite course. The second one is whether or not the selected curriculum development approach for deciding the chains has a significant impact on the academic success relationships between a pre-requisite and its follow-up course. To answer these questions, course data of 441 undergraduate students who graduated from the Atilim University between Fall 2001 and Spring 2015 semesters were collected and analyzed. The results indicate that the succes levels gained in a pre-requisite and its follow-up course are corelated. Moreover, different cirriculum development methods can affect this corelation. Thus, cirriculum developers should consider appropriate approaches to improve student success for deciding chaining courses and their contents.

Keywords: curriculum development; pre-requisite chain; academic success

1. Introduction

Learning can be defined as the lifelong process of transforming information and experience into knowledge, skills, behaviors, and attitudes [1]. Edward Thorndike, in the early 1900s, postulated several Laws of Learning whose first three laws are: *readiness, exercise, and effect* [2]. The law of readiness, the first primary law of learning, states that individuals learn best when they are physically, mentally, and emotionally ready to learn. The second law of learning, the law of exercise, suggests that drill or practice helps in increasing the efficiency and durability of learning. The last one, the law of effect, suggest that if the results are satisfactory, it is likely that behavior will be repeated. Behaviors that cause unwanted outcomes are less likely to recur.

In literature, educators have worked on curriculum development for many years and have developed different approaches considering Laws of Learning. Among these approaches, Tylers recommendation has been popular as a curriculum development method for 30 years [3]. Likewise, Jerome Bruner also suggested some basic principles for curriculum design and instruction in his famous book 'The Process of Education' [4]. Tyler's and Bruner's ideas have been the most enduring among the principles of learning and curriculum development [3]. According to their ideas, organizing learning experiences are important for effective instruction

Tyler believes that three major criteria are required in building organized learning experiences: Continuity, sequence, and integration [5]. He further suggests that each learning experience should be built on earlier ones (vertical organization) and should be reinforced by activities in other subjects (horizontal organization). Contrary to Tyler's linear model, Jerome Bruner proposed a spiral model for curriculum development [4]. In a spiral curriculum development model, students revisit a topic, theme, or subject several times throughout their education.

In Tyler's model [6], pre-requisite chains are a way of ensuring that students enter into a course or subject with some prior knowledge as the model is top-down, linear, and sequential. Likewise, in Bruner's model [7], pre-requisite chains are used to re-visiting and re-examining fundamental ideas via the courses within the chains.

2. Research questions

In this study, pre-requisite chains which are assumed to be samples of both the spiral and linear curriculum development models are considered in a case study. The relationship of students' academic success between the pre-requisite courses and the follow-up courses are deeply investigated by testing following hypothesis.

Hypothesis 1 (Correlated Academic Success): The academic success achieved in a follow-up course is positively related to the academic success achieved in the pre-requisite course.

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Hypothesis 2 (Impact of Curriculum Development Model): The selected curriculum development model for deciding chains does not have a significant impact on the academic success relationships between a pre-requisite course and follow-up course.

3. Data collection and academic success metrics

The course data concerning 441 undergraduate students who graduated from the Computer Engineering, Software Engineering, or Information Engineering programs at Atilim University between Fall 2001 and Spring 2015 semesters were gathered. Two chains including three mathematics courses (Calculus I, Calculus II, and Differential Equations) were selected. In Calculus I and II, the subjects are Limits, Derivatives and Integrals, and the Fundamental Theorem of Calculus. On the other hand, Differential Equations course is about linear differential equations and their applications.

When the contents of the selected courses are analyazed, Chain A suits the spiral curriculum development model [8, 4]. However, since the topics covered in Chain B courses are sequenced systematically from simple to complex, easy to hard and from general to specific, Chain B can be considered to be structured as Tyler's linear model [6].

At Atilim University, Turkey, students are required to score higher than FF and FD grade letters to pass a course successfully. Engineering programs have pre-requisite chains, which mainly have two courses: one pre-requisite and one follow-up. Students can only register in a follow-up course in any chain only if they first manage to pass its pre-requisite successfully.

In this work, two academic success metrics are defined: the Number of Registrations (NoR) in a course and the Grade Letter (GL). The NoR indicates how many times a student has registered to a course to pass it. The second academic success metric is the Grade Letter (GL) received from the course at the end of the semester. These GLs and their corresponding weights in calculating the credits are as follows AA-4; BA-3.5; BB-3.0; CB-2.5; CC-2.0; DC-1.5; DD-1.0; FD-0.5; FF-0.0

4. Analysis and results

Both academic success metrics for the selected chain courses are analyzed. As a notation, Chain A (NoR) and Chain B (NoR) indicates the relationship between the chained courses according to NoR metric. For the second academic success metric, grade letters, Chain A (GL) and Chain B (GL) notation is established for showing the relationship between the last grade letter (which must be higher than FD) taken in a pre-requisite course (e.g., Calculus I) and the first grade taken in the follow-up course (e.g., Calculus II).

5. Characteristics of the collected data

It is observed that most students also passed the Calculus I and Calculus II course by taking it only once. That is, 76% of the students who were successful in Calculus I within the First attempt were also successful in Calculus II at the First attempt.

Surprisingly, 70% of these students managed to pass Calculus II upon only taking it once or twice. Similar observations can be done for 292 students out of 441 managed to pass Differential Equations in their First attempt. 188 of these students also passed the pre-requisite course, Calculus II, in the First attempt. On the other hand, there are 29 students who scored AA from Calculus I and 15 of them also received AA again in Calculus II.

6. Correlation of academic success between chained courses

These observations can lead us to consider if there is a statistically important correlation with respect to the selected academic metrics, the Number of Registration (NoR) or Grade Letters (GL), accomplished in the pre-requisite and follow-up courses. In order to confirm the relationship, Pearson Correlation is applied to the above-mentioned data.

As seen in Table 1, one can argue that for chains A and B with respect to both academic success metrics, the success relationships between the pre-requisite and follow-up courses have a positive correlation since all correlation coefficient values are greater than 0.

Table 1. Correlation Between Chained Courses with Respect to NoR and GL Metrics

Relationship	P value	X^2	Pearson Correlation	df	Level of Sig.
Chain A (NoR)	<0.0001	69.57	0.30	9	0.01
Chain B (NoR)	<0.0001	39.39	0.18	9	0.01
Chain A (GL)	<0.0001	291.853	0.53	32	0.01
Chain B (GL)	<0.0001	185.110	0.43	32	0.01

7. Relationships of success levels between chain courses

In this section, whether the level of success accomplished at a pre-requisite course lasts in a follow-up course at a similar level or not is aimed to be observed. For this reason, the students are first grouped according to their success in the pre-requisite course. By doing so, the intention is to analyze the sub-group relationships across the chained courses.

The number of student in each group according to the NoR and GL values given in Table 2, Table 3 and Table 4 is used for applying Post hoc and the Analysis of Variance Test (ANOVA) and of Robust Tests (Brown-Forsythe and Welch Tests), to discover if there is a significant difference in either NoR or GL values across the chained courses.

8. Results for NoR metric

Homogeneity of variances test to NoR Metric is applied, comparing NoR groups at Chain B, the NoR metric values of Differential Equations course do not pass the homogeneity of variance test, and, hence, Chain B is excluded in the analysis of variance tests and Robust Tests. On the other hand, for Chain A, Robust Tests (Brown-Forsythe and Welch tests) is applied, whose results confirm that there is a significant difference between NoR groups for Chain A as given in Table 2.

In the first three rows of Table 2, the number of the students who pass the pre-requisite course of Chain A in the first attempt (Groups (I)) is compared with the other groups (Groups (J)). The third column provides the mean difference between these groups. The number with an asterisk indicates that the relationship between these two groups show a significant difference. Likewise, the fourth column presents the standard error values [9] while the last column indicates the Sigma values of Games-Howell Post hoc test, specifying whether or not the distribution of Group I and J are different. If the sigma value is lower than 0.05, it is accepted that the distributions of these two groups are significantly different.

The first row shows that Group 1 students have different success distributions in the follow-up course compared to the other groups since the Sigma values are lower than 0.05.

However, student groups 2, 3, and 4 do not differ from each other as Sigma values are higher than 0.05. That is, those who passed the pre-requisite course (Calculus I) after registering more than once do not have statistically different NoR metric values in the follow-up course (Calculus II) than each other. As a result, it can be concluded that the ones who directly passed the pre-requisite course demonstrate different levels of success in the follow-up course than the others.

9. Results for GL metric

For the Grade Letters (GL) academic success metric, ANOVA tests are applied for both chains (see Table 3 and Table 4). The results show that for

Table 2. Multiple Comparisons Brown-Forsythe and Welch for Chain A (NoR)

Groups (I)	Groups (J)	Mean Difference (I–J)	Std. Error	Sig.
1	2	–0.581*	0.093	0.000
	3	–0.382*	0.109	0.004
	4	–0.716*	0.137	0.000
2	3	0.199	0.132	0.439
	4	–0.135	0.156	0.824
3	4	–0.333	0.166	0.191

Table 3. ANOVA Test for Chain A (GL)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	176.366	6	29.394	33.798	0
Within Groups	377.45	434	0.87		
Total	553.816	440			

Table 4. ANOVA Test for Chain B (GL)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	108.769	6	18.128	20.732	0
Within Groups	379.491	434	0.874		
Total	488.260	440			

both chains, the student groups created according to the GL received in the pre-requisite course achieved different academic success levels in the follow-up course.

In these two tables, it can be observed that student groups created according to the grades achieved in the pre-requisite course attained different levels of success in the follow-up course compared to the others. Thus, Hypothesis 1 (*Correlated Academic Success)* is supported. Yet, one cannot assert the validity of the second hypothesis (*Impact of Curriculum Development Model*).

The results of Shiffle Post hoc test are presented for both chains. There, one can see the differences in the success in the follow-up courses of the student groups compiled according to the grade letters received within the pre-requisite course.

The results for Chain B show a similar pattern as discussed for Chain A above. However, the differences between the group success in the pre-requisite course is less significant. As a result of the above discussions, one may observe that tests results indicate a significant difference between success groups with regard to the success levels achieved in a follow-up course. The results show that students received similar grade letters achieved in a pre-requisite course, also tend to receive similar grades in the follow-up course.

10. Discussion

Curriculum planning is a systematic process to create positive improvements in an educational system. It is an important teaching practice when educators make decisions that ultimately affect students' opportunities to learn [10, 11]. For this purpose, several models have been suggested, but the Linear and the Spiral models have been the most prevalent ones among the others [12, 13].

Pre-requisite chains are proposed as a way of ensuring that students take courses in some order (e.g., top-down, linear, or sequential) by expecting that previous course experience positively would impact academic performance in subsequent courses [14–16].

As mathematics courses create a strong background for future courses, they are considered to be very essential for engineering cirriculums [17]. In deed, studies emphasize that success in introductory mathematics courses, such as Calculus I, Calculus II and Differential Equations, is necessary for success in subsequent engineering courses [18, 20, 21]. Thus, universities are adviced to develop programs with pre-requisite chains for mathematics courses to improve student success [17–20].

However, there have been few studies investigating the impact of the pre-requisite chains on student success in engineering cirriculums. Therefore, in this work, two research questions are designed. The first research question is whether academic success in a follow-up course is positively related to success attained in the pre-requisite course. This question is named as "*Correlated Academic Success*". The second one is whether the selected curriculum development approach for deciding the chains has a significant impact on the academic success relationships between a pre-requisite and its follow-up course. The second question is shortly called "*Impact of Curriculum Development Model*". To investigate the answers, two chains among three mathematics courses (Calculus I, Calculus II, and Differential Equations) are selected. Then, using statistical test, the validity of the hypothesis is discussed.

Before, providing the conclusions, a critical literature survey, limitations of the study, and implications to the cirriculum designers are presented below.

11. Related work

In [21], the authors study on the students performance in Introductory Statistics course who took one of its two pre-requisite courses (Finite Mathematics or Data and Chance). They concluded that two pre-requisite courses have different effects on the success in the follow-up course. That is, students who took the Finite Mathematics as the prerequisite course received signiffcantly better grades in Introductory Statistics course than those of students who took Data and Chance. Similarly, in [22], the authors reported that there are a number of positive attributes of pre-requisites but also negative impacts, such as increasing time to graduate and adding to the cost of education according to students. Furthermore, the authors found that some pre-requsite course (the microbiology lecture course) does not impac success in the follow-up course (the lab). According to findings of these studies, the assumption 'being successfully in *any* pre-requisite course should lead to a similar success in the follow-up course' is questionable. Thus, the first research question of this work (*Correlated Academic Success*) has not been completely answered by these studies. The authors just concluded that the content and arrangement of the pre-requisite course is important to be useful for its follow-up but they did not discuss which cirriculum development model is necessary or better for this reason.

In [17], author proposed to implement early remediation program at the beginning of Calculus I for engineering students who are not good at algebra and trigonometric skills. Thus, students could have a chance to develop necessary skills before delve into Calculus I. The results indicate that this approach can increase the students success at Calculus I. Likewise, the authors of the references [18] and [20] have also proposed a "mathematics bridge program" in which last only 1 week before taking the calculus course. They also reported an increase in the student success in the calculus course. However, in these referenced works, the researchers did not study on the success relationship among chained mathematics courses. Unfortunately, these observations cannot present answers to both research questions at hand.

Kauffman and Gilman collected the data of 163 students for two different pre-requisite courses (Technology Lab I ve II) and the follow-up bussiness cooperative experineces (Coop) program [23]. They reported that no relation is found between students' completion of the pre-requiste courses and their success in Coop program. According to this observation, Hypothesis 1 (Correlated Academic Success) of the present paper is invalid. However, in the referenced work, it is also noted that the skills needed to be successful in the Coop program can be owned by the students even though they have not taken the pre-requiste course. As Coop program is not a course and the succes depends on some skills which are not even covered in pre-requisite courses (Technology Lab I ve II), it can be argued that this observation cannot be applied to regular pre-requiste chains.

Krieg and Henson compared the grades received in follow-up courses between students who accomplished the pre-requisite in an online format against a face-to-face one by investigating a university's data of a ten-year period [24]. They concluded that students who take a pre-requisite course in a traditional format achieve better in subsequent courses than students who take a pre-requisite course online. However, they do not examine either the success relationship among the pre-requisite and follow-up courses or the impact of cirriculum develoment method.

As seen above references, there have been a considerable interest on the pre-requisite courses in the literature. However, the scope, goals, and results of the above-mentioned studies are not completely in line with those of the present work. One of the studies with similar scope and goals was conducted by Anderson et al. [25]. They found that successfully completing calculus and economics courses positively affects the achieved success in subsequent economics courses. In another work, McMillan and Adeyemi focused on the success relationships between the graduate pre-requisite management courses and the graduate Organizational Behavior courses, and found a positive relation between the grades received in these courses as well [26]. The results in these referenced works support the validity of Hypothesis 1 (*Correlated Academic Success*) and are in accordance with the findings of the present work. Unfortunately, these works did not test the Hypothesis 2 (*Impact of Curriculum Development Model*).

On contrary to the above findings, after examining the relationship between completion of the prerequisite course (Organic Chemistry) and performance in follow-up course (Introductory Biochemistry), Wright et. al. could not find statistically significant differences between average biochemistry grades or grade distribution among students with or without the organic chemistry prerequisite [27]. Thus, their conclusion is in contrast with the results reported in above reference and in this work. Moreover, Wright et. al. only considered one chain and did not report the cirriculum method used to develop this chain.

As summarized above, few studies focused on the first research question (*Correlated Academic Success*). Most of these studies reported that academic success in a follow-up course is positively related to success attained in the pre-requisite course [18, 20, 25, 26]. However, in some studies, the researchers could not find this correlation [23, 24, 27]. For the the second research question (*Impact of Curriculum Development Model*), to the best of our knowledge, there is no work examining whether the selected curriculum development approach for deciding the chains has a significant impact on the academic success relationships between a pre-requisite and its follow-up course. Thus, the present work, considering both research questinons, contributes the literature considerably.

12. Limitations of quantitative analysis

Although the quantitative methods used to answer our research questions were useful and helpful for drawing conclusions, there are some limitations of the presented analysis. To begin with, the sample of the study has been limited to merely one university in Turkey, and the collected data is composed of only the records of the students who graduated from this university. Second, the considered chained courses are limited to three mathematical courses (Calculus I, Calculus II, and Differential Equations). Third, among the several curriculum development methods, only two (Spiral and Linear) are selected for this research. Lastly, since there are no official records stating which courses were designed according to which curriculum development methodology, the classification of the chains are done according to the definition of the cirriculum development methods.

13. Implications for curriculum developers

The results of this study have several practical implications for curriculum developers:

- First, there should be more case studies focusing on the relationships between the selected curriculum development method and students success observed in chained courses.
- Second, the pre-requisite chains designed for a program should be validated in order to justify their effectiveness on the expected student success.
- Third, some pre-requisite chains might be obsolete if their effectiveness is found to be questionable. Therefore, curriculum developers should review the existing pre-requisite chains periodically with empirical data so that pre-requisites and their follow-up courses should be well designed to support student success throughout the curriculum.

14. Conclusions

The goal of this study is two-fold. The first goal is to examine the impact of the pre-requisite courses on the success in a follow-up course for two mathematics course chains. The second one is to investigate the impact of the selected cirriculum development method on the success relationships between a pre-requisite course and follow-up course.

After analyzing the collected data in detail, it is concluded that:

- *The academic success achieved in a pre-requisite course is positively related to the academic success achieved in the follow-up course*. However, the power of this relationship can differ between the selected chains considerably. Specifically, in this case study, for both academic success metrics, Chain A produces higher correlation values between the chained courses whereas Chain B presents lower correlation values. Therefore, one can argue that Chain B between the courses Calculus II and Differential Equations may not be necessary.
- *The selected curriculum development model for deciding chains does have a significant impact on the academic success relationships between a pre-requisite course and follow-up course*. When the Hypothesis 2 has been deeply analyzed, it is observed that for both academic success metrics, the correlation between pre-requisite and follow-up courses in Chain A is higher than that of Chain B. As noted above, Chain A is suitable for the spiral curriculum development model whereas Chain B is appropriate for linear model. Thus, it can be decided that the pre-requisite chain developed according to spiral model leads to a better student success in the follow-up course than that of linear model.

In future work, the authors intend to remove the above-mentioned limitations by working on different pre-requisites for other core engineering courses. Furthermore, if there are such success relationships between pre-requisite and non-pre-requisite courses will be examined. For this purpose, some non-pre-requisite courses can be chosen as a control group and then, the academic performances of the students enrolled in different combinations of pre-requisite and non pre-requisite courses can be studied.

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