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INTERCONNECTION BETWEEN STUDENT'S PREREQUISITE COURSES ACHIEVEMENT AND SUBSEQUENT ACHIEVEMENT IN MECHANICS

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ABSTRACT

This study investigated the interconnection between student's achievements in prerequisite courses with their subsequent achievement in mechanics. Eighty-five preservice physics students' achievement in four prerequisite courses for mechanics, namely Basic Physics I, Basic Physics II, Mathematics Physics I, and Mathematics Physics II, were analyzed statistically to determine the relationships and effects of prior achievement to subsequent learning achievement. Results suggested that students' achievement in mechanics was significantly related to students' achievement in prerequisite courses. The effects of each course on student's achievement in mechanics were estimated and discussed.

Keywords: student's prior achievement; prerequisite course; physics education; preservice physics student

ABSTRAK

Penelitian ini menyelidiki keterkaitan antara prestasi siswa dalam mata kuliah prasyarat dengan prestasi mereka di mata kuliah mekanika. Prestasi belajar delapan puluh lima mahasiswa calon guru fisika pada empat mata kuliah prasyarat mata kuliah mekanika yaitu Fisika Dasar I, Fisika Dasar II, Matematika Fisika I, dan Matematika Fisika II dianalisis secara statistik untuk mengetahui hubungan dan pengaruh prestasi awal terhadap prestasi belajar selanjutnya. Hasil menunjukkan bahwa prestasi siswa di bidang mekanika sangat terkait dengan prestasi siswa dalam mata kuliah prasyarat. Efek dari setiap mata kuliah prasyarat pada prestasi siswa dalam mata kuliah mekanika diestimasikan dan kemudian dibahas.

Kata kunci: prestasi awal siswa; mata kuliah prasyarat; pendidikan fisika; mahasiswa calon guru fisika

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INTRODUCTION

Extensive research in science education illuminates current education problems in developing learners' adequate understanding of a particular science concept, and mechanics is no exception. Misconceptions on mechanics were found in all education levels (see Eryilmaz, 2002; Stylos, Evangelakis, and Kotsis, 2008; Martín-Blas, Seidel, and Serrano-Fernández, 2010; Liu and Fang, 2016; Kuczmann, 2017). Furthermore, Zhou and Xiao's (2018) study in 479 preservice physics teachers currently preparing for teacher certification in China showed that they still perceived mechanics as difficult subject. Esin, Ahin, and Yagbasan's (2012) study also suggested that preservice physics teachers ranked mechanics as difficult subjects. Of course, the perceived difficultness is unfortunate because students' characteristics such as attitude or motivation strongly related to students' achievement in physics (for example Gungor, Eryilmaz, and Fakioglu, 2007; Lawrenz, Wood, and Kirchhoff, 2009; Veloo, Rahimah, and Rozalina, 2015). Students' answers in Esin et al. (2012) further indicate that mechanics' perceived difficultness stemmed from students' lack of background knowledge (Esin et al., 2012).

Wilson, Ackerman, and Malave (2000) study proved that conceptual understanding is a strong predictor in mechanics achievement and conceptual understanding has a longer-term directional effect on later physics achievement. The notion that prior understanding or achievement is consequential to physics achievement has been raised in previous studies (Sadler and Tai, 1997; Cavallo, Potter and Rozman, 2004; Taasoobshirazi and Carr, 2009; Tyson, 2011; Bazelais, Lemay and Doleck, 2018). Strong academic background and taking courses related to physics in high school proved to correlate with how well they can perform in physics courses in college (Sadler and Tai, 1997; Bazelais et al., 2018). A recent

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study of the impacts of prerequisite skills on student learning in follow-on courses by Terry, Kontur, and de La Harpe (2016) found that the learning gap between students with sufficient prerequisite skills versus poor prerequisite skills steadily increases, showing that prerequisite skills are critical to subsequent learning.

The importance of adequate background knowledge has been used as a basis for designing a physics curriculum in which basic, general, or introductory physics and or math are commonly used as prerequisite courses for mechanics. Study of the direct impact of such courses on students' achievement is rarely investigated, although mathematics-based courses have been proven to increase students' likelihood in better physics score attainment (Sadler and Tai, 1997; Maloney, O'Kuma, Hieggelke, and Van Huevelen, 2001; Tyson, 2011) and in understanding physical system (Bao and Redish, 2002). Therefore, the purpose of this study was to empirically investigate and model the relationship between prerequisite courses for mechanics and students' achievement in mechanics.

METHOD

Eighty-five preservice physics students final grade in mechanics and in four prerequisite courses (Basic Physics I and II, Mathematics Physics I and II) were collected from Physics Education Department Administration office at Universitas Syiah Kuala, Aceh Province-Indonesia. Students' achievement in mechanics and four prerequisite courses were available in the form of a letter (A, A-, B, B-, C, C-, or D) and transformed into score: A (4), A- (3.5), B (3), B-(2.5), C (2), C- (1.5), and D (1). Students' scores were analyzed with SPSS version 23. A linear relationship between variables was modeled in which each variable was assigned as an independent variable (x) or dependent variable (y). Independent variables were prerequisite courses score: Basic physics I (x1), Basic physics II (x2), Mathematics physics I (x3), and Mathematics physics II (x4). The dependent variable was mechanics course score (y) in which all were represented in Equation 1:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 \qquad \text{(Eq.1)}$$

RESULTS AND DISCUSSION

Students' achievement in mechanics and in four prerequisite courses for mechanics is depicted in Table 1. On average, students performed the poorest in mechanics and performed the best in Basic Physics II. Regression analysis resulted in an R-square of 0.172, and this value indicates that 17.2% variance in Mechanics score can be predicted from prerequisite course score variables. The P-value associated with F-value for the relationship between prerequisite course score with Mechanics score is less than 0.05 (Table 2), which indicates that prerequisite course score significantly and reliably predicts Mechanics score as a dependent variable. The overall significant test does not address any of the particular independent variables' ability to predict the dependent variable, and therefore, estimate for each prerequisite course is tabulated in Table 3.

Relationship analysis of students' scores in the prerequisite courses with their mechanics' achievement showed that Basic Physics I and Mathematics Physics II score are better predictors of students' mechanics achievement than Basic Physics II or Mathematics Physics I. It is also reflected that for every point increase in students' Basic Physics I score, their mechanics score is predicted to be higher by 0.335 points, and for every point increase in students' Mathematics Physics II score, their mechanics score is expected to be higher by 0.314 points. P-value for those courses are also lower than 0.05 which can be interpreted that both courses are statistically significant predictors for later mechanics achievement. The results corroborated previous findings that conceptual understanding of previous concepts is consequential to the understanding of the subsequent physics achievement (Sadler and Tai, 1997; Cavallo et al., 2004; Taasoobshirazi and Carr, 2009; Tyson, 2011; Bazelais et al., 2018). The relatively high predicting effects of mathematics-based courses such as Mathematics Physics I and II further verify the interconnectedness between math and physics (Sadler and Tai, 1997; Bao and Redish, 2002; Tyson, 2011). Students' understanding of math is essential because students need to use mathematics to represent physics and build their conceptual understanding of the physical system into their equations (Bao and Redish, 2002).

One of the materials delivered and tested in mechanics exam was particles' kinematics so that students should be able to understand the concepts such as particle's motion and trajectory. Previous studies (Malone, 2008; Poutot and Blandin, 2015; Maries and Singh, 2016; Nugraheni, 2017) found

Table 1. Preservice Physics Students' Achievement in Mechanics and Four Prerequisite Courses

Variable (Course)	N	Min. Score	Max. Score	Mean ± SD
Basic Physics I	85	2.0	4.0	3.188 ± 0.567
Basic Physics II	85	2.0	4.0	3.294 ± 0.396
Mathematics Physics I	85	2.0	4.0	2.976 ± 0.681
Mathematics Physics II	85	1.0	4.0	2.847 ± 0.622
Mechanics	85	1.0	4.0	2.776 ± 0.792

Table 2. Overall Relationship between Students' Achievements in Four Prerequisite Courses with Subsequent Achievement in Mechanics

	Model	R Square	Sum of Squares	df	Mean Square	F	Sig.
1	Regression	0.172	9.072	4	2.268	4.154	0.004[a]
	Residual		43.681	80	0.546		
	Total		52.753	84			

a. Predictors: (Constant), Basic Physics I, Basic Physics II, Mathematics Physics I, Mathematics Physics II
b. Dependent variable: Mechanics Score/Grade

Table 3. Relationship between Students' Achievements in Four Prerequisite Courses with Subsequent Achievement in Mechanics

Variable (Course)	Regression Coefficient	Beta	P_{value}
Mechanics (dependent)	α	0.075	0.927
Basic Physics I	b_1	0.335	0.032*
Basic Physics II	b_2	0.035	0.890
Mathematics Physics I	b_3	0.208	0.154
Mathematics Physics II	b_4	0.314	0.019*

Students' Achievement in Mechanics = 0.075 + 0.335 Basic Physics I + 0.035 Basic Physics II + 0.208 Mathematics Physics I + 0.314 Mathematics Physics II

that students commonly have misconceptions concerning particle motion, trajectory, or velocity, and the misconceptions resulted in their inability to correctly answered mechanics question. Students learned basic concepts of mechanics such as measurements, vectors, motions, Newtonian law II, energy, particle system and collision, rigid bodies equilibrium, and gravitation in Basic Physics Course II so that their understanding of these concepts significantly affecting their grade in Mechanics. Among four prerequisite courses, Basic Physics I was the least predictors for Mechanics achievement (Table 3). Concepts covered in Basic Physics I was Electricity and Magnetism in which these concepts were not delivered or tested in Mechanics course so that students' grades in Basic Physics I insignificantly influenced Mechanics Grade. Results in this present study suggested the consequential effects of prerequisite courses in subsequent mechanics achievement and confirmed Terry et al. (2016) notion of prerequisite skills importance to subsequent learning. It is also important to note that a relatively high degree of score dispersion or variation (SD) in mechanics and prerequisite courses score (Table 1) indicates a wide gap in student learning achievement. Therefore, it seems reasonable if educators should also design a learning approach that will improve students' achievement in these courses. Such efforts can be made by formulating instructtional plan specifically intended to induce a conceptual change in physics (Dykstra, Boyle, and Monarch, 1992) or by using numerous learning approach proven to improve physics learning such as Problem Based-Learning (Sahin, 2010) or Project Based-Learning (Baran, Maskan, and Yasar, 2018).

CONCLUSION

Students' achievement in Mechanics was significantly related to students' achievement in prerequisite courses. Math-based courses and courses which introduce the concepts of mechanics to the students are consequential to students' achievement in mechanics, and therefore, students and educators must also consider the interconnected nature of these courses to achievement in mechanics course.

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