# HOW DO COGNITIVE ABILITY AND STUDY MOTIVATION PREDICT THE ACADEMIC PERFORMANCE OF IT STUDENTS?

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## Abstract

Information technology (IT) students' dropout during the first year of their higher education studies is a big problem in Estonia. In general, students' cognitive ability and motivation to study have been described as important factors in several models predicting students' academic achievement, which is directly linked to dropout. However, the findings are sometimes contradictory and not specifically about IT studies. In the case of IT students, we might expect differences compared with other students because of the recent trends where more digitalized learning environments are used. Therefore, our aim was to discover how motivational aspects and cognitive ability of digitally competent students are combined in predicting academic performance and dropout and what the role of both of them is. In our study, we collected data from 44 first-year IT students. We asked them to fill in a study motivation questionnaire and do a cognitive ability test. In addition, data about their academic performance was collected from the higher education institutions' study information systems. Our findings demonstrated that students' cognitive ability correlated with their intrinsic study motivation, but not with their extrinsic motivation or amotivation. Gender plays an important role in predicting study motivation – girls are shown to be more motivated. A path analysis showed that gender had a similar effect on both intrinsic and extrinsic motivation, but no effect on students' cognitive ability. However, whereas students' grade point average is positively influenced by their cognitive ability and intrinsic motivation, extrinsic motivation seems to have a negative effect on academic performance.

Keywords: IT education, study motivation, cognitive ability, academic performance, dropout.

## 1 INTRODUCTION

About one third (32%) of Estonian information technology (IT) students drop out during the first year of higher education studies [1]. Several authors have shown that dropout is strongly linked to lower academic performance, which, in turn, is influenced by the characteristics of learners and the learning community (see [1], [2], [3], [4]). There are six groups of factors influencing students' dropout from higher education studies according to the review by Kori et al. [1]: the student's income, demographics, institutional characteristics, psychological factors, social integration, and academic performance in higher education studies. However, Chen [5] has found that college grade point average, one of the main characteristics of academic performance, is the biggest dropout predictor.

Nowadays, the meaning of and engagement in a learning community is changing because of the expansion of digital communities. This is especially the case in IT studies, where students are more familiar with IT technologies for learning. Therefore, IT students are a promising group to study in order to discover how cognitive abilities and motivational aspects of digitally competent students are combined in predicting academic performance and what the role of both of them is.

### 1.1 Cognitive ability

Many studies have demonstrated that academic performance correlates with students' cognitive abilities. Combining the results of cognitive ability tests with high school average scores has led to the strongest correlations with academic performance in the first university year [6]. In the Estonian context, Niitsoo et al. [7] have also shown that mathematics state exam results are one of the predictors of students' academic performance in IT studies.

Cognitive abilities have been described as a set of mental abilities needed in carrying out a task. They are measured through different intelligence tests, and strong correlations between students' academic performance and cognitive abilities have been revealed. For example, Lynn, Meisenberg, Mikk and Williams [8] found correlations from .83 to .92 between TIMSS and PISA test results and the average national IQ scores. The general effect of intelligence on educational achievement based on the meta-


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analysis by Sipe and Curlette [9] is around 0.6 and has generally been found to be stronger than the effect of motivation and several other factors. Therefore, we could assume a strong effect of cognitive abilities on academic performance in IT studies as well; however, some differences might appear, because digitally competent learners – as we might expect in the case of IT students – could be more influenced by motivational aspects, as they have more possibilities and capabilities of designing their own personalized learning process. Therefore, IT students should be more responsible in their learning process, and motivation might have a stronger effect on their academic performance compared with their cognitive abilities.

The change towards a more digitalized learning process might also have an effect on gender-related differences in students' performance. Lynn and Mikk [10] compared the results of nine international studies on learning science and demonstrated that male learners significantly outperformed female learners in learning science. However, in another study comparing reading skills, girls were shown to usually outperform boys [11]. All these comparisons were made on comprehensive school level. No similar studies have been conducted in the case of IT students at higher education level; therefore, it would be interesting to find out if gender needs to be taken into account in supporting IT students in their studies. At higher education level, we might expect some differences, as older students should have improved skills of self-regulation to personalize their learning process, and as for IT students, we might assume higher capabilities of personalizing their learning process through digitalization. Therefore, it is of interest to us if gender has an effect on academic performance, either as a predictor of cognitive ability or a predictor of study motivation.

## 1.2 Study motivation

Academic performance can also be predicted by achievement motivation (see [12], [13]). Higher motivation should lead to better results. However, it is not always as clear. Several studies have shown only a weak effect or no effect of study motivation on academic performance ([14], [15], [16]). Indeed, Niitsoo et al. [7] showed in the context of Estonian IT studies that time spent studying during a semester was a significant predictor of students' academic performance. Study time also characterizes students' motivation: motivation influences students' approach to their learning [17]. Bruinsma [18] also found that students with higher motivation earned more credit points; Gottfried [19] linked higher motivation with lower dropout rates.

More specifically, different types of motivation can be identified based on the reasons that motivate a person. This may be important in making recommendations aimed at supporting learning. In the Self-Determination Theory [20], intrinsic and extrinsic motivations are distinguished between. In the case of intrinsic motivation, something is done because it is inherently interesting or enjoyable, whereas extrinsic motivation is characterized by leading to a separable outcome. A third type of motivation is often specified as well – amotivation [21]. This characterizes a situation where one lacks intention to act. On comprehensive school level, it has been demonstrated that motivation type has an effect on academic performance and dropout [22]. In our study, we were interested in finding out if male and female students could have different types of motivation: women are generally much less attracted to studying IT – only about 25% of IT students in Estonia are female [23]. One of the reasons might be related to the comparatively high average salaries in the IT field. Ayub [24] found that female students usually had higher intrinsic motivation, whereas male students had higher extrinsic motivation. This was explained by differences in gender roles, according to which men are subject to greater expectations of earning money for their family.

In addition, it was hypothesized that different types of motivation might have different effect on academic performance. Here, the findings of other studies are sometimes contradictory. Some authors have demonstrated that intrinsic motivation leads to better learning outcomes than extrinsic motivation ([13], [25], [26]). According to Ratelle, Larose, Guay and Senecal [27], students with higher intrinsic motivation tended to show better academic performance but were also more successful in adapting to university studies and experienced less stress. However, Matthews, Hoessler, Jonker and Stockley [28] found in their study that intrinsic study motivation did not predict academic performance. Thus, it needs to be clarified what the predictors of academic performance are in the context of IT studies.

## 1.3 Research questions

The overview of previous studies reveals quite a consistent understanding that cognitive ability has a positive effect on academic performance. Indeed, the gender-related differences are not so clear. The results of studies about the effect of study motivation on academic performance are not very

consistent. Gender-related findings about the effect of different types of motivation seem to be particularly contradictory. However, these three factors – cognitive ability, study motivation and academic performance – have not been linked in the context of IT studies at the level of higher education studies, where dropout is an issue. Therefore, we were interested in how cognitive ability and study motivation could lead to better academic performance and if gender plays an important role in this. Three research questions were formulated in this study:

1) Which gender-related differences are there in IT students' cognitive ability, study motivation and academic performance?
2) How do IT students' cognitive ability, intrinsic motivation and extrinsic motivation predict their academic performance?
3) What is the effect of gender in predicting IT students' academic performance?

# 2 METHODS

## 2.1 Participants

In this study, data was collected from 44 first-year students who started their higher education studies in IT related curricula in 2013 in one of the three main higher education institutions providing IT studies in Estonia. There were a total of 783 first-year IT students at these higher education institutions where the data was collected, but only 44 of them voluntarily filled in all the data collection instruments used in the current study. Therefore, it must be kept in mind in interpreting the results of the study that less than 6% of the population participated in the study, meaning that while we can describe trends, no generalizations can be made.

The ratio of female students was higher in our sample than in the population. In our study, 24 students were male and 20 female, while only 25% of the students in higher education IT studies are female in Estonia [23]. The average age of the students at the beginning of the first semester was 20.4 years (the youngest student was 18 and the oldest 38). This means that most of them started their higher education studies quite soon after graduation from secondary school (usually at the age of 18 or 19). The age difference between female and male students was not statistically significant. Only three students (one male and two female) were already working in the IT field. 27 students had some previous experience in studying IT (e.g., elective courses in school).

## 2.2 Instruments and data collection procedure

All students who started their IT studies in 2013 in the higher education institutions involved in the study were asked to fill in a study motivation questionnaire and do a cognitive ability test. In addition, some background information (gender, age, work and study experience in the IT field) was asked and data about their academic performance (grade point average and number of collected credit points) was collected from the higher education institutions' study information systems.

The study motivation questionnaire measured intrinsic motivation, extrinsic motivation and amotivation. An Academic Motivation Scale (AMS-C 28) College (CEGEP) version was used (adapted by [29] from [30]). The scale contained 28 items (12 intrinsic motivation, 12 extrinsic motivation, and 4 amotivation) on a 7-point Likert scale, and the students were asked to indicate the extent to which each of the items corresponded to the reasons for why they started their higher education studies. The options were the following: 1 – does not correspond at all; 2 – does rather not correspond; 3 – corresponds a little; 4 – corresponds moderately; 5 – rather corresponds; 6 – corresponds a lot; 7 – corresponds exactly. The scale has been validated in previous studies and found to be reliable ([31], [32]). Intrinsic and extrinsic motivation are both divided into three subcategories on the scale, amotivation being the seventh category [30]. Intrinsic motivation is divided into intrinsic motivation to know, intrinsic motivation toward accomplishment, and intrinsic motivation to experience stimulation. Extrinsic motivation is divided into identified extrinsic motivation, introjected extrinsic motivation and external regulation. The Academic Motivation Scale was selected for the current study, as it had been used widely and already adapted into Estonian.

This study motivation questionnaire was filled in during lectures at university at the beginning of the second semester of the first study year. The students who did not participate in the lecture where the questionnaire was filled in were asked to respond to the questionnaire electronically, but less than 5% of the students used this option. The questionnaire was filled in by more than half of the students

(489); however, most of this data has not been used in the analysis presented in this article, since many of the respondents did not do the cognitive ability test.

The cognitive ability test used was a test developed at the University of Tartu to predict students' academic performance. The test is a short version of the scholastic aptitude test of the University of Tartu [33]. The version used in the current study focused on three dimensions (subscales): vocabulary, mathematical reasoning and spatial reasoning. There are 15 items on each subscale, 45 items in total. To every item, there were mostly five, but in some cases three (some vocabulary subtest items) multiple choice answers and only one correct answer per item. For every correct answer, the test-taker received one point, meaning that the maximum possible score was 45 points. The test was assembled from the scholastic aptitude test items from the years 2008–2012, considering their empirical level of difficulty (M=.58, SD=.09) – the selected test items in all subtests should be equally difficult, i.e. the difficulty level throughout the test is not progressive [see 34]. The research was conducted via the Internet in an online research environment, and there was a 60 minute time limit for the test, which should be sufficient to answer all the items with no time pressure. The time limit was set to ensure that the items would be answered sequentially, with no long disruptions. In the instructions to the test, test-takers were encouraged to use a paper and pen for calculations and notes, but not a calculator. The students voluntarily took a cognitive ability test at home at the beginning of the second semester; therefore, the response rate was low. 105 students did the cognitive ability test, but only 44 of them also filled in the study motivation questionnaire. The data of these students is used in the current analysis.

## 2.3 Data analysis

In order to find gender-related differences in students' cognitive ability, study motivation and academic performance, the Mann-Whitney U-test was used. The Wilcoxon test was used in comparing the levels of different dimensions in the cognitive ability test and types of motivation. Non-parametric analyses were applied, as some data was not normally distributed. For the same reason, the Spearman rank order correlation was used to characterize relations between different variables. A 95% confidence level was applied for marking statistically significant differences and correlations. These analyses were made using IBM SPSS Statistics 22. The model for predicting academic performance using data about cognitive ability, motivation and gender was created with path analysis. The path analysis was conducted using the MPlus 7.11 program [35].

The main limitation of the current study was that the sample was small and some of the data was not normally distributed. Therefore, we can only present an initial idea about the regression model, and further investigation is required. We cannot claim to have found a model that meets the quality criteria expected in the case of regression models (Root Mean Square Error of Approximation, Chi-Square Test of Model Fit for the Baseline Model and Standardized Root Mean Square Residual). In describing the model, we used standardized regression coefficients and related standard errors.

# 3 FINDINGS AND DISCUSSION

## 3.1 Cognitive ability and study motivation of IT students

IT students' average score in the cognitive ability test used in the current study was 32.6 (SD=8.5) points (see Table 1), which is higher than in several samples where the same test was used. The cognitive ability test results of the IT students have been previously compared with other student samples as well [see 35]. We found that IT students had the highest score on the cognitive ability test, with the mean score of 31.0, which is much higher compared with other samples. In the Silm [36] study it was 25.1 for music students, 23.8 for first-year students in different Estonian colleges and universities, and 20.9 for upper secondary school students. Compared with others, IT students also spent more time on the test and were more motivated to do the test according to self-reported test-taking motivation questionnaire results. Whereas the highest results were generally obtained in the vocabulary subtest, the IT students had the highest score in the mathematics subtest and lowest in the vocabulary subtest.

In the current study, students had the highest scores in mathematical abilities (12.7 points) and much lower scores in spatial abilities (10.7) and vocabulary abilities (9.2). All these differences were statistically significant (for mathematical and vocabulary abilities $Z=-4.98$, $p<0.01$; for mathematical and spatial abilities $Z=-4.20$, $p<0.01$; for spatial and vocabulary abilities $Z=-3.28$, $p<0.01$). Female

students scored slightly higher in mathematical and vocabulary abilities and male students in spatial abilities; however, these differences were not statistically significant.

Based on previous studies (see [37], [38], [39]) which have shown that, on average, men perform better on IQ tests than women, we could have expected gender differences in our study as well. Gender differences in mental abilities is a hot topic, also discussed in Nature [40]. A meta-analysis based on 57 general population samples demonstrates that adult men have an IQ advantage of around 4–6 IQ points over women [39]. Gender differences in IQ test scores have been explained in different ways. For example, more than 20 years ago, Lynn [41] proposed that men's larger average brain size compared with women was the reason for men's greater average general intelligence. According to Kimura [42], many researchers of gender differences have found that women have better verbal skills compared with men, and men are better at solving mathematical and spatial tasks. Gender differences in test results have also been linked to differences in motivation (e.g., [43], [44]).

Thus, it is known that men have higher scores on IQ tests, but females often get higher grades in college. This has been explained by women's higher work ethics. This, however, could be linked to study motivation. In the case of IT students, we did not detect these differences. Whether female IT students differ from other female (students) needs further investigation.

Table 1. Cognitive ability, study motivation and academic performance of female and male IT students in their first year of higher education studies.

| | Average of the sample (SD) | Average of female students (SD) | Average of male students (SD) | U | p |
|---|---|---|---|---|---|
| Cognitive ability (max 45) | 32.6 (8.5) | 33.0 (7.8) | 32.3 (9.1) | -0.02 | >0.05 |
| Intrinsic motivation (max 7) | 5.0 (1.1) | 5.5 (1.3) | 4.6 (0.7) | -2.44 | <0.05 |
| Extrinsic motivation (max 7) | 5.3 (1.1) | 5.8 (0.8) | 4.8 (1.1) | -3.30 | <0.01 |
| Amotivation (max 7) | 1.8 (0.8) | 2.0 (0.6) | 1.5 (0.9) | -0.25 | >0.05 |
| Academic performance (GPA)(max 5) | 3.7 (0.9) | 3.82 (0.9) | 3.65 (1.0) | -0.39 | >0.05 |
| Academic performance (number of credit points) (nominal 60) | 63.3 (7.5) | 65.7 (3.5) | 61.4 (9.4) | -1.56 | >0.05 |

Next, we found that the students in our sample had high study motivation. On a 7-point Likert scale, their intrinsic motivation was 5.0 (SD=1.1), extrinsic motivation 5.3 (SD=1.1) ($Z$=-2.30; $p<0.05$) and amotivation only 1.8 (SD=0.8). Therefore, we decided to use only intrinsic and extrinsic motivation as variables in designing a model for predicting academic performance. The means of motivation of Estonian IT students are similar to the findings of Mägi [45], who studied Estonian first-year undergraduates' sample consisting of students of different majors of many universities. More specifically, the mean of intrinsic motivation for our IT students was 5.19 ($p<0.05$) and that of extrinsic motivation 5.18 ($p<0.05$). Therefore, the academic motivation of Estonian IT students seems to be similar to Estonian higher education students in general. In the case of study motivation, significant differences between female and male students appeared. Female students were more motivated. For intrinsic motivation, women scored 5.5 (SD=1.3) and men 4.6 (SD=0.7) points ($U$=-2.44, $p<0.05$); for extrinsic motivation, women scored 5.8 (SD=0.8) and men 4.8 (SD=1.1) points ($U$=-3.30, $p<0.01$). This shows that although there is only a small proportion of female students in IT studies, they are very motivated, and this needs to be taken into account in supporting their learning process. However, we have to add that we only measured motivation once during the first study year. Some other studies have showed that study motivation might change during the studies [see 37]. This could have an effect on the interpretation of our findings.

The first study year grade point average (GPA) score of the students was 3.7 (SD=0.9) on a 5-point scale. There were no statistically significant differences between female and male students here. However, it was interesting that female students earned more credit points, especially in the second semester. On average, the students in the sample got 63.3 (SD=7.5) credit points (1 European credit

point = 26 hours of work), which is slightly more than is expected per study year (60 credit points). This shows that our sample contains mainly successful students. Only seven students out of 44 earned fewer than 60 credit points. In the larger group of the same cohort (N=509), the average number of credit points was 57.9, and 40% of students earned fewer than 60 credit points in the first study year. Therefore, our findings might have a bias that does not allow making generalizations. Female students got an average of 65.7 (SD=3.5) credit points compared with 61.4 (SD=9.4) credit points of male students (U=-1.56; p>0.05).

Correlation analysis (see Table 2) showed that cognitive ability seemed to have the strongest correlation with intrinsic study motivation ($\rho$=0.25) and grade point average ($\rho$=0.57). However, the correlations with motivation were weak. Correlation coefficients between cognitive ability and extrinsic study motivation and amotivation were particularly weak. This shows that in supporting IT students' learning processes, we have to focus on factors that have an effect on intrinsic motivation, as increased extrinsic motivation might even have a negative effect on study outcomes. In this context, it is notable that in Estonia, many IT students are supported with special scholarships, they will often get a free laptop from the university, and it is widely known that the salaries and available employment possibilities are very promising (for reasons why IT students are interested in IT studies see [23]). It is not known if these incentives have had an effect only on recruitment or have also influenced retention or even the academic performance of the students. This could be an interesting topic for further studies. However, it has been shown that students who have less programming experience before starting higher education IT studies are more led by extrinsic motivation [46]. Therefore, IT education should already be introduced in comprehensive school in order to avoid a situation where decisions about continuing education are made based on variables influencing the external regulation of learning processes.

Table 2. Correlations between cognitive ability, study motivation and academic performance (GPA = grade point average) of IT students in their first year of higher education studies.

| | Cognitive ability | Intrinsic motivation | Extrinsic motivation | Amotivation | Academic performance (GPA) |
|---|---|---|---|---|---|
| Cognitive ability | 1 | 0,25 | -0,13 | -0,02 | 0,57* |
| Intrinsic motivation | 0,25 | 1 | 0,66* | -0,39* | 0,24 |
| Extrinsic motivation | -0,13 | 0,66* | 1 | -0,41* | -0,12 |
| Amotivation | -0,02 | -0,39* | -0,41* | 1 | -0,04 |
| Academic performance (GPA) | 0,57* | 0,24 | -0,12 | -0,04 | 1 |

*statistically significant correlations

## 3.2 The effect of gender, cognitive ability and study motivation on IT students' academic performance

Path analysis was used to build a model for describing how IT students' academic performance could be explained by cognitive ability, study motivation and gender. The findings are shown in Fig. 1. The model describes 51% of the variance of students' first year grade point average (GPA). All three variables in our study – cognitive ability, intrinsic motivation and extrinsic motivation – have a significant effect on predicting outcomes. Only gender appears to have no significant direct effect. At the same time, gender is an important predictor of motivation.

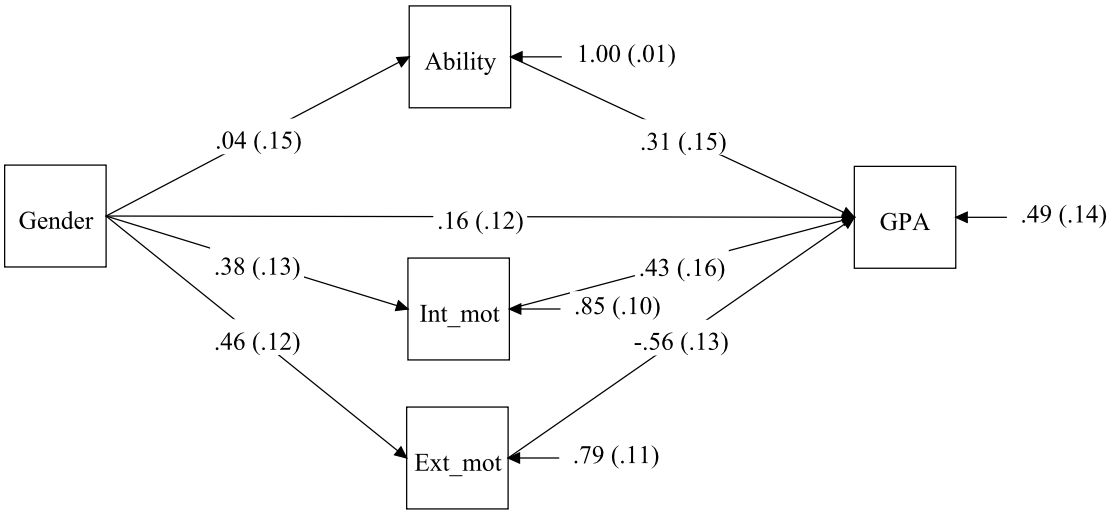


Fig. 1. Path analysis diagram for predicting students' grade point average (GPA) based on cognitive ability (Ability), intrinsic motivation (Int_mot), extrinsic motivation (Ext_mot), and gender.

In our study, both the intrinsic and extrinsic motivation scores of female students were significantly higher than these of male students. Thus, it could be expected that female students will have better academic performance, because their cognitive ability is similar to male students and motivation even higher compared with male students. However, this is not the case. It might be explained by the different effect of intrinsic and extrinsic motivation. Our model shows that intrinsic motivation has a positive effect on grade point average, whereas the effect of extrinsic motivation is negative. While female students scored higher on both types of motivation, it might be that extrinsic motivation has an effect on them that leads to a drop in academic performance, and, therefore, there are no differences in the academic performance of female and male students.

It was also interesting that according to our study, the effect of motivation seems to be stronger than the effect of cognitive ability. Similar results were obtained by Ray, Garavalia and Murdock [47] as well as Robbins et al. [48]. Some other studies, however, have reported that motivation should generally have a more marginal effect [see 9]. This difference could be explained by the contextual differences of learning in the IT field. We hypothesize that IT students are digitally more competent and their learning process might therefore be more personalized and digitalized. In this case, the effectiveness of the learning process could depend more on students' self-regulation and motivation. However, students' self-regulation skills and digital competencies were not under investigation in the current study.

In addition, interestingly, we did not detect any notable effect of gender on students' cognitive ability. Some other studies have demonstrated that men should outperform women ([34], [35]). The IT field might exhibit an interesting difference – it seems that the female students who start studying IT are different from the general cohort and their cognitive ability is therefore not different from that of their male peers. Thus, the model describing IT students cannot be easily used in other contexts.

## 4 CONCLUSIONS

Our study shows that IT students, especially female students, are an interesting group that seems to differ from many other groups of students; therefore, the general models for predicting students' academic performance might not work here. Even though we did not collect information about students' digital competencies, we can describe some characteristics of the sample. In the case of IT students, there are no differences between female and male students' cognitive abilities, and female students have significantly higher motivation than male students. Interestingly, this does not result in female students' higher academic performance compared with their male peers. Female students' average scores do not differ significantly from male students. This paradox could be explained using the regression model developed in our study. It shows that whereas cognitive ability and intrinsic motivation have a positive effect on academic performance, external motivation has an even stronger

negative effect. Thus, it negatively "compensates" for the positive effects and results in no differences in the academic performance of female and male IT students.

It is important to note that this model for predicting study performance might not be applicable in other contexts due to the differences we detected in the case of IT students compared with other students. However, the model has several limitations even in the context of IT studies. First, we measured study motivation only once during the first study year. Potential changes in motivation during the studies and their role in predicting academic performance need further research. Second, our sample represented only 6% of all IT students in three Estonian higher education institutions. These students seem to be quite successful, and, therefore, this model requires clarification in a larger group. Third, owing to the small sample, our model did not meet the quality criteria for model fit. Thus, we can conclude that this study proposed some interesting findings but should be continued with a larger sample. In future research, dynamic change of motivation during studies should be taken into account in order to develop a more generalizable model.

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