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The paper. The paper is carefully formatted according to the template of the journal (see bellow). Special attention is paid to the exact application of the Harvard referencing convention to both continuous citations and list of references. If an electronic source has the DOI number assigned, also it will be provided in the list of references. Manuscripts are submitted via the editorial system in the DOC.

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The whole collective of editors of ERIES Journal hope that the beginning of 2021 finds all of our readers, reviewers and editors well and the continuing pandemic of COVID-19 soon be solved, and our lives will come back to our pre-pandemic lives quickly. With the first issue of the year 2021 (Vol. 14, No. 1) that you hold in your hands, we are more than pleased to present five articles from authors from Colombia, the Czech Republic, Mexico, Russia and Turkey.

The first article entitled "To What Factors do University Students Attribute Their Academic Success?" by Blanca Elba García y García from Universidad La Salle México explores attributions to which undergraduate university students ascribe academic achievement. The questions that guided the study were the following: What are the causal attributions that predominate in students' academic achievement? Is there a difference between male and female students? Is there a difference if average grades and the number of failed subjects, factored as benchmarks of academic achievement, are considered? Do the measured attributions have any weight when predicting students' grades? The author used a non-probability convenience sampling from three private universities in Mexico with a sample of 165 undergraduate students from various specialties. Out of the total, 74 students were men and 91 women, with averages ranging from 6 to 10 grades. The results indicate that the most important attribution for academic achievement was intelligence. Sex-related differences were found in two attributes: calm and effort.

The second article "A Case Study on Goal Orientations for Teaching" by Hülya Yıldızlı from Istanbul University-Cerrahpaşa analysed actions, views, and emotions in relation to teachers' goal orientations and the reflection of goal orientations on their teaching practices. In addition, the study investigated whether there were differences among teachers' practices based on their goal orientations. Ten teachers who taught in different schools and school levels participated in the case study. Those teachers were grouped into two goal orientations: those with Learning-Mastery-Goal-Orientations (L-M-GO) and those with Learning-MasteryPerformance-Goal-Orientations (L-M-P-GO). The results suggest that all teachers, regardless of their goal orientations, define themselves as individuals who made efforts to learn. However, those with L-M-P-GO orientations experienced negative emotions and ideas in their learning journeys.

The third article "Students' understanding of axial and central symmetry" by collective of authors Vlasta Moravcová, Jarmila Robová, Jana Hromadová and Zdeněk Halas from Charles University investigated students' understanding of the concepts of axial and central symmetries in a plane. Attention is paid to whether students of various ages identify a non-model of an axially symmetrical figure, know that a line segment has two axes of symmetry and a circle has an infinite number of symmetry axes, and can construct an image of a given figure in central symmetry. For this purpose, the authors used long-term empirical research combining quantitative (didactic testing of a large sample of respondents and statistical data processing) and qualitative methods (use of semi-structured interviews and in-depth analysis of students' opinions and errors). The sample consists of 1,458 Czech students from ISCED I graduates, ISCED II graduates, and ISCED III graduates. The results show that students have two principal misconceptions: that a rhomboid is an axially symmetrical figure and that a line segment has just one axis of symmetry. Moreover, many students confused axial and central symmetry.

The fourth article "Assessing and Classification of Academic Efficiency in Engineering Teaching Programs" by Enrique De La Hoz, Rohemi Zuluaga and Adel Mendoza from Universidad Tecnológica de Bolívar, Universidad del Sinë and Universidad del Atlántico uses a three-phase method to evaluate and forecast the academic efficiency of engineering programs in Colombia. In the first phase, university profiles are created through cluster analysis. In the second phase, the academic efficiency of these profiles is evaluated through Data Envelopment Analysis. Finally, a machine learning model is trained and validated to forecast the categories of academic efficiency. This proposed methodology enables to evaluate and predict university programs' academic efficiency between institutions with similar characteristics, avoiding a negative bias toward those institutions that host students with low educational levels. The authors analyzed 256 university engineering programs in Colombia using data from the national examination of the quality of education in Colombia in 2018. The results reveal a formation of two groups of programs: the first with high results in basic professional skills and the second group with high results in secondary basic skills.

The last article "A Study of Students' Preferences in The Information Resources of The Digital Learning Environment" by Tatiana Noskova, Tatiana Pavlova and Olga Yakovleva from Herzen State Pedagogical University of Russia studied the diversity of students' information preferences in the digital learning environment. The authors hypothesised that students use a variety of information sources, but they mainly apply the methods of work that they have mastered in the "traditional" (face-to-face) learning paradigm. The results show that students use a variety of information sources, but they mainly apply the methods of work in the "traditional" learning paradigm. They insufficiently use the digital environment potential of collaboration, knowledge exchange, and knowledge extraction from authentic sources. What is more, the obtained results indicate problems in students' information culture and shortcomings in the methodological support of students' autonomous work.

We would like to thank all authors who have submitted their manuscripts to ERIES Journal and special thanks to all reviewers for their effort in revising the manuscripts. We hope that all our readers will find this first issue of the year 2021 appealing. We also hope that the published articles will positively contribute to the field of efficiency and responsibility in education.

Sincerely

Martin Flégl
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CONTENT

Full research paper

TO WHAT FACTORS DO UNIVERSITY STUDENTS ATTRIBUTE THEIR ACADEMIC SUCCESS?

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ABSTRACT

This study explores the attributions to which undergraduate university students ascribe academic achievement. Attribution theory was used as a means to understand scholastic success-failure. The questions that guided the study were the following: What are the causal attributions that predominate in students' academic achievement? Is there a difference between male and female students? Is there a difference if average grades and the number of failed subjects, factored as benchmarks of academic achievement, are considered? Do the measured attributions have any weight when predicting students' grades? A Likert scale measuring eight different attributions of academic achievement was applied to 165 students. The results showed that the most important attribution for academic achievement was intelligence. Sex-related differences were found in two attributes: calm and effort. In general, students with four failed subjects were those with the lowest averages measured in attributions. The variables that predicted good grades for male students were effort and good teachers, for female students, a liking for teachers, luck, and attention.

KEYWORDS

Academic achievement, causal attributions, effort, exit attribution, motivation for achievement

HOW TO CITE

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Highlights

- *The study discusses the role of eight attributions to the academic success of university students and their relationship to academic achievement.*
- *Students perceived that intelligence, effort and attention are the most important attributions to academic success.*
- *Predictor attributional variables of grades by males and females are different.*

INTRODUCTION

Much of the research that has been developed to understand the factors that determine academic achievement, analyze a wide variety of variables and theories, which do not directly consider the students' rationale about factors that lead them to success in their studies. This study aims to explore the success attributions that predominate among university students and their relationship to academic achievement. The basis of the study is the attributional theory originally set forth by Heider (1944; 1958) and Weiner's works (1985; 1972) on attribution and motivation for achievement. Essentially, this theory points out that people, in order to make sense of their lives, tend to seek cause-and-effect relationships in order to explain their own behavior, other people´s and, in general, the events that surround them. Kelley (1967) proposes that people create causal schemes that are used to explain the phenomena around them and to make inferences take into account three conditions: the individual himself (internal attribution), the stimulus (external attribution) or the circumstances surrounding the fact.

Weiner (1972, 2010b) based on Heider and Kelly's proposals tries to apply the attributional theory to understand the causes of success and failure related to academic achievement. It clarifies that this theory alludes to a phenomenon of subjective causality, it is not necessarily about finding the real causes of events. Attribution is a process of causal perception that varies by gender, age, context, group or culture, it is also different depending on whether attribution is made to one's own behavior or other people's (Digia and Zdravkovi, 2019; Weiner, 2010b). However, it is possible to observe that in certain contexts the same causes appear regularly, which allows us to understand with some degree of generality the origins that are attributed to events, this is applicable in the educational field.

In particular, the causes attributed to school success or failure on the part of both students and teachers are capacities, skills, intelligence, homework difficulty, teacher's characteristics, or luck (Weiner, 1985). Whatever the attribution, it will positively or negatively impact students' achievements and therefore their motivation, feelings, behavior, and school decisions. Hence the importance of understanding this process in educational environments and in particular from the perspective of students (Weiner, 2010a).

Finally, in order to understand the attributional styles of individuals and in particular students, it is important to consider at least three variables involved in the process of building causality schemes. The first is the recognition that the causes we identify in the facts, present a bias, that is, causal attribution is subjective, and according to Weiner (2010b) responds to a hedonic process. In this way, there is a tendency to derive internal causes of the behavior of others and external causes to their own. It is common to find that success will always be seen as a result of effort, an internal cause and failure due to external causes like luck. The second variable is related to the communications that students receive from their teachers, whether conscious or not, they make comments that can be used as explanations for school performance (Matteucci and Gosling, 2004). Finally, the third variable is the management of impressions that individuals make to manipulate the causal beliefs of others, using resources such as denying, making excuses, and seeking justifications, especially when school objectives are not achieved.

Weiner (2010a) notes that causal attributions have at least four characteristics:

- *Locus or location*. Considering Rotter's (1966) contributions to control locus, Weiner (2010a) notes that the causes of a fact can be perceived from within or outside the actor, can be made internal or external attributions. In this way, the one who makes external attributions to his achievements depends on the environment and the others. Conversely, those who make internal powers consider that the things that happen to them are the product of their own actions, trust their own resources and are able to transform their environment.
- *Controllability*. There are causes that the person can manage at will, unlike others beyond their control. If school failure is attributed to a lack of effort, then it is something that students will be able to control, instead if they attribute it to the characteristics of the teacher, they will hardly be able to control their success or failure.
- *Stability*. The cause may or may not be permanent in time. Intelligence is conceived as an ability that does not change throughout life, when failure is attributed to it, it will hardly be thought as something that we can change and therefore will always be wrong in studies.
- *Globality*. Causes can be generalized to a variety of situations. If luck is the attribution students recognize as the cause of their school failure, they are likely to use it to explain their stumbles in other contexts.

In this regard, Weiner (2010a) notes that these dimensions provide the meaning that students will use to explain their academic achievement. For example, he has found that controllable and temporarily stable attributions positively impact motivation for study, persistence and academic achievement, producing feelings of pride in students. In this same sense, Vélez (2007) points out that the meaning that students attribute to school success, will be used as a scheme that will guide their behavior in regard to their studies.

Based on these ideas, there are many researchers who have studied how these attributions work to explain the success-failure of students. Van Overwalle (1989), Batool and Akhter (2006), García (2006), Boruchovitch (2004), Kamal and Bener (2009), Lei (2009), Perry, Daniels, and Haynes (2008), Sucuoglu (2014), Smith and Skrbi (2017), and Munir (2020) who have explored attributions such as effort, difficulty of tasks, quality of teachers, attention, ability and luck, as determinants of academic success. All of them found that basically, effort and ability are the most frequently mentioned reasons as the reasons that lead to school success, and their main features are to be internal and controllable. Specifically, Batool and Akhter (2006), point out that external attributions such as luck or task difficulty, both external and uncontrollable, lead students to school failure.

More recently, Taskiran and Aydin (2018) in their study reinforce the trend of research in this regard, they find that controllable and unstable attributions, such as effort, teachers, motivation and class participation, are the most frequently leading to the success of those who learn a foreign language. Bouchaib, Ahmadou, and Abdelkader (2018) found that both successful and unsuccessful students noted that extrinsic attributions are important for academic achievement, however successful students also emphasized the role of internal attributions such as ability and effort.

There are studies that analyze the mediating role of school success-failure attributions in self-efficacy. Bandura (1986, 1997) defines the self-efficacy as the set of beliefs people have about their ability to achieve goals or face situations originated in their social media. Students´ beliefs about their academic ability influence perseverance, persistence, performance, and self-regulation of learning; self-efficacy becomes a motivating force predictive of self-beliefs and academic performance (Pajares, 1996). Stajkovic and Summer (2006), and García-Fernandez et al. (2016) point out that self-efficacy and causal attribution are reciprocally related. When individuals have high levels of self-efficacy, they attribute their success to internal causes, they have a strong personal conviction on their skills in order to achieve their goals. Bouchaib, Ahmadou, and Abdelkader (2018) recognize the strength of students' beliefs in their skills to learn and achieve high levels of competence. For this reason, predictive capacity of academic self-efficacy perceived by students on high self-attributions, such as ability and effort, has been studied (Hsieh and Schallert, 2008; Lee, Song and Kim, 2018; Sáez et al., 2018). García-Fernández et al. (2016) studied this relationship in a sample of 874 Chilean teenage students. Regression analyses showed that academic self-efficacy was a predictor of self-attributions such as ability and effort.

A relationship has also been found between attributions and school anxiety. In this sense, Lagos et al. (2016) found that when attributions relate to external causes, high school students presented higher averages of anxiety. Also, when effort was recognized as a cause of success, high anxiety levels were present. Gonzálvez et al. (2018) found that students' rejection of mathematics was mediated by maladaptive attributions such as lack of ability and effort, as well as external causes. They conclude that such self-attributions do not promote learning and negatively affect academic development and self-confidence.

Maymon et al. (2018) conducted a study with the intention of finding out whether positive emotions can be predicted from internal and controllable causal attributions, contrary to what stable attributions which can be predictive of negative emotions. Indeed, they found that stable and external attributions produce maladaptive emotions such as hopelessness, boredom, anxiety and guilt. On the other hand, external but controllable attributions produce fewer emotional problems, students find themselves more hopeful and less anxious. Finally, as hypothesized, the effects of stable attributions have negative effects on their emotions.

Gender comparisons have been another trend in studies on this issue. For example, Boruchovitch (2004) found that men, unlike women, attribute success in mathematics to intelligence and that they like their teachers. Rodríguez-Marín and Inglés (2011) found a very similar attribute profile between the genders, except because women believe success is due to ability and failure to lack of effort. Digia and Zdravkovi (2019) conducted a study to understand how attributional styles related to the way students faced exam situations, they found that while the men interpreted failure as a lack of ability, the women focused more on the problem in test situations and attribute success to their effort. These authors also claim that women have more functional attributions than men. This partially explains the obtained results, women may be directed towards greater effort, while men are directed towards developing abilities.

Based on the attributions used by Boruchovitch (2004) in her research with Brazilian students, the goal of this research is to find out the relationship between the causes that undergraduate students attribute to their academic achievement and school performance.

Thus, it is intended to answer the following questions:

- What are the causal attributions that predominate in the academic success of students?
- Is there any difference between men and women?
- Is there any difference considering the number of subjects failed as benchmarks of academic success?
- Do the measured attributions have any weight in predicting the grades obtained by students?

The following sections of the paper describe the measuring instrument that was applied to a group of university students and the forms of data processing. In the results section, the attribution patterns found in the sample are presented, comparisons are made by gender and failed subjects, finally presenting the weight of each attribution of success measured in the prediction of students' grades.

MATERIALS AND METHODS

Participants

The sample based on a non-probability convenience sampling from three private universities in Mexico, consisted of 165 undergraduate students from various specialties. Of these, 74 were men and 91 women, with averages ranging from 6 to 10 grades; 65 of them had approved all their subjects throughout their school life and the rest had between 1 and 15 failed subjects.

Measuring instrument

For the design of the scale of successful attributions, the eight variables proposed by Boruchovitch (2004) were used. Hence, four internal causes (calm, effort, attention, intelligence) and four external causes (liking their teachers, easy tasks, good teachers, luck) were measured. Unlike multi-item scales, the instrument was built using a single-item technique; examples with this type of measurements can be found in studies such as Cheah et al. (2018), Fisher, Matthews and Gibbons (2015) and Diamantopoulos et al. (2012). The attributions were measured on a 10-point Likert scale at which each was evaluated globally and independently. However, considering that items all together measured success attributions, the item-total analysis used in Cronbach's reliability was applied in order to discard items that affect scale consistency. The results yielded moderate alpha values between.65 and.69, therefore any item was removed from the scale, because total reliability was not affected.

Procedure

The questionnaires were applied at three different private universities, in classrooms, or in the open spaces of their campuses. They were informed that the questionnaire was completely anonymous and if they were willing to answer it, it would be taken as their informed consent to be able to use the data in this study, always retaining anonymity.

Data Analysis

Different statistical processes were carried out to answer the research questions. A descriptive analysis was made in order to identify the predominant attributes in the sample based on the averages obtained and were represented on a bar chart. The *t*-test of mean contrasts was used to find differences by gender. The sample was also classified into three groups to identify differences considering the number of failed subjects by applying a simple classification variance analysis. Finally, a regression analysis of successive steps was used to know the weight of each attribution measured in predicting the students' grades.

RESULTS

- What are the causal attributions that predominate in students' academic success?

Table 1 shows the attributional pattern that characterized the students in the sample. As can be seen from the values of the averages, the study participants consider that all the reasons for success presented contribute to their academic performance. The lower mean corresponds to luck with a M = 6.21 (on a scale of 1 to 10), although to a lesser degree than the others, it is still present among the reasons that favor school achievement, however it is a totally uncontrollable, unstable

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and external element in relation to the students' actions. The attribution with the highest mean is intelligence ($M = 8.15$), students point that it is an internal and stable aspect over time, however uncontrollable since they cannot change it at will, it is the one that most determines their academic achievement. It is also worth noting that effort ($M = 7.42$) and attention ($M = 7.04$), aspects that depend entirely on the student, yield high averages. Also, having good teachers ($M = 7.18$), a factor totally out of the students' hands, seem to be determinant in their success. The trends observed in the sample were corroborated with the t-test for one sample. The t values were found to have fluctuated between 3.81 and 18.20 with $df = 119$ and $p < .000$; thus, all trends were significant.

Attributions	Mean	Std. Dev.
Intelligence	8.15	1.10
Effort	7.42	2.33
Good teachers	7.18	2.22
Attention	7.04	2.42
Liking for teachers	6.92	2.20
Calm	6.87	2.46
Easy task	6.59	2.40
Luck	6.21	2.84

Table 1: Causal attribution related to academic success, average values, 2018 (source: own calculation)

- Is there a difference between men and women?

Table 2 shows statistically significant differences between men and women, associated to both the calmness and the effort in their approach to academic work. It is men who give greater weight to calm in order to succeed. In regard to effort, the data is reversed, because it is women who consider the role of this aspect most important in their achievement. The remaining means are very similar in both genders, however, it is important to highlight the difference in attribution related to luck, because although it is not significant, women seem to assign greater weight than their men counterparts.

Attributions	Mean		Std. Dev.		t
	M	W	M	W	
Internal Calm					
Calm	7.23	6.37	2.38	2.47	1.911
Effort	6.80	7.79	2.78	1.90	-2.342
Intelligence	8.25	8.08	2.15	1.70	.440
Attention	6.86	7.17	2.60	2.30	-.680
External					
Easy task	6.82	6.43	2.40	2.41	.870
Good teachers	6.60	6.89	2.11	2.30	-.700
Liking for teachers	6.31	6.75	1.99	2.34	-1.100
Luck	6.43	5.66	2.85	2.76	1.460

[1]p = .05; [2]p = .03

Table 2: Attributions to success by gender, 2018 (source: own calculation)

- Is there any difference considering the number of failed subjects as benchmarks of academic success?

To answer this question, the failed subjects were classified as shown in Table 3 and contrasts were made with a simple classification variance analysis. Before describing the results, it is worth noting that most students, 61%, have failed among one and more than four subjects throughout their academic history and, in general, these have the lowest mean values in the measured attributions, the reasons for success explored in this study, are less important to them in contrast to the other two groups (without failing subjects or with 1 to 3 subjects noted).

The first observed statistically significant difference is associated with effort, the higher the number of failed subjects, yields a decrease in the mean. In Table 3 we can see that the averages decrease from 8.06 to 6.19, students who fail more subjects consider that effort has less impact on the success of their studies. However, the average is 6.19 on a scale of 1 to 10, that is, they are somehow aware of the role of effort in studies.

Another important difference is in attention, students with more failed subjects think this aspect is less important in their academic results. The same is true of the attribution related to teachers (Table 3), especially in the liking of teachers, it is observed that students with 1 to 3 failed subjects are those who have the highest means, followed of who have not failed any subject and finally, the students with four or more failed subjects have minor mean. It is worth highlighting the role of luck as a success factor, it increases slightly as the students have more subjects failed, this small difference was statistically significant.

- Do the measured attributions have any weight in predicting the grades obtained by students?

A regression analysis of successive steps was applied to answer this question, with the intention of finding the number of variables that would allow the best fit in predicting and obtaining a regression equation based on statistical criteria. Two different analyses were run, one for males and one for females. Tables 4 and 5 show the results obtained from the regression equations of academic success for each case. As observed, the attributions that predict grades are different in both genders.

Table 4 presents the regression results of males, it shows that effort ($b = .46$) and good teachers ($b = .32$) are the two variables that predict the averages of grades earned by students in their subjects, the six remaining variables did not enter the equation. Consequently, as students strive in their studies and consider having good teachers, they will most likely achieve high grades. The coefficients b featured in the variables are high and significant ($t = 3.88$ with $p = .001$ and $t = 2.68$ with $p = .01$, respectively). In case of women, the three variables that had the best fit in the regression equation were, the liking for teachers ($b = .38$), luck ($b = -.23$) and the third variable was attention ($b = .22$). All b are statistically significant $t = 3.41$ with $p = .001$, $t = 2.09$ with $p = .04$ and $t = 2.01$ with $p = .04$ (Table 5).

Attributions	Failed subjects			F
	None	1 to 3	4 or more	
Internal				
Calm	7.02	6.43	6.66	.550
Effort	8.06	7.93	6.19	9.511
Intelligence	7.86	8.46	8.23	.990
Attention	7.63	7.65	5.92	7.542
External				
Easy task	6.80	6.90	6.14	1.180
Good teachers	7.28	7.31	5.80	6.693
Liking for teachers	6.84	7.43	5.59	7.712
Luck	5.15	6.56	6.47	3.384

[1]p < .001; [2]p = .001; [3]p = .002; [4]p = .03

Table 3: Means obtained by number of failed subjects, 2018 (source: own calculation)

Attributions	Unstandardized coefficients		Standardized coefficients	t	p
	B	Std. Error	b		
Effort	.22	.04	.61	5.50	.001
Good teachers	.17	.04	.32	2.68	.010

$R = .68$, $R^2 = .46$, $F = 20.66$, $p < .001$

Table 4: Men's regression equation, 2018 (source: own calculation)

Attributions	Unstandardized coefficients		Standardized coefficients	t	p
	B	Std. Error	b		
Liking of teachers	.10	.03	.38	3.41	.001
Luck	.05	.02	-.23	-2.09	.040
Attention	.06	.03	.22	2.01	.040

$R = .49$, $R^2 = .24$, $F = 6.98$, $p < .001$

Table 5: Women's regression equation, 2018 (source: own calculation)

DISCUSSION

The objective of this research was to find the relationship between the causes that undergraduate students attribute to their academic achievement and school performance. Participants, while considering that all the causes explored as contributors to their achievement in school, particularly point to an attributional pattern characterized by four main reasons: intelligence, effort, good teachers and attention, which are the most frequently found in literature. Such attributions are considered by some authors as functional causes that contribute favorably to the school performance (Taskiran and Aydin, 2018; Bouchaib, Ahmadou and Abdelkader, 2018; Weiner, 2010b; Boruchovitch, 2004; Kamal and Bener, 2009). These two attributions characterized by being internal and controllable, are functional or adaptive since they allow academic achievement and lead to positive emotions (e.g. feeling proud of themselves), with favorable consequences on school performance (Weiner, 2010a; Maymon et al., 2018). It is these attributions that lead students to self-efficacy in their studies (García-Fernández et al., 2016).

The instability of these attributions is likely to make students aware that they may have some kind of control over them and put them at stake to achieve the goals that are proposed. They are attributions that will always accompany them and help them make decisions that will reinforce their self-esteem and motivation for achievement (Weiner, 1985), that is, they will be taken as a cognitive scheme that will determine their future behavior. As the school context fosters and supports these reasons for academic success, students will achieve better performance.

The attribution with the highest mean was intelligence, a cause that is not controllable, but is stable and internal. One tends to think that we are all born with a level of intelligence that does not change in time, hence its stability. In this sense, it can be said that if it is used as a source of positive academic results, those who consider having low intelligence, will surely think that they will not be able to face academic challenges. That is, intelligence can become a dysfunctional attribution of academic achievement and therefore not contribute to good performance in students. Fortunately, this idea can be refuted with Gardner's educational work (1993) on multiple intelligences, which points to the existence of various potentialities that humans can develop and employ in various situations. Even Feuerstein's proposal (e.g. Feuerstein et al., 1984) on cognitive modifiability, opens up the possibility that intelligence could be transformed like other abilities, he rejects the idea that it will be fully fixed throughout life. He claims that any individual is able to improve their intellectual capacity and learn through pedagogical experiences mediated by a docent.

Maymon et al. (2018) point out that stable attributions, just because they cannot be changed, generate negative feelings. In this sense, intelligence becomes a dysfunctional attribution, for something that remains the same over time will always interfere with learning. Explaining school failure through this attribution can lead students to feel hopelessness, boredom, anxiety, and guilt (Maymon et al., 2018). Moreover, if one factors the global aspect of the attributions, intelligence can become the explanation for achievements or failures in other contexts.

So, it is recommended to address this aspect in the tutoring and orientations that take place across schools, directing students towards more functional causes to increase their performance, for instance, effort and persistence. Particularly this would have to be addressed to students who have low academic achievement, because from the data of this research for them, intelligence is one of the important attributions in their school performance.

Despite the fact, that effort presents one of the highest means, those who fail more school subjects consider that effort has less impact on the success of their studies. The difference between those who have failed subjects and the rest of the students is almost two points. That is, for underperforming students this attribution is less important, although the average size is above the midpoint of the scale, they are somehow aware of the role of effort in education.

As already noted, having good teachers, is among the four attributions found with the highest means in this study; it is an external attribution, unstable and uncontrollable, that appears in various investigations (e.g. Boruchovitch, 2004). It is a very recurrent explanation in students' positive school performance, however, given its peculiarities in some cases it could be a dysfunctional attribution to explain academic failure, especially if it is recurrent. While it is true that a good teacher can contribute to the academic achievement of a student, also, in some cases, as Matteucci and Gosling (2004) point out, it could be used as a resource to make excuses and seek justifications for poor performance.

The lowest mean found in attributions corresponds to luck, although to a lesser extent than the others, it is still present among the reasons that favor academic achievement. We could say that this totally uncontrollable, unstable and external element in the actions of students, is a dysfunctional attribution, which insufficiently contributes to their scholastic achievement, nonetheless it is recurrent in their discourse to justify high or low performance.

As for gender contrasts, our findings are aligned with the trends in a number of research studies, in that virtually, differences do not exist, men and women seem to have the same pattern of response (Boruchovitch, 2004; Rodríguez-Marín and Inglés, 2011). We can conclude that, with the exception of calm to execute the academic work, as well as effort, both genders attributed equal importance to the other reasons measured for academic success. For men, calm is more important than for women. It seems that in the academic achievement work frame women assign less importance to this aspect, in comparison to effort. They perceive that the latter is an important condition for achieving scholastic success. As Digia and Zdravkovi (2019) point out, these differences are likely to relate to the parenting habits that characterize women's education unlike men.

Finally, the applied regression analysis yielded two differential patterns between men and women. In males, effort (internal cause) and good teachers (external cause), are the grades predictors, so as they actively engage in their studies and are accompanied by a good teacher, their performance will be successful. Effort, a functional attribution, carries the greatest weight in prediction, it corresponds to an internal, and controllable aspect, which leads the student to be aware that much of his accomplishments depend on him. The second attribution, good teachers, carries a lower weight in prediction, in that it corresponds to an external and uncontrollable cause. This way, we can conclude that the male students in this study attribute their academic success greatly to their responsibility and commitment, but it will also rely on having good teachers.

In women, three predictor causes were found, the first one has to do with the liking of teachers, an internal attribution, controllable and unstable, which is also the one that has the most weight in academic achievement among the members of this sample. This implies that if they perceive that a teacher is not to their liking, they will probably have difficulties in their subject matter. The second cause, luck, was considered a cause of success, they believe their studies depends on fortuitous factors and beyond their control. These two attributions can become dysfunctional and of little help in improving academic performance. The third variable that entered the regression equation was attention, an internal cause, controllable but unstable, that can be directly handled and that has a positive impact on their achievement. As we see in women, two predictors of academic success could be characterized as dysfunctional, because they are not controllable, they will offer inadequate help in their performance.

CONCLUSION

From the results of this study, we can derive that participants attribute their academic success to both internal and external causes, some of them can control and use them intentionally to improve their school performance, others depend on context such as assignments and teachers, or fortuitous elements such as luck. The interesting facts about the data presented is that none of the attributions presented averaged below 5, the averages exceeded 6 points; they all are important to the students of the sample and perceived as reasons to explain their school performance. In other words, although the reasons presented in this study are not the only ones in existence to achieve scholastic success or failure, study participants will resort to them, when they think they owe their achievements to any of them. The point is that some of these attributes can be considered dysfunctional, e.g. luck, or difficult to manage as students liking of teachers or difficulty with homework.

This work represents an exploratory approach to what students consider important for achieving good results in their studies. This line of work will allow developing educational intervention strategies with students, as well as teachers and tutors, based on the conceptions of the students themselves. In such way, considering the perspective of students, we will be able to understand how self-attributions can affect their performance and help them build functional attribution schemes that change their reasoning behind academic success in order to increase their motivation. It is important to remember that these schemes or attributions will have a positive impact to their study motivation, persistence, and achievement, resulting in feelings of pride that will help them maintain interest in school. The meaning that students attribute to school success will be used as a scheme that will guide their behavior to academic work. As can be seen, this research reinforces the idea that the teaching-learning process, not only depends on cognitive variables; the motivational and affective aspects are intimately linked to this process, so its analysis shows a more complete view of the complexities of school performance challenges.

In the future, it will be important to compare the findings with students at public universities. It is hypothesized that their attributional patterns of success are different, depending on the social and cultural contexts of their places of origin, and the visions that characterize public and private education. Contrasts could be made between undergraduate students and graduates, signatures, or fields of study. Other research paths to explore are variables of extrinsic-relational attributions such as teacher support, family, friends, or the school´s organizational structure. Finally, it is recommended to make convergence validity assessments with multi-item instruments of scholastic causality attributions, to reinforce the use of measurements using a single item.

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Full research paper

A CASE STUDY ON GOAL ORIENTATIONS FOR TEACHING

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ABSTRACT

The present research aimed to explore actions, views, and emotions in relation to teachers' goal orientations and the reflection of goal orientations on their teaching practices. The study also aimed to compare whether there were differences among teachers' practices based on their goal orientations. A case study design was adopted and 10 teachers who taught in different schools and school levels participated in the study. Those 10 teachers were grouped into two goal orientations; those with Learning-Mastery-Goal-Orientations (L-M-GO) and those with Learning-Mastery-Performance-Goal-Orientations (L-M-P-GO). A questionnaire and semi-structured interviews were held with teachers and the collected data were analysed using qualitative techniques. The results suggested while all teachers-regardless of their goal orientations- defined themselves as individuals who made efforts to learn, those with L-M-P-GO orientations experienced negative emotions and ideas in their learning journeys. Moreover, all teachers reported that there were certain cases where they avoided work. There were differences between teachers' classroom practices and ideas based on their goal orientations.

KEYWORDS

Case study, classroom practices, coding, qualitative data analyses, teachers' goal orientations

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Highlights

- *Teachers who have Learning-Mastery-Performance-Goal-Orientations experienced negative emotions and ideas in their learning journeys.*
- *Regardless of their goal orientations, success was considered as a source of motivation for all teachers and they wanted others to know about their successes.*
- *Regardless of their goal orientations, teachers were found to group students based on their levels and taught their lessons at the level of an average student.*
- *Teachers with Learning-Mastery-Performance-Goal-Orientations were found to support in-class competition.*

INTRODUCTION

Researches on goal orientations, which are important for both students and teachers during teaching/learning processes, advocate that individuals can possess multiple goal orientations simultaneously. For example, qualitative research studies (Levy, Kaplan, and Patrick, 2004; Yıldızlı, 2020) suggested that individuals strongly possess one of goal orientations and other goal orientations less strongly. Goal orientations they possessed can differ depending on the circumstances and personality traits. The analysis of related frameworks (in relation to goal orientations in the literature) suggested that the detrimental effects of the performance-approach should be re-examined since it was later split into two sub-categories; performance-approach and performance-avoidance (Pintrich, 2000). Additionally, the view that performance-approach can be interrelated with mastery-approach resulted in the development of perspectives advocating multi-goal theses by researchers (Barron and Harackiewicz, 2001; Linnenbrink, 2005). If researchers are to study teachers' goal orientations and their practice in classes and schools in relation to those orientations then investigating the interaction between teachers, students, classes, and schools becomes important. The present study aimed to reveal the similarities and differences among teachers' (those with different goal orientations) classroom and school practices as well as their emotions and views on those practices. Classroom and school practices were evaluated based on the dynamics of goal orientations towards teaching.

Theoretical Framework

Many studies have been conducted on students' goal orientations. More recently, however, attention has started to shift onto teachers' goal orientations. In fact, this topic, in the international literature, has been introduced as a factor that has been studied in the last 15-20 years and found to affect motivational beliefs in relation to the teaching profession. Goal orientations relate to the goals individuals set for themselves and affect the actions they take in relation to those goals. Goal orientation is a dimension that also relates to individuals' attitudes towards tasks, completing the tasks, and evaluating performance in a given task. It is a motivational belief that questions why individuals want to be successful, why they want to complete a given task, and how they decide on the criteria of success whilst completing the task (Pintrich, 2000). A number of different categorizations are available in achievement goal theory. For example; (1) learning goal and performance goal (Dweck, 1986), (2) task involvement and ego involvement (Nicholls, 1984), (3) mastery goal and performance goal (Ames, 1992), (4) learning-approach, performance-approach, and performance-avoidance (Elliot and Harackiewicz, 1996), and (5) 2x2 goal orientation (learning/performance x approach/avoidance; Elliot and McGregor; 2001). The most frequently mentioned and utilized model in the literature is the 2x2 goal orientation model. This model includes the following dimensions; 1) Mastery/learning-approach: Individuals who have mastery-approach goal orientations aim to develop their knowledge and skills 2) Performance-approach: Individuals who have performance-approach goal orientation have the tendency to try and show their skills and performance to others (receiving appreciation of others, extrinsic standards) 3) Mastery/learning-avoidance: This orientation includes more negative feelings in relation to learning processes (a fear to realize goals, being worried, having mostly negative feelings) 4) Performance-avoidance: Individuals who have performance-avoidance goal orientation tend to hide their incompetencies from others (not wanting and preventing others from seeing their failures, avoiding help seeking, extrinsic standards) (Dweck, 1990). While the main assumptions regarding goal orientations are defined as above, it is observed that there are opinion differences among theorists in terms of the assumptions surrounding the main dimensions of goal orientations. For example, while Barron and Harackiewicz (2001) accepted mastery/learning goal orientation as an individual's effort to take control of the given task (task standard), Grant and Dweck (2003) describe it as an active effort to develop competencies (intrinsic standard). Those two views resulted in the emergence of new models such as Elliot, Murayama and Pekrun's (2011) 3x2 model (as cited in Daumiller, Dickhäuser, and Dresel, 2019). This model proposed a new goal structure by categorizing goals as self-based, task-based, and other-based and utilizing a competence based evaluation criteria (task, self, and other).

Teaching in today's world is an important profession where learning does not stop. The school environment is one where teachers display high performance, develop their professional skills throughout their career, and learn new things (Borko, 2004). Therefore, considering that each teacher is at the same time a learner, the way they face difficulties in their job and, the way they respond to and interpret problems they experience can vary (Nitsche et al., 2011). Goal orientations for teachers have an important role in predicting their motivational and teaching performance (Kucsera et al., 2011). There are a number of studies conducted to categorize the different goal orientations that teachers have and various tools have been developed to measure teachers' goal orientations. Those data collection tools are based on the three different goal orientations (*learning-approach, performance-approach, performance-avoidance*) (Butler, 2007; 2012, Kucsera et al. 2011; Wandevalle, 1997). Butler's (2007; 2012) model, on the other hand, included the following; (1) *Mastery-approach,* (2) *Ability-approach*, (3) *Ability-avoidance,* (4) and *Work-avoidance.* Later on, Butler (2012) added the fifth dimension titled *relational* to this categorization. Those two dimensions (work-avoidance and relational) are significant because the tasks and responsibilities that teachers (who deal with many people during a day) are given in the workplace can result in differences in individual preferences (Daumiller, Dickhäuser and Dresel, 2019). And it is important to understand whether these preferences have any impact on the learning environment. More details in relation to those orientations as well as the results of research on exploring teachers' behavioural patterns in the classroom are summarized as following: 1) Mastery-approach: Focus on learning, being open to develop professional skills, creating learning focused classroom environments, high self-sufficiency, high interest in the profession, completing the tasks in the best way possible during the process of teaching, providing meaningful learning, and so on. 2) Ability-approach: Wanting others to know their quality teaching skills, being praised, receiving approval, putting competition into the centre of classroom practices, taking skill differences into account, focusing on overachievement, not taking student interests and requests into account, using exam scores as indicators for assessment 3) Ability-avoidance: Not wanting others to know about their low quality teaching skills, avoiding help seeking, avoiding failure, avoiding difficult tasks, preferring easier tasks, looking for external reasons as the source of a problem, and evaluating themselves based on extrinsic standards 4) Work-avoidance: Tendency to display low performance, not wanting to have too much workload, and little interest in school related duties 5) Relational: Establishing close relationships with students and providing social support (Butler, 2007; 2012; Dickhauser, Butler and Toenjes, 2007; Kucsera et al. 2011; Meece, Anderman, and Anderman, 2006; Patrick et al, 2001; Throndsen and Turmo, 2012).

Teachers who have mastery-approach are more focused on professional development, those who have ability-approach or ability-avoidance can have positive or negative behavioural patterns which change depending on extrinsic standards. As for work-avoidance, it refers to teachers avoiding exerting the effort necessary to do their job and trying to do the least amount of work possible. In the relational aspect, on the other hand, the communication established with students and the meaning attached to this communication is examined. The analysis of related literature suggests that goal orientations teachers possessed towards teaching are reflected in their classroom practices. It has been observed that teachers who have mastery-approach conduct classroom activities that are focused on learning and support the active participation of students, teachers who have performance-approach, on the other hand, focus on high performance and conduct competition based activities where students are compared with one another.

The analysis of studies on goal orientations indicates mastery/learning goal orientations are associated with positive behavioural patterns, and performance related goal orientations are either associated with positive behavioural patterns or do not reflect the expected negative behavioural patterns. For example, the results of the study conducted by Janssen and Prins (2007) suggested that employees who had a stronger learning-approach were more focused on developing themselves rather than looking for ways of validation. Additionally, the opposite relationship between performance-approach and performance-avoidance was evident in terms of individuals trying to develop themselves. Similarly, Midgley, Kaplan and Middleton (2001) found that students, in certain situations, can become adaptive learners even though they have performance-approach so long as their mastery/learning goal orientations are high. In addition, King and McInerney's (2014) study with college students suggested that mastery/learning goal orientations were similar across cultures, but other orientations were unique. Those results indicate that further studies (both conceptually and methodologically) are required to be able to better understand the meanings of mastery/learning goal orientations as well as the cultural differentiation of their effects based on contextual factors. Gordon, Dembo and Hocevar (2007), on the other hand, reported that teachers who used mastery control orientation in the classroom had higher levels of humanistic control ideologies, and performance-approach was not found to have any negative relationships with classroom control ideology. Similarly, in her study, Yıldızlı (2019) found that ability-approach goal orientation did not have any relationship with self-efficacy or burnout levels.

Another topic of interest is how goal orientations teachers possess affect teaching/learning processes within the classroom. If we classify the learning environments into two (learning and performance goal structure), teachers in performance-oriented learning environments focus on competition within the classroom, group students based on their skills, reward successful students, and prioritize general assessment (Eccles and Roeser, 2011). Teachers in learning-oriented classroom environments, on the other hand, prioritize individual learning and development. While learning-oriented classroom environments have positive relationships with all the behaviours expected from today's learners, performance-oriented classroom environments have different outcomes. For example, Elliot and Harackiewicz (1996) found that performance-approach condition was less effective for intrinsic motivation when compared to mastery-approach condition. Karabenick (2004) concluded that performanceapproach goal structure did not have a significant impact on students' help-seeking. And many studies found that goal orientation within the classroom can have different or the same effects on student behaviours (Murayama and Elliot, 2009; Wolters and Daugherty, 2007).

Another debated issue in relation to goal orientations is whether they are generalizable or not. More specifically, do cultural contexts and roles and identities that develop in cultural contexts have a significant role in shaping goal orientations? According to Urdan and Kaplan (2020), the relationship between achievement goal theory and the moral/philosophical views in relation to the aims of schools constitute the proof of the structure of the theory. Various factors (e.g. schools or classrooms serving a wide culture range, the definition of success being affected by certain beliefs, policies, and norms within a given education system, standardized tests conducted in a country, and how schools or classrooms define success) affect the structure of goal orientations. Considering the complexity of teaching/learning processes and the complexity of human beings, the need arises to answer the following question: Does this situation allow individuals to combine different types of goal orientations in an effort to continue their achievement in different circumstances? Therefore, the need arises to investigate in more detail the meanings and structures of mastery/learning goal orientations considering contextual factors. As such, it is noted in the literature that the methodologies utilized to investigate goal orientations with different populations should go beyond experiments and questionnaires, and expand towards more qualitative methodologies utilizing open-ended and inductive approaches (Urdan and Kaplan, 2020). As mentioned above, school and classroom are environments that form various behavioural patterns as a result of the interactions between different dynamics. Questions that will provide details about how individuals organize their lives and what meanings they attach to those experiences should be asked to collect in-depth data. As such, an in-depth picture can be depicted about teachers' viewpoints via the answers that reflect their viewpoints.

In line with this aim and significance, and taking goal orientations teachers have towards teaching into consideration, answers to the following research questions were sought:

1. What are the emotions, views, and actions of teachers with Learning-Mastery-Goal Orientations (L-M-GO) and Learning-Mastery-Performance-Goal Orientations (L-M-P-GO) towards teaching?
2. What kinds of classroom practices are reported by teachers with L-M-GO and L-M-P-GO orientations?

METHOD

The goal of the study was to reveal the emotions, views, and actions of in-service teachers in the context of goal orientations towards teaching including; mastery/learning, ability-approach, ability-avoidance, work-avoidance, and relational goal orientations. Teachers' classroom practices were also examined based on goal orientations they had. A qualitative research methodology was adopted to reach the objectives of the study. The data were collected via a questionnaire and semi-structured interviews.

Study group

10 in-service teachers working in Turkey were the participants. Those teachers were at the same time the students of the author as part of the Master's degree they were completing. A number of meetings were organized in order to explain the theoretical information on goal orientations and discuss it with the teachers. The reason for conducting those meetings was

to allow the participants to utilize the theoretical knowledge they received in describing and evaluating themselves in the context of goal orientations… Demographic information on the participants is provided in Table 1.

Gender	*f*	Subject	*f*
Male	2	Foreign languages	4*
Female	8	Mathematics	1
School		Classroom teacher	4
Kindergarten	3	Turkish	1
Elementary school	4	Kindergarten teacher	1
Secondary school	4	**Teaching experience**	
High school	3	0-5 years	3
		5+ years	7

**: indicates that teachers served in more than one type of school*

Table 1: Demographic characteristics of the participants

Data collection procedures

The data were collected utilizing a semi-structured interview schedule and a questionnaire. The following steps were followed:

1. Teachers (those who actively taught in a school) among the researcher's Master's degree students were identified and they were asked if they would volunteer in the study. Ethical approval was received to conduct the study. The fact that participating teachers were MA students was significant since the study required participants to possess a certain level of cognitive and affective awareness to explore and evaluate a theoretical construct.
2. Those 10 teachers were initially invited to meetings (a total of four meetings) which were held to provide teachers with theoretical information on goal orientations.
3. Teachers were then asked to describe and evaluate themselves in terms of goal orientations. The descriptions that teachers made were then categorized as learning and performance related approaches and presented in Table 2.
4. Face-to-face interviews were held with teachers who evaluated themselves in the context of goal orientations towards teaching. Initial coding was carried out following each interview and additional questions were added to the interview schedule for the following interviews to allow comparisons. This allowed the researcher to conduct reflective investigations.
5. Afterwards, teachers were asked to complete the questionnaire to allow the researcher to collect in-depth information regarding teachers' classroom practices.

Goal orientation	Teacher code
Learning/mastery goal orientation (L-M-GO)	T1, T2, T4, T5, T6
Learning/mastery-performance goal orientation (L-M-P-GO)	T3, T7, T8, T9, T10

Table 2: Teachers goal orientation descriptions

Data collection tools

Two data collection tools were utilized in this study; goal orientations view form and classroom practices view form. Both tools were developed by the researcher.

1. *Goal orientations interview schedule* "Goal Orientations for Teaching Scale" developed by Butler (2007, 2012) was adapted into Turkish by Yıldızlı et al. (2016). The scale included; mastery, ability-approach, ability-avoidance, work-avoidance, and relational categories. Interview questions were prepared considering those factors. Following the preparation of the questions, subject matter experts were consulted to check whether the questions reflected the topic of research and whether they were in line with the theoretical framework and understandable in terms of the language used. Questions were revised and finalized based on experts' comments. During the interviews, probes and prompts were used where necessary in order to gather more detailed answers. Sample interview questions included: (1) *As a teacher, how would you evaluate your learning processes? Can you provide examples? What actions do you take?* (2) *What meaning do you attach to the principal and other colleagues seeing and hearing your success stories? Would you be happy? Would this situation further motivate you in your job? Or does it not matter that others view you as a successful teacher? Can you say that it is not important that they do not realize this situation? What do you think about this?*
2. The other data collection tool utilized in the study was the *classroom practices questionnaire*. This form was utilized to reveal what teachers did in the classroom and what meaning(s) they attached to their practices. Similar to the first tool, experts were also consulted to revise this tool. Sample questions in the questionnaire included: (1) *Are students' levels different in your classroom? If so, what activities do you carry out for lower-level students?* (2) *What do you think about the exams that you prepare?*

Participant	Summary of the interview	Codes
T1	There is not much difference between students' level in my classroom. Nevertheless, differences are observed. Therefore, I try to create an individual learning environment and provide one-to-one support in lectures. Moreover, I do not time exercises for the whole group, instead, I time them individually. While students who complete a given exercise can continue to the next exercise, students who have lower levels do not have difficulties in reaching others; they follow the pace they are comfortable with.	Individual learning Lecture based One-to-one support Individual activity completion times

Table 3: Sample coding chart used in the study

1. Codes in relation to goal orientations	
Third round of coding	**Second round of coding**
1.a. Student-teacher's learning journey	1.a.1. Reasons 1.a.2. Thinking like a student 1.a.3. Lack of knowledge 1.a.4. Seeking solutions 1.a.5. The final outcome
1.b. Situations where teachers show the tendency to avoid work	1.b.1. Reasons 1.b.2. Behavioural patterns 1.b.3. Outcome
1.c. Teachers' relationships with students	1.c.1. Good relationship 1.c.1.1. Indicators of the relationship 1.c.1.2. Outcome of the relationship 1.c.2. Respectful relationship 1.c.2.1. Indicators of the relationship 1.c.2.2. Outcome of the relationship
1.d. Others learning about successes-failures	1.d.1. Success-failure 1.d.2. Others learning about successes-failures 1.d.3. Outcome
2. Codes in relation to classroom practices	
2.a. Taking individual differences into account and classroom learning activities	2.a.1. Classrooms 2.a.2. Processes 2.a.3. Outcome
2.b. Exams	2.b.1. The meaning and importance of exams 2.b.2. Issues focused on in exam papers 2.b.3. Sharing exam scores in the classroom
2.c. Within class comparisons	2.c.1. Importance of scoring high 2.c.2. Emphasis on being the best in academic achievement 2.c.3. Classroom comparison- showing model students
2.d. Making mistakes and supporting efforts	2.d.1. Making mistakes 2.d.2. Supporting efforts

Table 4: The second and third round categories developed in the study

Data analysis

1. The data collected from semi-structured interviews and the questionnaire were transformed into digital files.
2. The sentences that each participant uttered were analysed and coded separately. This was the first round of coding.
3. Following the first round of coding, basic analytic techniques such as summarizing and comparisons were utilized. The rationale was to explore whether there were practice and/or view differences between teachers who had different goal orientations. In order to achieve this, each participant's statements were summarized as a paragraph and the codes attached to their statements were organized into columns. The reason for creating tables was to allow the researcher to scan for patterns in the data, develop theses, and explore different aspects in relation to a given code (Miles, Huberman and Saldaña, 2014). A sample coding relating to the first round of coding is provided in Table 3.
4. The second round of coding utilized the codes which emerged in the first round and those codes were categorized
5. In the third and final round of coding, the categories that were developed were re-coded in line with the questions used. Table 4 includes a detailed map summarizing the data. Please note that the codes that emerged in the first round of coding are detailed in the results. The second and third round codes are not given in Table 4 in order to prevent repetition.

6. The data were organized taking the reported goal orientations of the participants into account (i.e. L-M-GO or L-M-P-GO) to facilitate the process of making comparisons (i.e. finding similarities and/or differences).
7. The processes during which the data were coded are detailed in the present research. At the end of one-on-one interviews, member checks were done in order to confirm the researcher's interpretation of the data. Participants were individuals with whom the author had contact with for a long time and, in return, this helped to establish a friendly environment encouraging honest responses. Last but not least, direct quotations were used to support the interpretations of the researcher.

RESULTS

1. Teachers' emotions, views, and actions in relation to goal orientations they possessed

1.a. Student-teacher's learning journey

All of the teachers participating in the study, as mentioned before, described themselves as learning-focused teachers. In their descriptions, teachers used terms such as "student-teacher", "never-ending student life", and "being a student forever". The researcher deemed "student-teacher's learning journey" appropriate as the higher hierarchical code in relation to those descriptions. The emotions and views teachers had and the actions they took in relation to this topic were coded within this sub-section and presented in Table 5.

	Reasons	Thinking like a student	Lack of knowledge	Seeking solutions	The final outcome
L-M-GO L-M-P-GO	**Individual factors** • Job satisfaction • Technology related factors- Adaptation to the digital age • The desire/need to not repeat themselves • Lack of undergraduate tuition **Factors relating to learning processes** • Heterogeneous classrooms • Not adhering to annual teaching plans • The obligation to know about different methods • Understanding learners • Changes in learners • Technology related factors- Adaptation to the digital age • Unsuitable annual plans • Inconsistencies between theory and practice • Increasing student curiosity and interest	• Trying to learn like students • Questioning what can be done • Not being bothered by learning	**Positive emotions and views** • Not knowing is an advantage • Not knowing is a natural phenomenon • The teacher cannot know everything • Important for doing research and development **Negative emotions and feelings** • Embarrassment from not researching • Sadness from not knowing* • Uneasiness* • Concerns of having too many things to learn* • Sadness for not having learned something before*	• Seeking different teaching approaches • Following platforms • Reading from various sources • Following webinars • Meeting colleagues from different countries • Receiving post-graduate tuition • Receiving help from colleagues • Participation in workshops	• Sharing new experiences with students • Showing that teachers are also learner • Learning with students • Loving to learn • Loving the sharing of ideas • Learning new things is fun • Enjoyment and happiness from learning • Staying updated • Learning how to do valid research • Creative plans • Increase of knowledge accumulation. • Creating a research interest among students • Showing that the teacher is motivated

**: Codes that emerged from the data that teachers who had L-M-P-GO*

Table 5: Student-teacher's learning journey

As can be seen in Table 5, teachers' learning journey was depicted using second-cycle codes such as reasons, thinking like a student, lack of knowledge, seeking solutions, and the final outcome. The reasons that pushed teachers to learn were categorized as individual factors and factors relating to learning processes. Individual reasons and factors relating to learning processes pushed teachers to learn. For example, T1 stated that *"student profile [was] continuously changing… technological factors [were] in the foreground"*. On the other hand, T3 noted that their *"teaching styles changed based on the students. The dynamics of different classrooms could be very different. There could be students who experience learning difficulties [and] some classrooms can be very homogeneous"*. It has been observed that teachers questioned themselves like students and they were not uncomfortable with being in process of meta-cognitive learning where they thought about what they could do. For example, T7 expressed that they *"were aware that [they] had a profession whose responsibility was really high and [they] tried to follow the most recent developments in [their] field"*. T2 noted that they *"tried to think like a student when [they] got prepared for teaching"*.

The analysis of positive and negative emotions and views teachers had during this process indicated that not knowing is a normal situation for teachers and it is what is necessary for doing research and development. In relation to this T1 remarked that they *"considered being able to make up for the areas where they lacked in as an advantage"*. Likewise, T6 noted *"not knowing something felt like a natural process since everything changed so fast"*. And T4 stated their *"self-confidence increased as they learned more"*. It has also been observed that teachers who experienced negative emotions and had negative views were mainly teachers who had L-M-P-GO. Those teachers associated not knowing with emotions and views such as "sadness, embarrassment, concerns of too many things to learn, and sadness for not having learned something before". For example, T3 stated that they *"wished they had learned it before. [They] experienced anxiety and started to think about how [they] would learn all of those"*. Similarly, T7 expressed that they *"felt very sad when they realized that they did not know something"*. The way teachers sought solutions for problems experienced in learning processes were similar. The final outcomes that teachers experienced in relation to learning processes, on the other hand, included both positive and negative expressions. For example: sharing their newly acquired experiences with students; showing that the teacher is also a student; learning with students; the enjoyment happiness and pleasure that learning new things gives; being able to stay updated; increasing knowledge; making creative plans; and so on. For example, T9 reported that *"there were so many things that they learned thanks to them [students]"*. T6 stated that *"learning new things was an enjoyable process. [They] liked trying out the new things [they] learned about and observing the outcomes"*.

1.b. Situations where teachers show the tendency to avoid work

The analysis of Table 6 suggests that there were situations where all teachers avoided work in school/classroom. Second cycle codes included reasons for avoiding work, teacher behaviours in the work environment, and the outcomes. The reasons why teachers avoided work were coded as: redundant tasks to show off; the principal's wish to be popular, the wish to make a name for the school, activities where managers consider their own benefit, activities where the number of participants is important, compulsory group work, compulsory projects, and unawarded works. For example, T2 underlined that *"what decreases [their] energy is being asked to complete redundant tasks and formalities. [They] did not like the word 'project' at all… It disturbed them that principals kept teachers busy so that they could benefit from teachers' efforts. [They] did not want to do the tasks that managers designed considering their own benefit"*. As a result of assigning tasks to teachers on a compulsory basis, teachers become unwilling to participate in projects, avoid expressing their opinions, try to complete a given task as soon as possible, are not able to completely devote themselves to the given task, or do not display behaviours that are aimed to develop group work. The following conclusion is drawn based on teachers' statements: conducting activities in a way that those activities lose their essence, teachers considering what they are asked to do to not correlate with teaching, and forcing and boring students result into ineffective group work. In relation to this, T1 noted that *"there were too many activities in MEB [referring to public schools]. Those activities tired [them] out… Conducting those activities in a way that they lose their essence prevented those activities from serving their purpose. The events were organized as a formality. Students did not participate voluntarily. [They] preferred avoiding compulsory events, both [their] students and [they].*

	Reasons	Behavioural patterns	Outcome
L-M-GO L-M-P-GO	• Redundant tasks to show off • Activities where managers consider their own benefit (concern of losing their positions, the wish to be popular) • Activities where the number of participants is important • The wish to make a name for the school • Compulsory group work • Compulsory projects • Unawarded work	• Unwillingness to participate in projects • Avoiding expressing an opinion • Completing the task as soon as possible • Not being able to completely devote the self to the task • Not displaying behaviours that develop group work	• Completing activities in a way that the activities lose their essence • Considering what they are asked to do to not correlate with teaching • Lack of fair assessment • Pushing students • Boring students • Ineffective group work

Table 6: Situations where teachers show the tendency to avoid work

1.c. Teachers' relationships with students

Table 7 provides information on teachers' views with regards to their relationships with students. Teachers' responses indicated two types of relationship; a good relationship and a respectful one. Indicators of teachers having a good relationship were as following: students not being afraid of the teacher, students becoming happy when they see the teacher, teachers supporting students and, spreading positive energy, voluntary participation in social events, valuing the relationship with students, being able to comfortably express emotions, establishing eye contact, focusing on love, and spending time with students outside the school. In relation to this, T4 stated that they *"preferred that students considered [them] as friends. This way, they [the students] could more easily share their feelings and ideas with them [the teacher]"*. Similarly, T6 noted they *"had relationships with students which were based on love. It was thanks to the relationships [they] established with students that [they] were able to meet with students outside the school frequently"*. A number of positive outcomes of the good relationship with students were reported by the teachers. For example, creating a positive atmosphere in the school, creating a perception that the school is an opportunity, both teachers and students becoming more self-aware, mapping the school as a good entity in students' minds, development of empathy, preparing plans that prioritize feelings and emotions, professional development, preparation for life, students becoming responsible, and decreasing expectations of reward. It is worth noting that few teachers (male and working in high schools) who had L-M-GO underlined that there should be a respectful relationship between teachers and students. T2 expressed the situation with following words: *"[I preferhaving a certain distance with the students… Students do not know where to stop"*. Keeping a distance with the students, concerns of students not knowing their positions, students paying more attention to their behaviours when they encounter the teacher, and students' careful selection of words to use when they talk to the teacher were among the reasons that male high school teachers wanted to have a relationship with students that was found on respect. Those teachers added that such a relationship teaches students how to behave respectfully in society.

	Good relationship	
	Indicators of the relationship	**Outcome of the relationship**
L-M-GO L-M-P-GO	• Students not being afraid of the teacher • Students becoming happy when they see the teacher • Supporting students • Spreading positive energy • Voluntary participation in social activities • Valuing the relationship with students • Trying to directly express themselves • Expressing emotions comfortably • Establishing eye contact • Focusing on love • Being able to spend time with students outside the school	• Creating a positive atmosphere in the school • Creating the perception that school is an opportunity • Becoming self-aware • Mapping the school as a good entity in students' minds • Knowing the students • Trusting the teacher • Preparing students for life • Professional development • Students' development of empathy • Preparing plans that give importance to feelings and emotions • Responsible students • Students who can find solutions to problems • Decreasing expectations of reward
	Respectful relationship	
L-M-GO	• Keeping a distance with the students • Concerns of students not knowing their positions • Students paying more attention to their behaviours when they encounter the teacher • Careful selection of words	• Learning how to behave respectfully in the society • Learning how to respect

**: Teachers who focused on respectful relationship were male teachers who worked in high schools*

Table 7: Teachers' relationships with students

1.d. Others learning about successes-failures

The analysis of codes in Table 8 indicates that teachers described being successful as spreading positive energy, getting students to like the lesson, increasing the trust students have in the teacher, observing that students in the classroom are happy, increases in students' academic achievements, diversifying professional experiences, development of students' ideas, development of humanitarian values among student, receiving positive feedback, establishing parent-school coordination, showing parent responsibility, and sharing professional knowledge with others. In relation to this, T1 expressed: *"Teachers who know their students, help them, and want to spend time with them are successful teachers. Those who enable students to get to know themselves, transform the school atmosphere into a positive one, and spread positive energy are successful"*. Regardless of teachers' goal orientations, all teachers wanted others to know about their successes. Teachers considered that when others know about their successes then those successes become a source of motivation, enable them to be tagged as role-model teachers, develop perceptions of an organized school, increase their sufficiency beliefs, and develop perceptions of a trust source. All those processes create the feelings of enjoyment, happiness, and pride among teachers. In relation to this, T4 expressed they *"would feel happy if they were able to serve as role models to others. That others acknowledged and appreciated [them] pleased [them]"*. Likewise, T8 noted that they *"wanted others to know and respect that [they] did their job good"*. It is understood that teachers want to experience success and want others to know about their successes. The analysis of the failure dimension, on the other hand, suggested that teachers described failure as students' academic underachievement, students being afraid of the teacher, teachers not developing themselves professionally, teachers not loving their jobs, and teachers not receiving positive feedback from their environment. While all teachers wanted others to learn about their successes, none of them wanted their failures to be learned about. Furthermore, teachers perceived that failures demotivate them from doing their job, increase beliefs of inefficacy, and create the image of a bad teacher. Failures result in experiences of sadness, regret and embarrassment. In relation to this, T2 remarked that they *"would become disturbed if others learned about a negative incident that took place between the teacher and students"*. Similarly, T4 underlined that *"unfortunately, [their] love and enjoyment for [their] job would be negatively affected"*.

	Success	Others learning about successes	Outcome
L-M-GO L-M-P-GO	• Spreading positive energy • Getting students to like the lesson • Trust in the teacher • Happy students in the classroom • Increase in academic success • Diversifying professional experiences • Developing students' ideas • Development of humanitarian values among students • Receiving positive feedback • Establishing parent-school coordination • Showing parent responsibility • Sharing professional knowledge with colleagues	• Role-model teacher • Source of motivation • Perception of an organized school • Receiving appreciation • Increasing respect • Increasing beliefs of self-efficacy • Source of trust	• Happiness • Enjoyment • Pride
	Failure	**Others learning about failures**	**Outcome**
	• Students' academic underachievement • Students being afraid of the teacher • Teachers not developing themselves professionally • Teachers not loving their jobs • Teachers not receiving positive feedback from their environments	• Job demotivation • Beliefs of insufficiency • Bad teacher • Not wanting others to learn	• Sadness • Regret • Embarrassment

Table 8: Others learning about successes-failures

2. Findings on teachers' classroom practices

Differences between teachers' classroom practices in terms of their goal orientations are presented in this section. Classroom practices were analysed under the following sub-headings; *(1) taking individual differences into account and classroom learning activities, (2) exams, (3) in-class comparisons, (4) making mistakes and efforts* and *(5) in-class competition*.

2.a. Taking individual differences into account and classroom activities

Table 9 indicated that crowded classrooms were an important factor for teachers in paying attention to individual differences. Regardless of their goal orientations, teachers reported that they grouped students in crowded classrooms based on their levels, in other words, teachers did their teaching based on the level of an average student. Furthermore, some of the teachers with L-M-GO orientations reported that they grouped students as low, medium, and high level groups and did their teaching considering the average level in each group. For example, T1 explained: *"The level of students that I teach are different from one another. On average, a classroom has 45 students. Whilst teaching, I assume that the students have one of the three levels of success; low, medium, or high. And I plan my lesson accordingly"*. Similarly, T9 noted that *"if there are students who have high and low levels of intelligence then [they] would teach the class according to medium level student"*. Teachers with L-M-GO orientations explained that if learning did not occur then they found the solution by providing students with extra-curricular activities (i.e. supporting courses). For example, T1 stated "*I try to find extra-curricular activities for students whose level is low. For this purpose, I opened a course on brain teasers and tried to include those low-level students"*. Teachers with L-M-P-GO orientations, on the other hand, explained that they tried to use various strategies such as re-explaining the topic, giving extra homework, and creating heterogeneous groups of students with different levels to allow peer learning. For example, while T9's solution was to *"ask students who managed to complete the given task to help another student who has not completed the task"*, T10 explained that they *"gave extra homework and checked whether it was done"*. In classrooms that were not crowded, teachers with both goal orientations tried to follow one-to-one instruction. Teachers stated that they gave extra homework, checked students outside the school, and so on.

Additionally, regardless of their goal orientations, teachers reported to have used various methods, techniques, and strategies that supported learning in the classroom. In relation to this, T1 underlined that "*[i]n addition to the texts and activities in the coursebook, [they] included activities such as drama, theatre, and brain teasers which the pupils enjoyed having"* and T10 explained they tried to facilitate learning by *"getting students to play group games, digital word games, and word games in the school yard which aimed to develop students' pronunciation"*.

Taking individual differences into account			
Orientation	**Classroom**	**Process**	**Outcome**
L-M-GO	Crowded classrooms	Grouping students as high, medium, and low level	Teaching the lesson based on this grouping
		Identifying the average student level	Teaching the lesson according to the level of the average student
		If learning has not taken place in the classroom	Out of class activities (i.e. extra courses) and guidance
L-M-P-GO	Crowded classrooms	Identifying the average student	Putting students who have different levels in the same group and allowing peer learning
			Giving extra homework
			Re-explaining up to three times
			Peer-support (enabling students to learn from their peers)
L-M-GO L-M-P-GO	Less crowded classrooms	Supporting individual learning	Allowing lower level students to experience a sense of accomplishment
		One-to-one support	Enabling the realization of individual learning
		Activity completion times based on students' levels	
		Worksheets designed for different level students	
		Utilizing educational technologies	
		Receiving support from the family	
		Extra homework	
		Out of class checks	
Classroom learning activities			
	Giving students the right to select (taking students views into account)		
	Activities that relate to daily life (using the school environment, exemplifications, using analogies)		
	Effective teaching-learning strategies		
	Creating a democratic environment		
	Freedom in completing activities		
	Out of class project tasks		
	Educational games, competitions, drama		
	Cooperation-based activities		
	Development of higher order thinking skills (problem-solving, critical thinking, creativity, and so on)		
	Parent participation		
	Drama practices and utilizing the resulting materials for teaching (i.e. poems, songs, and so on)		

Table 9: Codes on taking individual differences into account and classroom activities

2.b. Exams

The analysis of Table 10 suggests that there were significant differences between teachers' exam practices based on their goal orientations. All teachers, regardless of their goal orientations, perceived the exams to be important tools for teachers and students alike to evaluate their development. For example, T1 stated: *"I consider exams and all types of assessment to be important. This is because such kinds of assessments help not only me [the teacher] but also the students to see their own development and make arrangements accordingly"*. Similarly, teachers with both goal orientations perceived that exams were not sufficient to find out students' development levels and agreed that the whole learning process should be evaluated. To provide an example, T5 noted *"[They] tried to explain [to students] that [the exams] are tools of evaluation so that [the teacher] can see the areas where students need further support with and this was a situation that [the teacher] can compensate for"*. Similarly, T7 underlined *"[They] definitely thought that [they] should evaluate students. Of course, exam scores remain in the background, exams are for observing [students'] development"*. T2 stated *"Evaluation is one of the most important parts of teaching-learning processes; however, [they] did not consider exams to be sufficient to make a judgement about the students"*. The analysis of responses given by teachers suggested that teachers considered evaluating the whole semester, using formative assessment, evaluating the efforts students made in the classroom, and considering individual development reports. While there was no difference between teachers with different goal orientations in terms of the importance and meaning given to exams, differences were observed with regards to teachers' perceptions of whether exam results should be announced in front of all members of a classroom. Teachers with L-M-GO orientation perceived that student scores should not be shared in front of all students in the classroom for various reasons such as the possibility of damaging students' positive emotions, not being ethical, the possibility of causing negative emotions such as jealousy and hostility, and the importance of evaluating each student individually. In relation to this point, T4 expressed they *"did not share exam scores publicly in the classroom… This was extremely important to [the teacher]. It was important to prevent the creation of a competitive learning environment based on exam scores so that students who scored low would not be offended"*. On the other hand, teachers with L-M-P-GO orientations shared the view that exam scores should be announced publicly in the classroom. Their reasoning was based on their perception that it was important to announce the most successful students in a classroom so that they could be appreciated by others in the classroom, and show that success can be achieved by studying hard. Teachers with this goal orientation also expressed that they were fair in scoring exam papers and they wanted to show students that they were fair by sharing the exam scores with the whole class. For example, T10 explained they *"wanted to show them [the students] that one can become successful when they study hard and announced the exam scores publicly in the classroom to show it"*. T9, on the other hand, noted that they *"wanted to make sure they were fair in scoring students' papers since exam scores were important for students. Therefore, they shared scored exam papers with students and wanted students to check whether [the teacher] correctly scored [students'] papers. Moreover, [the teacher] also wanted students to see the mistakes they did (i.e. lack of knowledge, operation mistake, and so on)"*. Additionally, situations that teachers focused on in exam papers were investigated. The results indicated that teachers -regardless of goal orientations- ensured that students were able to realize the mistakes they did in the exam, checked the answers they provided in the exam, identified the areas which they needed further support with, and questioned themselves in an effort to understand why they were not able to correctly answer a problem or question. Few teachers with L-M-P-GO orientations explained that they distributed exam papers to students to confirm that they correctly marked and scored students' papers. T9's above statement is an example of this case. In addition, T3 expressed they *"wanted [students] to realize their mistakes and try to figure out why they might have done it wrong"*.

Orientation	The meaning and importance of exams	
L-M-GO L-M-P-GO	Exams are important tools that show students' development.	A tool for teachers to observe self-development
		A tool to observe student development
		Failing those who make mistakes
		Assessing learning outcomes
L-M-GO L-M-P-GO	Exams are not the only important tool to evaluate student learning.	Assessing the whole semester
		Formative assessment
		Assessing efforts in the classroom
		Supporting exam point of view
		Understanding the areas students need support with and providing that support
		Taking individual development reports into account
		Exams not being able to sufficiently contribute to the process of identifying students' levels
		Taking students' performance into account
		Using homework as a supportive learning tool
		Focusing on the development is important
	Situations focused on in exam papers	
L-M-GO L-M-P-GO	Focusing on mistakes/errors	
	Asking students to check their answers	
	Identifying the areas students need further support with	
	Asking students why they could not do a certain part of the exam	
L-M-P-GO	Confirming that the teacher marked the paper correctly	
	Sharing exam scores in the class	
L-M-P-GO	Exam scores should be shared in the classroom because…	The most successful students should be presented. Being appreciated by other students is important. It is important to show the classroom that the teacher is fair. It is important to show that everybody receives the score they deserved. It is a means to show that the teacher is right. It increases motivation. It is a means to show others that "when you study you succeed".
L-M-GO	Exam scores should not be shared in the classroom because…	It is not ethical to share student scores. It can cause negative emotions such as jealousy, hostility, and so on. Children who had good emotions can suffer. It is important to evaluate each student individually. Exam scores should be explained to students one by one to provide individual support.

Table 10: Teachers exam practices

2.c. In-class comparisons

As can be seen in Table 11, teachers' responses in relation to in-class comparisons were organized under three categories; the importance of scoring high in the exams, emphasis on being the best in academic success, and in-class comparisons and highlighting model students. The data indicated that all teachers considered scoring high in exams meant happiness for teachers and students, and was a source of motivation and a tool for teachers to evaluate themselves. In relation to this, T2 shared they considered *"high scores suggest that the learning activities had been successful. It was also important to [the teacher] since it would increase student motivation which would be worth the efforts"*. Teachers with L-M-P-GO orientations, on the other hand, considered scoring high in exams as an indicator of being a good teacher and proof of student learning. They also perceived it would be a positive source of motivation for other students in the classroom. In fact, few teachers perceived that working harder pays off with high scores and serves as proof for less successful students. What should be emphasized in this respect is the fact that all teachers -regardless of their goal orientations- perceived having high scores would be a source of motivation. For example, T9 explained that they *"felt that [the teacher's] efforts were rewarded when students scored high in the exams"*. Similarly, T8 noted *"the high scores students get from exams indicate that they learned the course content and those who scored lower points are reminded that they need to study harder to make up for the content they did not know well enough"*.

In relation to being the best in academic success, teachers with L-M-P-GO orientations noted the importance of emphasizing the need to be the best. The rationale for this perception was that such emphasis could enable students to go beyond their capacity, and motivate students to exert further efforts in learning. It was also considered as an indicator of being a good teacher. Teachers with L-M-GO orientations, on the other hand, underlined the need to not emphasize being the best. Their rationale was that students should be evaluated individually and such emphasis can damage the relationship between teachers and students. In addition, students should be taught that having humanistic values was more important than academic success. For example, T5 explained they *"believed the way is to appreciate students' efforts to do their best regardless of the outcome. Each student is born with different skills and characteristics"*.

As for in-class comparisons and highlighting model students, teachers with L-M-P-GO orientations considered in-class comparisons and highlighting model students to be important. Their rationale was that it was a source of motivation, allowed appreciation from others, and served as a tool for other students to explore their potential. Teachers with L-M-GO orientations, on the other hand, underlined that such comparisons should not be made. Their rationale was that comparisons decrease the connection between students, negatively affect motivation, disturb other students, ignore individual differences, and disrupt establishing an equal distance between the teacher and each student. This was also considered to prevent individual assessment as well as students' realization of their potential. For example, T5 noted that they *"witnessed the emergence of negative emotions many times [as a result of comparisons]"* and T1 commented that they *"thought [comparisons] negatively impact on the relationships among students which, permanently, could cause them to look for motivation in wrong places throughout their lives"*. The analysis of this dimension clearly indicates that there was a difference between teachers with different goal orientations. These statements are in line with the dimension of being the best in academic success which was covered above. In relation to this, T5 reported they *"had model students in their classroom; however, [they] did not think that it would be right to highlight those students in the classroom. [They] tried to appreciate each and every one of my students and show [their] love to them"*.

2.d. Making mistakes and supporting efforts

The analysis of Table 12 suggests that all teachers associated making mistakes with positive meanings. Teachers considered making mistakes as proof of students trying to complete the given task, a tool for identifying the problem and providing feedback, and a means that show the necessity to use various teaching methods as well as a guide that directs learning processes. The meanings teachers attributed to making mistakes also included; enablers of learning and development, and guides for finding the right answer in a fast way. For example, T1 explained that *"mistakes indicate that students are trying"* and T2 stated *"each mistake is an opportunity. It allows [students] to reach the right answer"*. Similarly, T3 noted that if students make mistakes then *"there was a need to re-consider teaching methods"*.

In relation to supporting student efforts, teachers reported that they followed various practices such as rewarding students, increasing their intrinsic motivation, getting them to like the lesson, doing student-centred activities, allowing students to experience the sensation of success, and trying different methods and techniques. For example, T1 underlined that they *"tried to reward students when they make an effort"* and T2 stated they *"tried to get students to like the lesson… [they] tried to make connections between the lesson and real life, talked about students' interest areas, and used activities that would attract students' attention"*. Some of the teachers with L-M-P-GO orientations reported that they would articulate mistakes to support students' efforts. Those teachers also reported that they would get students to ask for help from their more knowledgeable peers, get them to dream, and talk about the advantages of earning money. For example, T9 stated that they *"would get students to dream about the future and frequently mention the advantages of earning money"*. The teachers were also asked about what sort of expressions they used to support student efforts. The answers included:

T1: *Let's not forget our goals!*

T2: *Do your best, every answer you give does not have to be correct; I want to see your effort.*

T5: *I love you very much!*

T6: *Let's fulfil our responsibilities.*

T9: *If your parents are fulfilling their duties as parents then you have to fulfil your duties as a student.*

	Importance of scoring high in the exams	
Orientation	**Teacher**	**Student**
L-M-GO L-M-P-GO	A tool for teachers to check and evaluate themselves	Source of motivation
	Source of happiness	Source of happiness
L-M-P-GO	Proof of studying harder for those who are less successful	Source of motivation for other students
	Proof of having taught the course content well	Proof of students having learned the course content
	Emphasis on being the best in academic success	
L-M-P-GO	Being the best should be emphasized because…	It is a tool for students to go beyond their capacity.
		It motivates all students.
		It is a tool of exerting efforts.
		It is a proof of being a good teacher.
L-M-GO	Attention should be paid to exerting effort because…	It is important to support students.
		Liking only the successful students is a wrong teacher behaviour (liking students unconditionally)
		Showing students themselves
		People who have humanistic values are successful.
	In-class comparisons- highlighting model students	
L-M-GO	Comparisons should not be made and model students should not be highlighted in the classroom because…	It decreases the connection between students. It negatively affects motivation (unsuccessful students or students who try to become the best). Other students become uncomfortable. It ignores individual differences. It prevents individual assessment. It prevents students from realizing their potential. It prevents the connection between teachers and students being equal for each student.
L-M-P-GO	Model students should be highlighted in the classroom because…	It increases motivation.
		It is appreciated in the environment.
		It enables other students who explore their potential.

Table 11: Teachers' practices on comparing students in the classroom

Orientation	Making mistakes
L-M-GO L-M-P-GO	Proof of trying to do
	A tool for identifying the problem
	Guiding the learning process
	Supportive feedback to mistakes
	The need to utilize various methods
	Enabling learning and development
	Getting students to find out the right answer
	Supporting efforts
L-M-GO L-M-P-GO	Verbal support
	Giving rewards
	Increasing intrinsic motivation
	Getting students to like the lesson
	Student-centred activities
	Allowing the sensation of success
	Self-paced development
	Various methods and techniques
L-M-P-GO	Articulating student mistakes
	Asking help from a more knowledgeable peer
	Getting students to dream
	Talking about the advantages of earning money

Table 12: Teacher practices with regards to making mistakes and supporting efforts

2.e. Competition in the classroom

Analysis of Table 13 suggests there were a mix of positive and negative perceptions with regards to competition in the classroom. Few teachers indicated that ensuring fair competition was impossible and others considered competition to be an obstacle. Nevertheless, they also added that students needed to enter competition since the competition was an indispensable part of life. In relation to this, T2 stated they *"perceived competition as a barrier that prevents students from developing positive relationships with their selves, peers, teachers, and families. However, the culture of competition has become a natural part of life and it is difficult to isolate the classroom from this"*. Some teachers explained that rankings did not matter and competition was not a source of motivation. What was important for those teachers was that students were in a competition with themselves. For example, T1 noted they *"tried not to create a competitive environment for students who could develop negative emotions in a competitive environment"*. Furthermore, few teachers mentioned that team games should be preferred to competitions in the classroom. Teachers with L-M-P-GO orientations, on the other hand, had positive perceptions of having a competition in the classroom. According to those teachers, competitions increase students' hunger for learning, are tools for instigating students with low levels, and tools that activate students. T9 remarked that they *"organized competitions to increase students' motivation in certain topics, or fire low level students up"*. Similarly, T7 explained that *"the feeling of competition allows people to become more open to learning. Students become more motivated"*.

Competition in the classroom		
L-M-GO	Positive	Competition is an obstacle but also an indispensable part of our lives
		Making students compete with their own development
	Negative	Unimportance of ranking
		Creation of negative feelings
		Impossibility of a fair competition
		Preferring team games
		Not being a source of motivation for all students
L-M-P-GO	Positive	Increasing the hunger for learning
		A tool for instigating students with low levels
		Paying attention to use it at a necessary amount
		A tool that activates students

Table 13: Teachers practices with regards to competition in the classroom

DISCUSSION

The results of the study showed that participating teachers defined themselves to be student-centred. They used terms such as "student-teacher" and "being a student forever" when describing themselves. The analysis of the data suggested that there were many reasons for teachers to be involved in continuous learning. Those included; individual, classroom, school, and student-related reasons. Regardless of their goal orientation, teachers expressed that they did not mind the learning journey and underlined they were happy and satisfied for gaining new experiences and being with students as a result of their journey. Learning-centred teachers try to improve their development in both formal and informal educational contexts. Such activities can develop teachers' knowledge and skills (Lohman, 2006) and, at the same time, are related to teachers' goal orientations (Kunst, van Woerkom and Poell, 2018). Teachers who defined themselves as having L-M-P-GO orientations explained that they experienced negative emotions during their learning journeys. They stated that not knowing resulted in situations where they felt "shy" and "upset" because of "the anxiety of having too many things to learn". There were differences in the negative ideas and emotions teachers experienced because of "not knowing". Achievement goal orientation plays an important role in predicting various emotions relating to success. Studies on this topic were conducted with students, school teachers, and university instructors (Rinas et al., 2020). For example, the study Rinas et al. (2020) conducted with university lecturers and studies of Janke and Dickhauser (2019) and Wang et al. (2017) which were conducted with teachers investigated the relationship between educators' emotions and their goal orientations. The results showed that mastery/learning goal orientation was positively correlated with enjoyment. Additionally, Janke and Dickhauser (2019) found that performance-approach goal orientation was negatively correlated with anxiety and shame while performance-avoidance goal orientation was positively correlated with those two emotions. The external standards that teachers with performance goal orientations set for themselves may cause such negative emotions.

It is understood from the literature that individuals who had mastery/learning goal orientations focus on developing their skills (Butler, 2007, 2012; Roeser, Midgely and Urdan, 1997). All teachers in the present study described themselves as making efforts in their journey towards learning. This finding supports the idea that teachers with performance goal orientations can also have positive perceptions towards learning. Related literature indicated that individuals with performance goal orientations had positive perceptions of self-concepts, attitudes, value given to academic studies, making an effort, and meta-cognitive skills (Elliot and McGregor, 1999; Midgley, Arunkumar, and Urdan, 1996; Pajares, Britner, and Valiante, 2000). The meta-analysis study conducted by Payne, Youngcourt, and Beaubien (2007) revealed that there was a low positive correlation between learning and performance goal orientations. Similarly, the study conducted by Retelsdorf et al. (2010) found that while mastery/learning goal orientation was positively correlated with interest in teaching and classroom teaching activities, ability approach goal orientation (among performance-oriented approaches) had a neutral effect and was not a predictor of interest in teaching and classroom teaching activities. Kunst, Woerkom and Poell's (2018) study conducted with teachers revealed that teachers' participation in professional development activities was higher among teachers with high mastery/learning goal orientation, and teachers with high performance orientation and low performance-avoidance orientations were also high. This situation indicates that not only mastery goal oriented teachers but also teachers with various goal orientation combinations have high levels of eagerness for learning and development. Therefore, it can be interpreted that learning for professional development in today's world has become a necessity rather than an option.

The analysis of relationships between teachers who want to develop professionally and their students highlight the importance of this relationship for the success of teaching practices. Previous research concluded that the positive relationship between teachers and students positively affects student participation and academic success, and provides students with socio-emotional support (Butler, 2012; Butler and Shibaz, 2014; Davis, 2003; Roorda, Koomen, Spilt, and Oort, 2011). Teachers who are effective communicators can nurture friendship with students, which positively affect students' perceptions of learning environments (Haralambos and Holborn, 2008). Related research also indicated that teachers' orientations in relation to building social relationships with students were positively correlated with using mastery-oriented teaching techniques (Butler, 2012; Wang et al., 2017) and teaching-related enjoyment (Wang et al., 2017). It was observed that there were teachers -regardless of their goal orientation- who wanted to establish good relationships with students. A noteworthy aspect, however, is that male teachers in the present study who taught in high schools underlined that they wanted to have a relationship with students which was based on respect. This finding can be discussed from various perspectives. It is possible that as they become teenagers, students become more independent and start to focus more on their peers (Roorda, Koomen, Spilt, and Oort, 2011; Hargreaves, 2000) resulting in a more respect-oriented relationship between teachers and students. From another point of view, the gender of the teacher might be the reason for male teachers' focus on respect-oriented relationship. Alternatively, ethnic and cultural identity roles and cultural factors might have an effect on teachers' goal orientations. In fact, recent research suggested that further research should be carried out on goal orientations and gender (Urdan and Kaplan, 2020).

The results indicated that there were instances where teachers avoided work even though they had mastery/learning goal orientations. Those situations included when teachers were given redundant tasks to sow off, compulsory group work where having the high number of participants was the main priority, tasks that were not rewarded, and compulsory projects. A picture where teachers avoid making an effort or try to complete a given task as soon as possible was depicted in relation to tasks given on a compulsory basis. Teachers perceived that neither teachers nor students benefited from such tasks. Work-avoidance is classified as a different goal orientation. The analysis of related literature suggests that work-avoidance goal orientation is associated with abstaining from making an effort, avoiding difficult tasks, having negative attitudes towards given tasks, limited cognitive participation, and boredom (Dowson and McInerney, 2001; Seifert and O'Keefe, 2001). In fact, the analysis of teacher responses suggests that they were bored and avoided tasks which they perceived to be meaningless or which were given as compulsory tasks. It is indisputable that project work is quite advantageous for both students and teachers when it is administered in line with the project goals. However, teachers in this study were found to abstain from participating in projects. In fact, one of the participants clearly articulated their negative feelings towards the word "project" by stating that they did not like the word at all. The review of literature suggests that work-avoidance goal orientation is associated with a lack of perceived meaning and boredom (Dowson and McInerney, 2000; Jarvis and Seifert, 2002; Seifert and O'Keefe, 2001). In this sense, the goals aimed to be achieved are not realized when teachers are asked to undertake tasks they do not like. Whatever task that teachers are given should be meaningful to them and support should be provided to help them undertake the given task. Dickhäuser et al (2020) found that teachers' goal orientations are operationalized as positive feedback culture has a positive correlation with learning goal orientation. Similarly, Janke and Dickhäuser's (2019) research revealed that teachers' learning goal orientations were positively correlated with the school environment where autonomy support was provided or a cooperative climate was present.

One of the practices that the positive feedback culture allows is the feedback given to teachers' successes and/or failures. All participating teachers in the present study wanted their successes to be known and appreciated by others and considered it as a source of motivation. In other words, there was not a much difference between teachers who possessed different goal orientations in terms of wanting their successes being heard by others and wanting to have positive perceptions in their social environment. This suggests that having a positive perception in their social environment is important for teachers. Others knowing about their successes was perceived by teachers as allowing them to be branded as "model teachers", increase their self-efficacy and self-respect, and increase the trust and respect others had in teachers. Having such social needs met is, in a way, a reward. Research has found that such rewards motivate teachers at work, encourage them to work and love their profession, and reveal the difference between those who work hard and those who are lazy (Yıldırım, 2008). Research has also found that teachers wanted their successes to be appreciated and rewarded by the institutions in which they worked (Çelebi, Vuranok and Turgut, 2015). As a result, teachers experience enjoyment, satisfaction, and pride. It has been observed that teachers want a school system where they are supported and rewarded. If such needs are not met, teachers become more inclined to exert work-avoidance behaviour. Additionally, regardless of their goal orientations, all teachers, who wanted their successes to be known by others, were uncomfortable with the idea of their failures being known by others. This suggests successes or failures are not adequately addressed. These results provide further support to the ideathat individuals can possess multiple goal orientations (Hidi and Harackiewicz, 2002), and, for example, while on one hand side they want to increase their knowledge and skills on the other hand they do not want to lose face and, thus avoid actions which have a potential to make them look bad (Gordon, Dembo and Hecover, 2007). From another point of view, thanks to the adaptive effects of goal orientations, individuals who possess different goal orientations may reach the same result by following different strategies. In other words, while mastery/learning goal orientations support individuals through interest, effort and so on, performance goal orientation support individuals through the wish to become successful, both of which render individuals adaptive (Barron and Harackiewicz, 2001).

Achievement goal theory provides a rich framework that allows the explanation of the relationship between teachers' beliefs and classroom structures (Pintrich and Schunk, 2002). The results on taking individual differences into account and classroom practices category suggested that all teachers – regardless of their goal orientations- classified student levels and taught crowded classrooms at a level that was appropriate for an average student. Teachers with L-M-P-GO orientations expressed that they gave extra homework or directed students towards peer learning in cases where learning did not occur. Teachers with L-M-GO orientations, on the other hand, preferred to support learning with extra-curricular activities. If the classroom was not crowded, those teachers also reported that they tried to support students with one-to-one learning. Various characteristics of mastery-structured contexts have been highlighted in the literature; giving students a range of different and authentic tasks, focus on learning and development, creating heterogeneous student groups in terms of knowledge and skills, working with small groups, development-oriented evaluation, and flexible timing. In contrast, performance-structured contexts were characterized as lacking the variety of tasks given to students, students having the tendency to show their knowledge and skills to others, homogeneous student groups, normative assessment, and inflexible timing. When educational contexts are both mastery and performance-oriented, then classroom structures can also be mastery and performance-oriented (Linnenbrink, 2005). While on one hand, the Turkish education system underlines the importance of personal development on the other hand it asks that teaching processes have accountability mechanisms through the use of standardized tests. This, as a result, can create a mix of context combinations that are observed in the classrooms. The analysis of teachers' reported classroom practices suggests that teachers used a range of different methods, techniques, and strategies to support learning. Teachers' practices can be both performance and mastery oriented. That is to say, teachers with mastery/learning goal orientations do not always create mastery structured classrooms. Evaluating this within the context of the Turkey indicates that while the education sytem highlights the importance of development on one hand side, it expects accountability for the learning processes by following standardized tests on the other. Therefore, this can result in combined contexts within the classrooms. The analysis of teachers' classroom activities showed that all teachers (regardless of goal orientations) followed different methods, techniques, and strategies in the classroom.

It has been observed that teachers' practices were similar with regards to making mistakes and supporting efforts. All teachers perceived that making mistakes was a process that supported learning. However, responses provided by a few of the teachers with L-M-P-GO orientations were noteworthy to remark. In fact, teachers with such goal orientations –as explained above- could not sufficiently undertake activities which take individual differences into account when their classrooms were crowded. To support students' efforts, such teachers reported that they explicitly told students about their mistakes, made students to ask for help from more knowledgeable peers, asked students to dream, and talked with students about the advantages of earning money. These bring up the following questions: Is explicitly telling students about their mistakes a supportive feedback? Or does not asking students to get help from more knowledgeable peers increase competition? It was clear that teachers grouped students based on academic success. Since when has learning course content become equal to earning money? Does such discourse really serve the purposes of education which aim to nurture individuals? Should such discourse be used as a tool to motivate students? It is also worth noting teachers also had performance goal orientations. Performance goal orientation prioritizes showing successes to others and becoming better than others (Butler, 2007; Nitsche et al., 2011). And this might result in teachers with performance goal orientations to support such teaching practices.

The analysis of expressions teachers used to support student efforts showed that those statements were superficial and did not include individual solution suggestions. Making mistakes in the classroom and supporting students' efforts is an important part of teaching-learning processes and provide valuable clues to evaluate student learning. Additionally, the feedback provided to students determines the quality of teaching-learning processes. To enable student learning, teachers should provide nutritious feedback to students. None of the general comments made by the participating teachers seemed to provide students with information that would help them increase their performance (Brookhart, 1997).

In the study, participating teachers' perceptions of exams supported the educational contexts dimension. All teachers considered that exams were not sufficient to evaluate students. They, nevertheless, added that exams were still an important part of the evaluation. In relation to sharing exam results in front of students, while teachers with L-M-GO orientations advocated the idea that exam results should not be publicly announced in the classroom, teachers with L-M-P-GO orientations supported the idea that exams can be publicly announced. Teachers in the latter group considered that announcing the most successful students to the whole class not only increased student motivation but also provided teachers with a mechanism to check and show students that the teacher has accurately administered the evaluation criteria. This group of teachers had the tendency to create a classroom environment where what others thought about an individual matter. Related research found that teachers with such orientations take skill differences among students into account, focus on high achievement and follow practices that enable others to observe the achievements (Butler, 2007, 2012; Dickhauser, Butler and Toenjes, 2007). Findings in the category of in-class comparisons also supported results in relation to teachers' exam practices. While teachers with L-M-GO orientation did not approve practices that emphasize being the best, teachers with L-M-P-GO orientations underlined the importance of emphasizing being the best. The former group did not perceive this situation to support learning. However, the perceptions of the latter group were the opposite. Perception differences based on goal orientations included findings that supported each other. While practices such as emphasizing being the best in the classroom or comparing students with one another create a positive effect for students who score high, less successful students are negatively affected by such practices (Patrick, Kaplan and Ryan, 2011). Teachers should take such issues into account when planning teaching activities. How can teachers emphasize being the best when they claim that they focus on personal development? To what extend do they really value personal development? It is clear that teachers with L-M-P-GO orientations undertook activities that were not consistent.

At the same time, emphasis on being the best in the class points to the competition. In the present research, teachers with L-M-GO orientations were indecisive about competition in the classroom and had both positive and negative perceptions on this matter. Teachers with L-M-P-GO orientations, on the other hand, had positive perceptions of competition in classrooms. Indecisive teachers reported that while they did not think that a fair competition possible, students should enter competition since it was an indispensable part of life. Those with negative perceptions considered competition to impede learning and those with positive perceptions treated it as a source of motivation. In fact, the researcher of this study asked participants about the competition without specifying the type of competition (i.e. individual or group). Nevertheless, all participants perceived competition as group competition and gave answers considering exams. It is possible that all teachers attached the same meaning to the term "competition" since they were also brought up and encultured in the same education system. Exams play a central role in the Turkish education system. Exams indicate that there are rankings where the "good" and "bad" are on the radar. And this is reflected as competition in classroom environments. Performance-oriented behaviours and the outcomes of such behaviours can in fact motivate students and teachers towards success in classrooms where normative assessment and social comparison are strongly emphasized (Urdan and Kaplan, 2020), which might be a potential reason why teachers were indecisive.

CONCLUSION

The results of the present study were based on teachers' perceptions. Findings, in general, suggested that along with changes in the dynamics of education systems, behavioural patterns in relation to goal-orientations become more interwoven. Although teachers considered their classroom practices to be sufficient for the student, further research can be carried out to identify how students perceive their teachers' practices. Future research can also investigate the practices of teachers who possess different goal orientations so that more detailed information can be reached in relation to this topic. The present study adopted a qualitative approach. The sample size in qualitative studies depends on the aim of the study and such studies can be conducted with a lower number of participants in order to gain an in-depth understanding of the research topic (Patton, 2002). As such, the present study was conducted with a small number of participants in an effort to gain an in-depth information regarding teachers' goal orientations. As can be seen in the results, insights into participating teachers' behavioral patterns were gained at the end of the research process. Nevertheless, future research can focus on recruiting a higher number of participants in order to understand behavioral patterns of the teacher with different goal orientations. Such research can allow the re-evaluation of the generalized information on goal orientations.

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Full research paper

STUDENTS' UNDERSTANDING OF AXIAL AND CENTRAL SYMMETRY

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ABSTRACT

The paper focuses on students' understanding of the concepts of axial and central symmetries in a plane. Attention is paid to whether students of various ages identify a non-model of an axially symmetrical figure, know that a line segment has two axes of symmetry and a circle has an infinite number of symmetry axes, and are able to construct an image of a given figure in central symmetry. The results presented here were obtained by a quantitative analysis of tests given to nearly 1,500 Czech students, including pre-service mathematics teachers. The paper presents the statistics of the students' answers, discusses the students' thought processes and presents some of the students' original solutions. The data obtained are also analysed with regard to gender differences and to the type of school that students attend. The results show that students have two principal misconceptions: that a rhomboid is an axially symmetrical figure and that a line segment has just one axis of symmetry. Moreover, many of the tested students confused axial and central symmetry. Finally, the possible causes of these errors are considered and recommendations for preventing these errors are given.

KEYWORDS

Axial symmetry, central symmetry, circle, geometrical concepts, line segment, rhomboid

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Highlights

- *Students are persuaded a rhomboid is an axially symmetrical figure.*
- *Students believe a line segment has just one axis of symmetry.*
- *Students prefer a vertical axis of symmetry.*
- *Czech mathematics textbooks do not contain a sufficient number of non-models of symmetrical figures.*

INTRODUCTION

Geometry is an important area of school mathematics that can be difficult for students.[1] Some current critical points of teaching geometry in the Czech Republic have been described by Rendl and Vondrová (2013). Similar problems also occur in other countries (Adolphus, 2011; Mirna, 2018; Geçici and Aydın, 2020). Some of the problems in the current teaching geometry are related to a number of changes that have taken place in the past in our country. The teaching of mathematics changed as a result of the school mathematics modernization between 1965 and 1985 (Tichá, 2013). Jirotková (2017: 154) pointed out that 'the conception of teaching geometry at all levels changed from geometry of speculation to axiomatic structure geometry' in this period and that it caused that 'pupils' ideas of [basic] concepts were often deformed as they were not anchored in the pupil's experience.' In our teaching experience, we also encounter the problematic understanding of basic geometrical concepts in students. Therefore, we have focused on this issue more in-depth.

The analysis of students' understanding of geometrical concepts can be supported by several cognitive theories, the most well-known of which is probably van Hiele's Theory (van Hiele, 1986; Mayberry, 1983). This theory describes the five thought levels of student thinking in geometry, which are commonly called: *visualization*, *analysis*, *abstraction*, *deduction* and *rigor*. Tall et al (2001) look at teaching geometry from the perception of shapes through the manipulation of prototypes of objects to the proof and axiomatic construction of geometry. According to the Theory of Generic Models (Hejný, 2012), students gain abstract knowledge from isolated models through generic

1 In Czech legislation, the terms *pupil* and *student* are distinguished according to age and are not interchangeable. However, for simplicity, we use the term *student* for all age groups in this paper.

models and the whole cognitive process begins with motivation. Hejný (2000) also deals with the term *procept* in geometry, in which two cognitive principles – *pro*cess and con*cept* – are connected. This term, as an expression for a type of high-quality knowledge, was introduced by Gray and Tall (1994), but they did not use it in connection with geometry. The terms *process* and *concept* are related to procedural and conceptual knowledge, which are two key cognitive principles in mathematics education. The first one means an action sequence needed for solving mathematical problems, the second one can be defined as an understanding of the fundamental principles and connections of a particular mathematical domain (Hiebert and Lefevre, 1986; Star, 2005). According to many researchers, these two types of knowledge interact (e.g., Rittle-Johnson and Alibali, 1999; Rittle-Johnson, Siegler and Alibali, 2001; Rittle-Johnson and Schneider, 2015; Vondrová et al, 2015).

As part of our long-term pedagogical research,[2] we deal with students' problems with geometry to improve the training of pre-service mathematics teachers for lower and upper secondary schools. We primarily focused on students' understanding of selected geometrical concepts. We have already examined students' concepts of a triangle (Robová et al, 2019), a trapezoid (Halas et al, 2019), a straight line (Moravcová and Hromadová, 2020) and the rotation of a straight line (Halas et al, 2020). In this paper, we focus on axial and central symmetry in a plane, thus loosely following the contribution (Moravcová et al, 2019) devoted only to axial symmetry and presented during the ERIE conference 2019.

Axial and central symmetry are special types of isometries. Axial symmetry in a plane given by a straight line (the axis of symmetry) is also called reflection/mirror symmetry/line symmetry, etc. Central symmetry in a plane (also point symmetry, point reflection, etc.) is a special case of rotation in a plane by 180° around a centre point.[3] It can also be composed of two axial symmetries with orthogonal axes. Czech students first become acquainted with axial symmetry in primary school. According to the national curriculum (Ministry of Education, Youth and Sports, 2017: 33), a student at the end of the 5th grade is able to 'recognize and draw a simple axially symmetrical figure on a square mesh and determine the axis of symmetry by folding a paper in its place'. By the end of the 9th grade (lower secondary school), a student is able to 'draft and construct a plane shape in a point symmetry and to determine an axially symmetrical shape' (Ministry of Education, Youth and Sports, 2017: 36). Translation and general rotation are taught at upper secondary school (Ministry of Education, Youth and Sports, 2007). These curricular requirements are usually reflected in the contemporary Czech mathematics textbooks. In the Czech Republic, all these isometries are taught with emphasis on their geometric meaning and visualization.

Many researches of the students' and pre-service teachers' knowledge have focused the isometries. Some of them have dealt with the comparison of all isometries. The results suggest that rotation is the most difficult of them; axial symmetry is the easiest (Ada and Kurtuluş, 2010; Hollebrands, 2004; Xistouri and Pitta-Pantazi, 2011). Several studies have highlighted frequent misconceptions such as: confusing axial and central symmetries (Son, 2006; Jagoda, 2008); problems with constructing a mirror image in axial symmetry with an oblique axis of symmetry (Jagoda, 2008); problems with finding the axis of symmetry correctly (Hacısalihoğlu-Karadeniz et al, 2015; Kaplan and Öztürk, 2014); and incorrect identification of a figure that is not axially symmetrical as an axially symmetrical one, e.g., a rhomboid (Son, 2006; Aktaş and Ünlü, 2017; Hacısalihoğlu-Karadeniz et al, 2015; Leikin, Berman and Zaslavsky, 2000). Aktaş and Ünlü (2017), Herendiné-Kónya (2008) and Hollebrands (2004) pointed out the problems that students of different ages have with constructing a simple planar figure in central symmetry. According to several research studies (e.g., Fryer and Levitt, 2010; Wang and Degol, 2017), males tend to be more successful in mathematics, especially in geometry. However, Kambilombilo and Sakala (2015) dealt with gender differences in the area of isometries and found out that there were no significant differences between males and females.

Some researchers have pointed out that students can achieve a better understanding of isometries with support of the education process by appropriate software, especially dynamic geometry computer programs (e.g., Ada and Kurtuluş, 2010; Köse and Özdaş, 2009; Hollebrands, 2004; Lobato and Ellis, 2002). The chosen procedural methods in teaching also have a significant influence on the quality of teaching (Jagoda, 2008; Herendiné-Kónya, 2008). Therefore, paying attention to the quality of the training of pre-service teachers is also important. Many studies have shown that pre-service teachers focus mainly on procedural knowledge and are not able to develop students' conceptual knowledge; moreover, they themselves do not have sufficient conceptual knowledge. In the training of pre-service teachers, emphasis should also be placed on conceptual knowledge (Shulman, 1986; Hacısalihoğlu-Karadeniz, Kaya and Bozkuş, 2017; Son, 2006; Thaqi, Giménez and Rosich, 2011).

In our pedagogical practice, we also encounter the above-mentioned problems (confusing axial and central symmetries, problems with the finding of all axes of an axially symmetrical figure, identification of an axially asymmetrical figure, etc.). Therefore, we focused, among other things, on monitoring these phenomena in our large-scale testing. Specifically, we were interested in three problems concerning axial symmetry and one problem concerning central symmetry:

- Do students recognize that a rhomboid is not an axially symmetrical figure?
- Are students able to find all symmetry axes of a line segment?

2 The research team consists of members of the Department of Mathematics Education, Faculty of Mathematics and Physics, Charles University, who are the authors of this paper.

3 More precisely, by $180° + k \cdot 360°$, where k is an integer.

- Do students know that the number of symmetry axes of a circle is infinite?
- Are students able to construct an image of a given figure in central symmetry?

According to mentioned research studies and our pedagogical practice, given topics are problematic for school mathematics and students do mistakes in these fields. We have also dealt with the achievement of students from different types of schools, the success of pre-service teachers and gender differences.

First, the paper presents the methodology of our testing. In the Results section, the statistical analysis of testing results is presented and the most important findings are pointed out. These findings are subsequently discussed in detail in the Discussion section. This section also introduces other interesting students' solutions and considers the possible causes of frequent errors. Last but not least, our conclusions are compared with other previous research. The Conclusion section briefly summarizes the most important results, answers the questions asked from the point of view of our research, suggests some recommendations for teaching mathematics and outlines the direction of our further research in this area.

MATERIALS AND METHODS

Our long-term empirical research into students' understanding of geometrical concepts combines quantitative (didactic testing of a large sample of respondents and statistical data processing) and qualitative methods (use of semi-structured interviews and in-depth analysis of students' opinions and errors).

In the first phase, we prepared three didactic tests for students of different ages: Test I for ISCED I graduates, Test II for ISCED II graduates, and Test III for ISCED III graduates and university students. The test tasks were focused on concepts from the field of planar geometry with emphasis on the concepts that students typically struggle with, according to our teaching experience. The tests were designed so that it was possible to monitor how students of all ages cope with the same or similar task (i.e., Test II is an extension of Test I and Test III is an extension of Test II). Formulations of the test tasks were based on commonly used textbooks and complied with the Czech national curriculum (Ministry of Education, Youth and Sports, 2007, 2017).

The clarity of the tasks and the time limit for solving each of three tests were first verified in the form of pre-tests with small groups of respondents. In addition, researchers conducted semi-structured interviews with several randomly selected students about their solutions in order to verify whether and how the students understand the questions, how they think about the solutions, whether they consider other answers to closed questions than those offered, etc. The original tests were then modified based on these pre-tests.

In this paper, we deal with axial and central symmetries in a plane. These symmetries were monitored in two test tasks which did not need to be modified after the pre-tests. One task in each of the tests was devoted to axial symmetry. We asked students to determine the number of symmetry axes of the three figures shown. The given figures were an isosceles triangle in Test I, a circle in Tests II and III, and a rhomboid and a line segment in all the tests (Figures 1 and 2). All the figures were placed in a square grid. In addition to indicating the number of axes, students could also draw axes in the pictures.

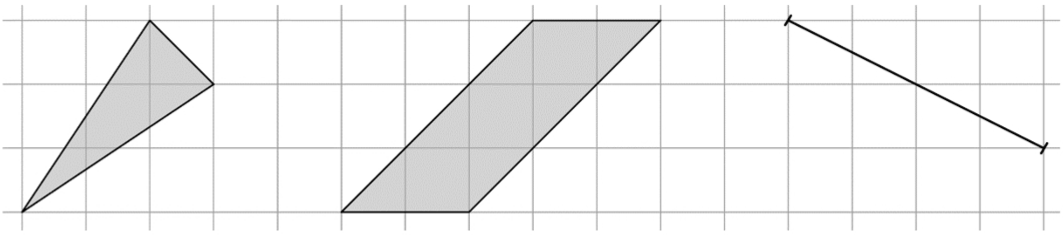

Figure 1: Given figures in task on axial symmetry in Test I (source: own data)

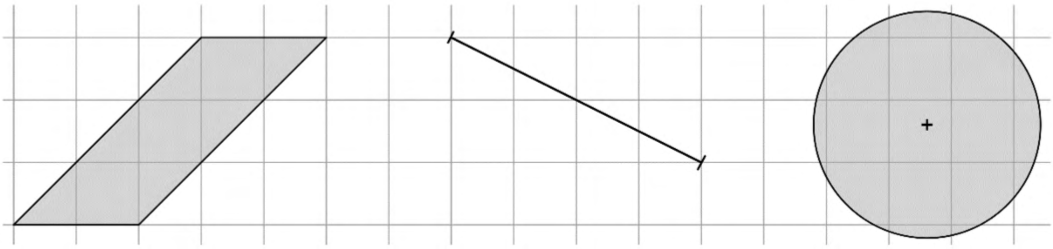

Figure 2: Given figures in task on axial symmetry in Tests II and III (source: own data)

In accordance with the Czech curriculum, it was possible to include central symmetry only in Tests II and III. We asked students to draw an image of a given pre-image in the central symmetry in a square grid. The pre-image in Test III (Figure 3, right) was slightly more complicated than the one in Test II (Figure 3, left), but they were quite similar. Vertices of the given pre-image and the centre point S of symmetry were placed in lattice points in both tests.

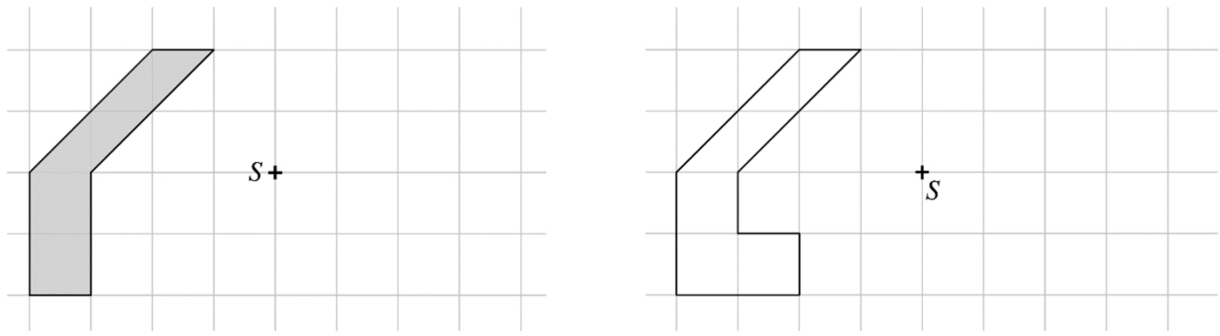

Figure 3: Given pre-image in task on central symmetry in Test II (left) and Test III (right) (source: own data)

The tests were administered to 1,458 Czech students who were selected on the basis of their availability. Test I was assigned to students of the first grade of lower secondary education (ISCED I level), Test II was assigned to students about to move from lower to upper secondary education (ISCED II level), and Test III was assigned to students about to move from upper secondary education to university (UNI) education (ISCED III level), and the pre-service teachers (PSTs) in their last two years of studies. The tests were solved anonymously; we registered only the gender of the respondents and the type of school – Tests I and II were solved by both basic school (BS) students and students of the corresponding grades of general secondary schools (GSS)[4] (Table 1). All tests were personally administered by one of the research team members to ensure equal conditions. Students were encouraged to read the assignment carefully.

Test	School type and grade (number of students)	M	F	Average age of students	Testing period	Total
I	6th grade of BS (177)	225	280	11	2017 Sept.–Oct.	505
	corresponding grade of GSS (328)					
II	9th grade of BS (180)	231	206	15	2018 Apr.– June	437
	corresponding grade of GSS (257)					
III	last grade of GSS (311)	291	225	19	2018 Apr.	516
	1st year of UNI (161)				2017 Oct.–Nov.	
	PSTs, i.e., 4th and 5th years of UNI (44)			22–23		
Total						1,458

BS = basic school, GSS = general secondary school, UNI = university, PSTs = pre-service teachers, M = males, F = females

Table 1: Overview of tested students (source: own data)

Students' solutions were coded for the purpose of evaluating the tests. In the task on axial symmetry (Figures 1 and 2), students' answers regarding the number of axes were coded with the corresponding numbers, including *0* for the answer "no axis". The code *inf* was used for the answer "infinite". In the task on central symmetry, the code *OK* was used for the correctly drawn image; the code *cs* was used when a student used the central symmetry, but he/she made an error and the image drawn was not congruent with the pre-image; the code *as* was used when a student drew the image in an axial symmetry; and the code *t* was used when a student drew the image in a translation. If a student did not provide any solution, the code *MA* (missing answer) was used.
The completed tests were naturally divided into groups according to the grade levels and type of schools of the respondents. The tests from every group were coded independently by various pairs of researchers. Any discrepancy in the coding of a specific student's solution was discussed among the whole research team until a consensus was reached.
The data obtained were subsequently statistically processed: tables of frequencies, relative frequencies, and for some pairs of characters contingency tables were also created. The χ^2 test (at a significance level of 0.01, unless otherwise stated) was primarily used to determine the various dependencies. Moreover, Fisher's exact test was used in cases where the input conditions for the χ^2 test were not met, or the χ^2 test worked out only at a significance level of 0.05.
In addition to the presented statistics of students' solutions, we also focused on a deeper analysis of students' errors, their thought processes and possible causes of some misconceptions. For this purpose, we analysed, among other things, the results obtained with respect to commonly used Czech textbooks, in which we look for the causes of frequent

4 Czech elementary education takes nine years, usually from the ages of 6 to 15. Students typically attend a regular 9-year basic school, which is divided into two stages: primary and lower secondary stages. In addition, they have the option to apply to a 6- or 8-year general secondary school, which is a school with an entrance examination, after their 5th or 7th grade of elementary education. Students can also graduate from basic school and then continue their studies at a 4-year general secondary school or another type of upper secondary school. General secondary school graduates usually continue their studies at university. For a scheme of the Czech education system see, e.g., (Pont et al, 2013: 18).

errors. We analysed four series of textbooks for primary education (published by Alter, Prometheus, SPN[5] and Fraus), four series for lower secondary education including a special one for general secondary school (Prometheus for GSS, Prometheus for BS, Prodos and Fraus), and three series for upper secondary education (Prometheus, Didaktis and Fraus). In the textbooks, we focused mainly on the use of concept models, emphasis on prototypical positions of figures and the occurrence of tasks similar to those of our tests.

RESULTS

This section presents statistical overviews of student solutions to individual test tasks which were presented in the previous section. First, the overall success rate is introduced for each question. Furthermore, the most common student misconceptions and interesting answers are pointed out. Subsequently, the successes of groups of students differentiated according to school type and gender are compared.

In the tables with overviews of students' solutions (Tables 2–6), the mathematically correct answer is always given in the first column. The numbers of occurrences of individual solutions are given in relative frequencies. The column labelled *OA* (Other Answer) always combines responses with low to negligible frequencies. The abbreviations BS (basic school), GSS (general secondary school), UNI (university) are used for the individual school types in the tables. Moreover, abbreviations PSTs (pre-service teachers in their last two years of studies), M (males) and F (females) are used.

Axial symmetry – an isosceles triangle

The question on the number of symmetry axes of a given isosceles triangle was included only in Test I (Figure 1). The total success rate of students was high; the correct answer was given by more than 60% of respondents (Table 2).

		1	0	2	3	*OA*	*MA*
Test I	*BS*	29.94	5.08	14.69	20.90	10.17	19.21
	GSS	76.83	8.84	4.88	3.35	1.22	4.88
	M	57.78	8.89	6.67	9.78	5.78	11.11
	F	62.50	6.43	9.64	9.29	3.21	8.93
	Total	60.40	7.52	8.32	9.50	4.36	9.90

Table 2: Isosceles triangle – relative frequencies of students' answers (source: own data)

Many students did not solve the task at all (almost 10%). The most common incorrect answer was that the isosceles triangle has 3 axes of symmetry. This answer and missing answer were given mainly by BS students (about 20% in both cases). The dependence of the correct answer and the type of school that a student attends was verified by a χ^2 test. Test criterion K was significantly higher (105.655) than the critical value of 6.635 on the significance level of 0.01. Therefore, the null hypothesis that the correct answer and the school type do not depend on each other was rejected. On the other hand, no significant statistical difference between males and females was found in this task.

Axial symmetry – a rhomboid

In the case of determining the number of symmetry axes for a given rhomboid, which was included in all three tests (Figures 1 and 2), the percentage of correct answers increased with age in our testing (Table 3). Conversely, the number of the most frequent incorrect answers ("2" and "4") decreased with increasing age, just as did the number of students who did not solve the task.

		0	1	2	4	*OA*	*MA*
Test I	*BS*	7.91	5.65	21.47	32.20	14.69	18.08
	GSS	41.46	10.67	24.70	12.20	5.49	5.49
	M	32.44	7.11	24.89	15.11	9.33	11.11
	F	27.50	10.36	22.50	22.50	8.21	8.93
	Total	29.70	8.91	23.56	19.21	8.71	9.90
Test II	*BS*	25.56	9.44	20.56	26.11	6.11	12.22
	GSS	52.53	12.06	15.95	12.45	3.89	3.11
	M	40.26	9.09	18.18	18.61	5.19	8.66
	F	42.72	13.11	17.48	17.48	4.37	4.85
	Total	41.42	10.98	17.85	18.08	4.81	6.86
Test III	*GSS*	56.27	12.22	17.68.	8.68	3.22	1.93
	UNI	50.93	13.66	16.15	12.42	3.11	7.45
	PSTs	61.36	20.45	13.64	2.27	0.00	2.27
	M	54.98	11.68	18.56	7.56	3.09	4.12
	F	55.11	15.56	14.67	8.89	2.67	3.11
	Total	55.04	13.37	16.86	8.14	2.91	3.68

Table 3: Rhomboid – relative frequencies of students' answers (source: own data)

5 SPN – State Pedagogical Publishing House, in Czech: Státní Pedagogické Nakladatelství.

We observe a higher success rate of GSS students than BS in Tests I and II. In both cases, the dependence of the correct answer and the type of school was again proved by a χ^2 test ($K = 61.987$ in Test I, $K = 31.74$ in Test II). In Test III, PSTs were the most successful (Table 3), but the dependence of the correct answer on the group of students is not statistically significant.

No statistically significant gender differences were generally demonstrated in this task in the whole sample. However, Fisher's exact test showed a statistical dependence in favour of males (the two-tailed p-value equals 0.0118) in Test I in the BS group.

In Test I, we were able to further investigate how individual students attempted to solve the number of axes of the isosceles triangle and the rhomboid, thus with the axial symmetry properties of two different polygons. The χ^2 test pointed out a strong dependence between the correct solutions in both tasks (test criterion $K = 100.737$, which is significantly higher than the critical value). The results showed a significant connection exists (Moravcová et al, 2019).

Axial symmetry – a line segment

The number of symmetry axes of a given line segment was also included in all three tests (Figures 1 and 2). The success rate of students in this task was relatively low and increased only slightly with age; it reached approximately 26% in Test III (Table 4). However, with increasing age, the number of the most frequent incorrect answers, i.e., "1" axis of symmetry, also increased. It is also worth noting that in Test I, 14% of respondents answered that the line segment has no axis of symmetry.

In the task on the line segment, we again observe a higher success rate of GSS students than BS ones in Tests I and II (Table 4). In Test I, the relationship between choosing the correct answer and the group was demonstrated by the χ^2 test ($K = 13.97$). In Test II, this dependence was not statistically significant. PSTs were the most successful in Test III again. According to Fisher's exact test, the relationship between this group and the correct answer is statistically significant (p-value = 0.0497).

		2	0	1	4	*OA*	*MA*
Test I	*BS*	14.12	23.16	32.20	6.21	4.52	19.77
	GSS	28.96	9.15	52.44	0.91	3.35	5.18
	M	25.78	16.00	40.89	3.56	2.67	11.11
	F	22.14	12.50	48.93	2.14	4.64	9.64
	Total	23.76	14.06	45.35	2.77	3.76	10.30
Test II	*BS*	22.22	6.67	51.11	2.22	6.11	11.67
	GSS	25.68	4.67	61.48	0.00	5.84	2.33
	M	25.54	6.93	54.11	0.43	5.63	7.36
	F	22.82	3.88	60.68	1.46	6.31	4.85
	Total	24.26	5.49	57.21	0.92	5.95	6.18
Test III	*GSS*	25.08	1.29	66.88	0.96	3.86	1.93
	UNI	24.22	3.73	66.46	0.00	0.62	4.97
	PSTs	38.64	4.55	56.82	0.00	0.00	0.00
	M	30.93	1.03	62.89	0.34	2.06	2.75
	F	19.56	4.00	69.78	0.89	3.11	2.67
	Total	25.97	2.33	65.89	0.58	2.52	2.71

Table 4: Line segment – relative frequencies of students' answers (source: own data)

In all three tests, males were more successful (Table 4). However, a statistically significant dependence of the correct answer in favour of males was demonstrated only in Test III (the test criterion K of χ^2 test equals 8.54).

Axial symmetry – a circle

Students were asked about the number of symmetry axes of a given circle in Tests II and III (Figure 2). This task was the most successful overall (Table 5). The most frequent incorrect answers were "0", "1", "2" and "4" axes of symmetry.

		inf	0	1	2	4	*OA*	*MA*
Test II	*BS*	51.67	10.00	8.89	5.00	1.67	6.11	16.67
	GSS	88.72	1.95	3.50	0.00	0.78	1.56	3.50
	M	73.59	4.76	7.36	0.87	0.43	3.46	9.52
	F	73.30	5.83	3.88	3.40	1.94	3.40	8.25
	Total	73.46	5.26	5.72	2.06	1.14	3.43	8.92
Test III	*GSS*	86.50	1.61	2.57	3.22	0.96	2.25	2.89
	UNI	85.09	2.48	1.54	1.54	0.00	1.54	6.83
	PSTs	97.73	0.00	0.00	2.27	0.00	0.00	0.00
	M	89.00	2.06	1.03	3.09	1.03	1.03	2.75
	F	84.44	1.33	3.56	2.22	0.00	3.11	5.33
	Total	87.02	1.74	2.13	2.71	0.58	1.94	3.88

Table 5: Circle – relative frequencies of students' answers (source: own data)

In Test II, GSS students were again more successful than BS ones. The χ^2 test confirmed the significant dependence of the school type and the choice of the correct answer. In Test III, PSTs were the most successful with a result of almost 100%. Only 1 student of this group wrote that the circle has only 2 axes of symmetry. The dependence of the answer on the type of study was also statistically confirmed in this group (χ^2 test criterion K = 4.88 is higher than the critical value 3.841 on the significance level of 0.05 and the two-tailed p-value of the Fisher's exact test equals 0.02).

There were no statistically significant differences between males and females in this task in total. A slight difference in favour of males was observed only in the GSS group.

Central symmetry

In the last monitored task, students were asked to draw an image of a given pre-image in the central symmetry in a square grid (Figure 3).

		OK	cs	as	t	OA	MA
Test II	*BS*	38.33	5.00	40.00	5.00	1.67	10.00
	GSS	48.25	5.45	35.02	4.67	2.33	4.28
	M	45.02	6.49	35.50	3.90	0.87	8.23
	F	43.20	3.88	38.83	5.83	3.40	4.85
	Total	44.16	5.26	37.07	4.81	2.06	6.64
Test III	*GSS*	67.85	2.25	28.61	0.32	0.32	0.64
	UNI	67.08	2.48	29.19	0.00	0.00	1.24
	PSTs	86.36	0.00	11.36	0.00	0.00	2.27
	M	73.20	2.06	23.37	0.00	0.34	1.03
	F	64.00	2.22	32.44	0.44	0.00	0.89
	Total	69.19	2.13	27.33	0.19	0.19	0.97

Table 6: Central symmetry – relative frequencies of students' solutions (source: own data)

The image was drawn correctly by almost 45% of students in Test II and almost 70% of students in Test III (Table 6). The most frequent error was using a different isometry. The substitution of an axial symmetry (code *as*) predominated. Almost 5% of respondents in Test II used a translation (code *t*). GSS students were more successful in Test II. The χ^2 test confirmed the statistical dependence of the school type and the correct solution only on the significance level of 0.05, so the dependence was also verified by Fisher's exact test (p-value = 0.0407). In Test III, PSTs were again the most successful and the dependence was confirmed here by χ^2 test (K = 6.6576).

In Test III, there was a statistically significant dependence of the correct solution on gender in favour of males (for all respondents, the χ^2 test comes out only on the significance level of 0.05, however, the two-tailed p-value of the Fisher's exact test equals 0.0272). Nevertheless, this result was affected by the results of the GSS group (only for this group, the χ^2 test criterion K equals 17.177). In Test II, males were slightly more successful, but no statistically significant difference was observed.

DISCUSSION

First, we analyse the results of students in individually presented tasks with respect to the research questions asked. Then we will think about the issue of gender and the difference between BS and GSS students.

Do students recognize that a rhomboid is not an axially symmetrical figure?

We asked all the age groups of students tested about the number of symmetry axes of a given rhomboid. In Test I, we observe a high number of incorrect answers. This number decreases with increasing age. Nevertheless, 45% of students did not successfully solve the task in Test III. Here we can observe a misconception: 'a rhombus is an axially symmetrical figure.' Even worse results in research into the same problem were obtained by Aktaş and Ünlü (2017), who found that only 6.4% of respondents described a rhomboid as an axially asymmetrical figure.

Many students drew axes of symmetry in the picture (Figure 4). Thanks to this, and also from interviews from the pre-test, we know that the symmetry axis of the rhomboid is most often considered a horizontal median (those who answered "1" axis of symmetry), both medians (those who answered "2" axes of symmetry), or medians and diagonals (those who answered "4" axes of symmetry). Answer "2" was generally one of the most frequent incorrect answers, as in other research (Aktaş and Ünlü, 2017; Son, 2006). Leikin, Berman and Zaslavsky (2000) also encountered medians as the axes of symmetry of a rhomboid.

One of the possible causes of these errors, especially in Test I, is the fact that the medians or diagonals divide the rhomboid into two identical figures. A task such as being asked to divide a given figure into two identical ones by a straight line is common in primary school. Hacısalihoğlu-Karadeniz et al (2015) also encountered this reasoning among pre-service teachers. Another reason for the errors in Test I may be the fact that students rarely encounter non-models while they are getting acquainted with axial symmetry at school (Hejný, 2012). In addition, a rhomboid is specific in that it is a non-model of an axially symmetrical figure as well as a model of a centrally symmetrical figure. In our opinion, students should encounter figures such as these while in primary education, i.e., at the time when they first encounter axial symmetry in school. However, we did not find a rhomboid or another figure

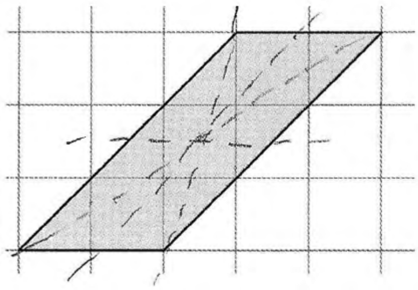

Figure 4: Four "symmetry axes" of the given rhomboid, student's incorrect solution (source: own data)

with these properties in the given context in the analysed textbooks for primary school. It appears only in textbooks for the next level of education but not with sufficient emphasis; the exception is the textbook (Vondra, 2013). The fact that students work more with a rhomboid in lower and upper secondary schools is probably why students were more successful in Tests II and III at this task.

Students who tried to complete the axes of symmetry proceeded to solve the problem procedurally. While this led some of them to find the correct solution, relying on procedural methods rather than conceptual understanding can lead to the incorrect solution (Son, 2006).

For comparison, in Test I, students were also asked about the number of symmetry axes of an isosceles triangle, which is a model of an axially symmetrical figure which is found in all the analysed textbooks. This task had a significantly higher success rate (more than 60%) than the task about the rhomboid (less than 30%). Students might have been confused that the triangle was not placed in a prototypical position (i.e., with a horizontally placed base). The most common incorrect answer was "3" axes of symmetry; students likely confused an isosceles triangle with an equilateral one. According to several researches (Tirosh et al, 2011; Budínová, 2018) students' concept of a triangle is associated with an equilateral one in a prototypical position. The picture in our test was contrary to the students' experience. The confirmed dependence of the correct answers in the test task on the number of symmetry axes of the given triangle and rhomboid in Test I indicates that students who solved the task about the rhomboid have a strong concept of axial symmetry.

Are students able to find all symmetry axes of a line segment?

The task on the number of symmetry axes of a given line segment seems to be problematic. The low success rate confirmed our assumption that the task was atypical for students. According to our analysis of textbook series, students usually encounter only 2D figures as examples of axially symmetrical figures in Czech primary school textbooks. This is probably the reason why over 10% of students did not solve the task at all in Test I. Even at higher education levels, it is a common task to construct the image of a line segment, straight line or half-line in axial symmetry, but not to find the symmetry axis/axes of these figures. In the analysed textbooks, we found only one task with a similar topic (Figure 5) in the exercise book (Gazárková, Melicharová and Vokřínek, 2013) for upper secondary school. We are not aware of any other research concerning this problem.

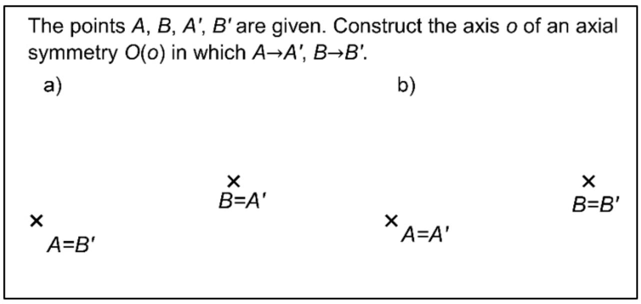

Figure 5: Task from a Czech exercise book, free translation (source: Gazárková, Melicharová and Vokřínek, 2013, p. 140)

Students often stated that the line segment has "1" axis of symmetry. The number of these responses even increased to almost 66% in Test III. The answer "1" is offered because students from the primary school encounter the term *axis of a line segment*. The axis of a line segment is a straight line which is perpendicular to the line segment and passing through its midpoint. Each line segment has exactly one axis, but two axes of symmetry. The difference between the *axis of a line segment* and the *symmetry axis of a line segment* (Figure 6) then disappears in students' minds. This confusion of two different concepts can be unhappily supported in the educational process by formulations/questions from textbooks such as the following: 'Is the straight line *o* [perpendicular to the centre of the line segment] the axis of symmetry of the *AB* line segment?' (Odvárko and Kadleček, 2011: 36).

Despite the low number of correct answers, we were pleased that about 25% of students did not let themselves be fooled and thought about the problem. We know from the pre-test interviews that they were often unsure of the correct answer "2", but they were able to think about the concept of axial symmetry and consider different answers. Some of them supplemented their answer with comments such as: 'Theoretically 2, if a straight line is its own axis of symmetry.'

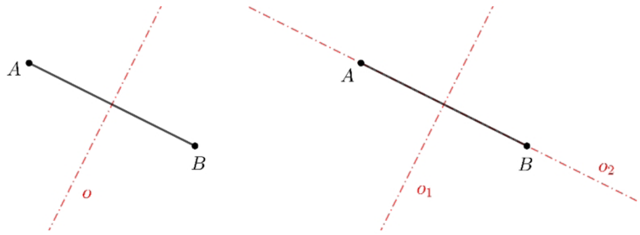

Figure 6: Illustration of the difference between the axis (left) and the symmetry axes (right) of the line segment *AB* (source: own picture)

With regard to the cognitive development of students, we do not perceive it as a problem that a large number of students in Test I were unable to solve this atypical task. The problem is that the relative number of correct answers hardly changed in Tests II and III. On the contrary, the misconception that a line segment has only one axis of symmetry clearly strengthened with increasing age (45% in Test I, 57% in Test II, 66% in Test III). This may indicate a misunderstanding of the concept of axial symmetry. Unfortunately, this error was also made by pre-service teachers.

Do students know that the number of symmetry axes of a circle is infinite?

The task on the number of symmetry axes of a circle is a standard task, found in almost all the analysed textbooks. Even so, we are not aware of a similar study that has dealt with this problem. We assumed we would observe the misconception 'a circle has only two axes of symmetry (horizontal and vertical)', which we encountered in our practical teaching experience; but it was not confirmed here. The answer "2", as well as other incorrect answers, was chosen by only a small number of the respondents. However, based on the student sketches in the tests, we can say that those who chose the answer "2" actually considered the vertical and horizontal axes of symmetry. In the case of the answer "1", students preferred the vertical axis; in the case of answer "4", they moreover considered the axes forming a 45°-angle with the horizontal/vertical straight line (Figure 7).

According to 10% of BS students in Test II, the given circle is not an axially symmetrical figure – they wrote that it has "0" axes of symmetry. However, this idea probably disappears with increasing age; it was stated by less than 2% of respondents in Test III.

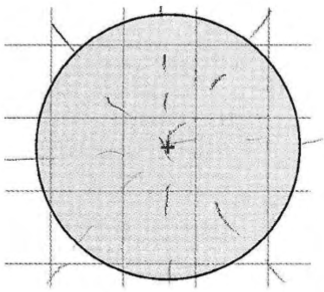

Figure 7: Four symmetry axes of the given circle, student's incorrect solution (source: own data)

There were also isolated interesting opinions in the tests; e.g., "360", which is probably related to the degree size of the full angle. Some students did not answer the given question exactly, but their answer was very precise from a mathematical point of view: '[symmetry axes of the given circle are] all straight lines that pass through the centre of the circle'.

Are students able to construct an image of a given figure in central symmetry?

Very similar figures were assigned in Tests II and III in the task on central symmetry (Figure 3). Students were asked to draw their images in central symmetry with the given centre *S*, with the help of a pre-drawn grid (the vertices of the figure and the centre of symmetry were grid points).

About 44% of Test II respondents and almost 70% of Test III respondents solved the task correctly, which is a very nice result. Several other students worked correctly with the concept of central symmetry, but they made more significant inaccuracies and did not draw the identical figure (the code *cs*). Aktaş and Ünlü (2017) obtained worse results in 8th grade students in a similar study; only 36% of students drew the image of the given simple pre-image in a central symmetry correctly or almost correctly.

One specific situation (the code *as*) significantly dominates among the incorrect solutions: students drew a vertical axis in the picture and constructed an image of the given figure in axial symmetry. In the vast majority of cases, they drew this axis passing through the given point *S* (Figure 8); other positions of the axis occasionally occurred. Several students first constructed an image in axial symmetry, but then realized their error and either corrected themselves or at least mentioned it in the attached commentary. One student solved the situation by additionally modifying the assignment (Figure 9).

Many respondents drew auxiliary lines through the vertices of the given figure and the centre *S*, even if they did not use these lines and drew the image in axial symmetry (Figure 10).

One of the possible reasons why students confused central and axial symmetry may be the fact that in mathematics teaching, axial symmetry is revised immediately before the introduction of central symmetry. Students fix in their minds the first information they encounter on a new topic (Ebbinghaus, 1913; Škoda and Doulík, 2011), or they do not fully understand the

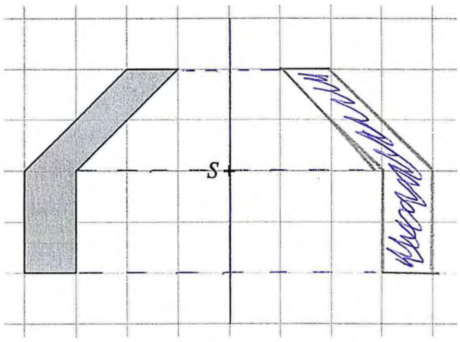

Figure 8: Use of the vertical axis in the test task on central symmetry, student's incorrect solution (source: own data)

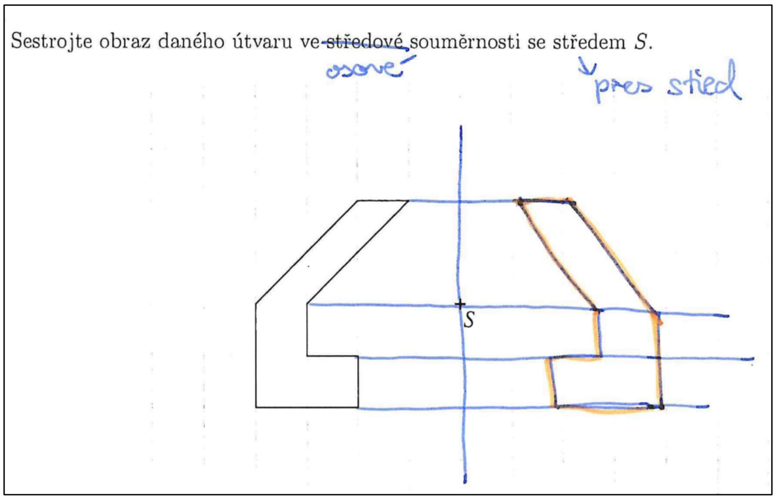

Figure 9: Student's incorrect solution and subsequent change of the assignment[6] (source: own data)

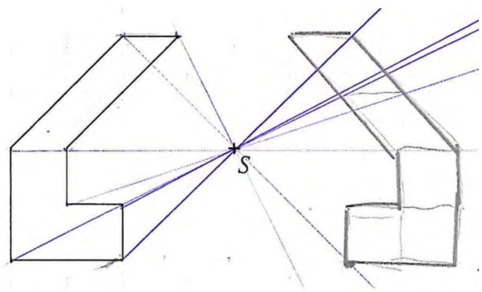

Figure 10: Student's incorrect solution in spite of the use of adequate auxiliary lines (source: own data)

concept of central symmetry and remain only at the level of an isolated model (Hejný, 2012). Also, in subsequent levels of education, central and axial symmetry are taught at the same time, often in one lesson or during one week. Son (2006) and Jagoda (2008) also encountered a confusion of axial and central symmetry among students.

The preference of the vertical axis could be caused by the fact that the vertical axis is predominately used in the pictures on the topic of axial symmetry in most of the analysed textbooks. The preference for the vertical (or horizontal) axis is in agreement with researches (Jagoda, 2008) and (Kambilombilo and Sakala, 2015), in which students had difficulty drawing images in axial symmetry with an oblique axis.

Almost 5% of students used a translation in Test II. Except for one situation, students translated the given figure horizontally to the right, most often by 3, 3.5 or 4 squares of the grid (Figure 11); or so that the point *S* was approximately the centre of the translation vector. While we expected the confusion between central and axial symmetry, we were surprised by the confusion of central symmetry and translation, as the pupils do not usually encounter a translation until upper secondary school. They may have been led to this solution by the fact that they could not remember the concept of central symmetry and they knew that axial symmetry would be wrong, so they simply tried something else. However, only one respondent in Test III drew a translated image.

Let's return to comparing the success rate by gender and between the BS and GSS groups. In most test tasks, males were better; however, the differences between males and females in many tasks were not statistically significant. The significant dependence of the choice of the correct answer on gender in favour of males was confirmed only in the case of

6 Free translation of the student's version of the assignment: 'Construct an image of the given pre-image in axial symmetry through the centre *S*.'

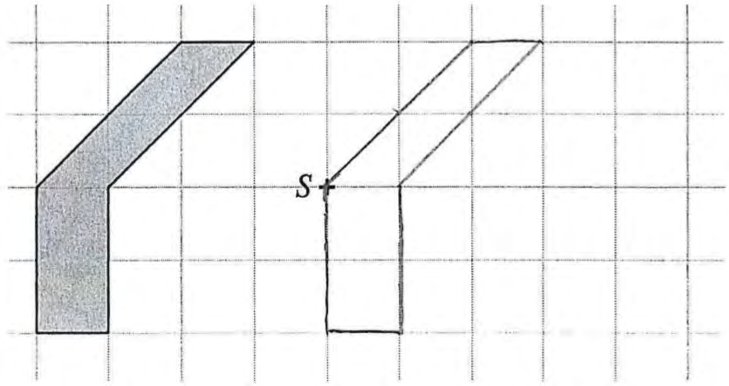

Figure 11: Student's incorrect solution of test task on central symmetry using translation (source: own data)

axial symmetry of the line segment in Test III, and in the task on central symmetry in Test III. This disproportion in favour of males is in agreement with most previous research (e.g., Smith and Walker, 1988), however, in our testing the overall difference between the males and females was not significant, which is in agreement with the research of Kambilombilo and Sakala (2015). Better results of the males obtained in some tasks may be related to a more positive attitude of the males to mathematics (Emanovský and Gonda, 2020; Ganley and Lubienski, 2016).

Moreover, a comparison of the success rate between BS and GSS students was possible in Tests I and II. GSS students were more successful in all test tasks than BS ones. In all tasks, except for the number of symmetry axes of the line segment in Test II, the hypothesis that the type of school and the choice of the correct answer do not depend on each other can be rejected. The higher success rate of GSS students is probably related to the fact that GSS are selective schools with an entrance exam and studying at them is more demanding (Martinková, Hladká and Potužníková, 2020); they can also use specific textbooks intended for GSSs.

It is positive that PSTs were the most successful of all test groups. On the other hand, there was a certain error rate even among them. Other researches (e.g., Ada and Kurtuluş, 2010; Hacısalihoğlu-Karadeniz et al, 2015; Kambilombilo and Sakala, 2015; Hacısalihoğlu-Karadeniz, Kaya and Bozkuş, 2017; Son, 2006; Thaqi, Giménez and Rosich, 2011) have also pointed out pre-service teachers' problems with the concepts of symmetry.

The causes of students' errors can be various; it is difficult to identify all of them. One of the possible negative influences can be inappropriately designed textbooks, as teachers and students work with them during the teaching and learning process. Primary school teachers in particular often consider the textbook to be a sufficient resource for preparation for teaching lessons. The influence of textbooks was also mentioned by Aktaş and Ünlü (2017). Other causes may be, e.g., the influence of the teacher (Aktaş and Ünlü, 2017; Hacısalihoğlu-Karadeniz et al, 2015; Hacısalihoğlu-Karadeniz, Kaya and Bozkuş, 2017; Son, 2006), the socio-cultural environment of students (e.g., Brand, Glasson and Green, 2010; Maaz et al, 2008), the popularity of geometry with students (e.g., Rendl and Vondrová, 2013), etc.

In our research, we observe that students have the greatest problems with atypical tasks. Similar tasks need to be included more often in textbooks and in the teaching process (Kambilombilo and Sakala, 2015), as they practise and examine mainly conceptual knowledge. A greater error rate occurs particularly when there is a lack of conceptual understanding of the topic. Students proceed procedurally rather than conceptually (they try to draw axes), they do not think about the concept of symmetry and they do not find all solutions. The students do not connect process and concept, i.e., they do not have developed the symmetry procept (Hejný, 2000). These errors do not decrease with increasing age and thus misconceptions arise in students' minds. Therefore, it is necessary to introduce more atypical problems and to place more emphasis on conceptual understanding in the training of pre-service teachers (Hacısalihoğlu-Karadeniz, Kaya and Bozkuş, 2017; Son, 2006; Thaqi, Giménez and Rosich, 2011).

CONCLUSION

Students' understanding of isometries is a precursor to understanding other mathematical concepts. Isometries are the easiest geometrical transformations and transformations are encountered by people in daily life. Therefore, we consider teaching and understanding the concepts related to isometries to be important at all education levels.

In the years 2017–2018, we carried out an extensive testing of Czech students in order to determine their understanding of certain geometrical concepts. In this paper, we have analysed the students' answers to the test tasks concerning axial and central symmetry in detail and have thought about the possible causes of frequent errors.

With respect to the research questions asked, we can say that the tested students identified typical axially symmetrical figures (an isosceles triangle, a circle) and most of them correctly determined the number of symmetry axes of these figures. Conversely, students had problems recognizing a given rhomboid (i.e., a centrally, but not axially, symmetrical figure) as a non-model of an axially symmetrical figure. Furthermore, students did not perceive that a line segment has two different axes of symmetry. However, they knew that a circle has an infinite number of symmetry axes. A significant number of the students confused central symmetry for axial symmetry in the construction task. These students preferred a vertical axis of symmetry. From a gender point of view, the results speak slightly in favour of males. This difference is most obvious in the highest age category of tested students (from 19 to 23 years). A significant difference in favour of general secondary school students at the expense of basic school students was confirmed.

Our pedagogical recommendations resulting from the above are: it is necessary to place greater emphasis on non-models and figures in non-prototypical positions in textbooks and teaching; during mathematics lessons, it is also necessary to work with atypical tasks (e.g., to look into symmetries of not only 2D, but also 1D figures), even in higher grades it is necessary to include elementary tasks on symmetries in teaching, and last but not least, greater emphasis should be placed on the spiral curriculum throughout the educational process and on the conceptual knowledge of pre-service teachers.

In further research, we continue to explore students' understanding of other geometrical concepts. Moreover, we observe the relationship between students' concepts and how students like geometry. Among other things, we also focus on the improvement of the training of pre-service mathematics teachers and the connection between conceptual and procedural knowledge.

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Full research paper

ASSESSING AND CLASSIFICATION OF ACADEMIC EFFICIENCY IN ENGINEERING TEACHING PROGRAMS

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ABSTRACT

This research uses a three-phase method to evaluate and forecast the academic efficiency of engineering programs. In the first phase, university profiles are created through cluster analysis. In the second phase, the academic efficiency of these profiles is evaluated through Data Envelopment Analysis. Finally, a machine learning model is trained and validated to forecast the categories of academic efficiency. The study population corresponds to 256 university engineering programs in Colombia and the data correspond to the national examination of the quality of education in Colombia in 2018. In the results, two university profiles were identified with efficiency levels of 92.3% and 97.3%, respectively. The Random Forest model presents an Area under ROC value of 95.8% in the prediction of the efficiency profiles. The proposed structure evaluates and predicts university programs' academic efficiency, evaluating the efficiency between institutions with similar characteristics, avoiding a negative bias toward those institutions that host students with low educational levels.

KEYWORDS

Efficiency, higher education, machine learning, predictive evaluation

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Highlights

- *A standardized framework for evaluating, calculating, and predicting the performance of engineering education is presented.*
- *Assessment of homogeneous universities makes it possible to correctly determine academic performance.*
- *Comparison of equivalent entities yields different average efficiency values for the global analysis.*

INTRODUCTION

The teaching of science, engineering, technology, and mathematics (STEM) is a critical aspect of countries' development. Different studies reveal positive association factors between economic growth and the number of professionals in STEM areas (Hoeg and Bencze, 2017; Sharma and Yarlagadda, 2018; Suter and Camilli, 2019). Bianchi and Giorcelli (2020) demonstrate how countries with better levels of science education have higher levels of innovation, represented in patent-for-invention registrations. Corlu and Aydin (2016) show that teaching in STEM areas generates higher levels of business creation. Therefore, it is essential to generate objective assessment tools for teaching STEM-related careers. Thus, this study presents a data-based model to analyze the fundamental characteristics and relationships of engineering education programs and the results of a standardized assessment to achieve academic efficiency. However, it is crucial to highlight the inequalities in terms of access, resources, and opportunities in higher education. So, to avoid the biases that represent the different levels in the basic academic competencies with which students access university education, the comparison of the programs must be fair, that is, comparing between equals. Consequently, this study identifies homogeneous groups of engineering programs to analyze and forecast their level of efficiency within their reference group.

This research is aligned within the area of learning analytics, promoting the use of data as input to support decision-making in educational environments. Universities are traditionally characterized as generating large volumes of data. However, Long and Siemens (2014) show that strategic and operational decision processes are developed under empirical and subjective schemes. In the educational field, data are mainly used to generate descriptive schemes such as the generation of reports and external and internal communication processes and transactions as accreditation and government oversight requirements. Thus, specific areas are identified where educational institutions have begun to implement data-based models to represent complex situations. First, student dropout has been studied from a predictive viewpoint. For example, Berens et al. (2019) and Suresh, Asokan and Vinodh (2016) developed models to predict student dropout using socioeconomic and academic variables. Heidrich et al. (2018) modeled student dropout using contextual variables obtained from the interaction of students in the educational process and monitoring the frequency of students' use of resources to support education, information such as the library, and complementary activities, among others (González et al., 2018).

From the efficiency analysis approach, several studies use machine learning techniques and Data Envelope Analysis to generate estimates of productivity and competitiveness. Most of these studies have been developed in the commercial and industrial field (Aldamak and Zolfaghari, 2017). Among these studies, the contributions of Granadillo, Gómez and Herrera (2019) stand out; the authors integrate financial items and levels of operational performance to estimate productivity indicators in the chemical sector in Colombia. Other studies develop multistage models in a similar approach, analyzing variables' performance and implementing supervised and unsupervised data learning models with efficiency analysis models (Fuentes, Fuster, and Lillo-Bañuls, 2016; Mikušová, 2017; Visbal-Cadavid, Mendoza and Hoyos, 2019).

This study analyzes how the differences between the study units can affect the results of the efficiency metrics in the Data Envelopment Analysis (DEA) models. These are applied in an educational context, considering the results of the state tests of quality of education in Colombia SABER PRO and SABER 11 as a study base. Cluster analysis, DEA, and a predictive model based on Random Forest (RF) are employed, respectively, allowing identification of the relationships between variables, creation of homogeneous groups, measurement of efficiency, and forecasting future efficiency categories. To the best of our knowledge, this efficiency analysis approach has not been previously developed in educational contexts. Therefore, one of this study's contributions is to propose an alternative approach for estimating educational efficiency, incorporating the creation of homogeneous groups to make a comparison between equals of efficiency levels. Simultaneously, the estimation of the efficiency levels is established using a direct estimation method as a reference base, considering all the observations in the database.

Consequently, it is necessary to organize a method in three phases that allow the following questions to be answered. How to define university profiles of engineering education considering state exams at the secondary and university level? What is the academic efficiency of the identified engineering profiles? How to predict through machine learning the efficiency category of a university program belonging to the engineering training profiles created? Therefore, the main objective of this study is to evaluate and forecast the academic performance of Colombian engineering programs, creating a replicable and reproducible method, offering objective guidelines for decision-making in a higher education environment.

The analysis of the efficiency of educational services is a field of great dynamism in the scientific community. From the first approach to the concept of efficiency applying linear programming techniques developed by Charnes, Cooper and Rhodes (1978), in recent decades there has been a greater dynamism in the measurement of efficiency in educational environments, schools, universities, and even systems countries education. DEA allows the incorporation of different combinations of input and output variables. Through a bibliographic review, Ferro and D'Elia (2020) classified the input variables in models of educational efficiency in teaching (dissemination of knowledge), research (production of basic or applied knowledge), and extension activities (also known as such as transfers, public, community or "third mission"), and input variables classified as human (teaching and research) and non-human (physical and financial resources).

Efficiency and Education

The type of educational data is a vital aspect in determining efficiency. Thus, there are different reports and databases where the results of large-scale tests are presented (e.g., PISA, SABER PRO, GMAT or TIMSS). These data can be the result of micro aggregations represented by average values of each institution or country. On the other hand, there are data at the individual level, which represent the performance of students in their interaction with a standardized test, the grades obtained in a study period, or external variables related to social, economic, and geographical aspects (Aparicio, Perelman and Santín, 2020; Thanassoulis et al., 2017; Visbal-Cadavid, Martínez-Gómez and Escorcia-Caballero, 2020). The primary consideration of these approaches is to assume that all study units have the same conditions, resources, and infrastructure, which can have fundamental implications for determining efficiency levels. Furthermore, standardized tests have limitations, such as the range of possible student responses, the context of each student to associate their reality with the questions and answers in predetermined categories, in addition to the difficulty of the test associated with the existence or lack of specific training on exam topics. The literature related to the measurement of efficiency in educational processes has shown increasing dynamics in recent years (Witte and López-Torres, 2017). Therefore, it is possible to find different approaches to evaluate efficiency in this sector (Agasisti, Munda and Hippe, 2019; Gralka, Wohlrabe and Bornmann, 2019; Khan, Khan and Hameed, 2019; Tran and Villano, 2019), in addition to studies applied to the Colombian context (Visbal-Cadavid, Mendoza and Hoyos, 2019).

Using global management variables, articulating neural networks, and DEA models, Visbal-Cadavid, Martínez-Gómez and Guijarro (2017) developed a model to predict the efficiency of public universities. In a similar approach, Aparicio, Cordero, and Ortiz (2019) make comparisons between efficiency analysis models using PISA tests as input data. Other authors have highlighted the relevance of grouping processes through cluster analysis to define complex association patterns related to the specific performance of variables generated in public reports, such as institutional budget, teacher salaries, campus area, and number of students, among others (Wolszczak-Derlacz, 2017). In addition, Nazir (2019) proposed limitations to carrying out the forecasting process based on the comparability and homogeneity of observations. To guarantee the efficiency of the prediction processes based on machine learning, it is essential to determine and characterize similarities between the study objects. It is also essential to highlight the investigations in which university institutions are defined and described in homogeneous groups. For example, Najadat, Althebyan and Al-Omary (2019) used non-hierarchical cluster techniques to create representative groups and identify leading institutions in the university context. Similarly, other investigations at the international level have estimated efficiency levels in large volumes of educational data. For example, Torres-Samuel et al. (2020) developed a Gaussian cluster model and a DEA model to evaluate the technical efficiency of higher education institutions in Latin America considering macroeconomic variables and research, innovation, and development results.

MATERIALS AND METHODS

Data Collection

Through a rational analysis, the generic components of the state test for secondary education, known as SABER 11, were identified as input variables and the components of the state test for higher education, SABER PRO, as output variables of an efficiency model. With the previously refined and selected information, the following phases were carried out: i) A cluster analysis using the unsupervised learning algorithm k-means to identify the formation of homogeneous groups in the data, associated with the results of the SABER tests; ii) An academic efficiency analysis was developed under an exit optimization approach to determine academic efficiency profiles (AEP); iii) A predictive model was defined to classify and predict belonging to an academic efficiency profile of an engineering program through Random Forest (RF) and Decision Tree (DT). The process flow and the articulation of the techniques is shown in Figure 1.

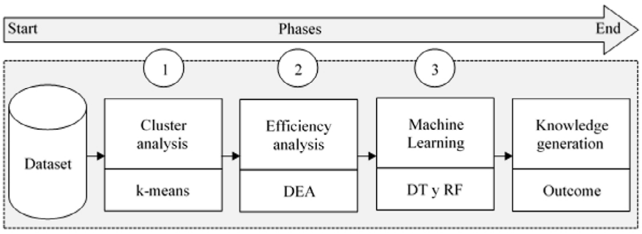

Figure 1: Research methodology

The components were identified through a rational analysis. The database used contains 12,411 observations, each of which represents a student. These observations come from 135 universities from Colombia (public: 30.37%, private: 69.63%) and eight academic degrees (civil, electromechanical, electrical, electronic, industrial, industrial automation, mechatronic, and chemical engineering). The base data were summarized by combining universities and undergraduate programs, leaving a total of 265 observations for analysis. It should be noted that universities do not have the same number of academic programs. In addition, the data come from the databases of the Colombian Institute for the Evaluation of Education (ICFES).

The names, mean, and standard deviation of the study variables are reported in Table 1. The suffix for variables labeled S11 corresponds to the high school level test and SPRO corresponds to the college level assessment. It should be noted that the scale of academic competencies is 0-100, but the scale of the variable Formulation of engineering projects (FEP_SPRO) is 0-200. In addition, the mean and standard deviation belong to the results of the academic competencies evaluations of the school (S11) and the university (SPRO).

Variable	Full name	Average	Standard deviation
MATH_S11	Math	64.32	11.87
ENG_S11	English	60.78	10.03
NS_S11	Natural sciences	60.71	10.12
CS_S11	Citizenship skills	63.95	11.16
CR_S11	Critical reading	61.80	14.30
QR_SPRO	Quantitative reasoning	77.42	22.67
CS_SPRO	Citizenship skills	62.20	27.67
ENG_SPRO	English	59.19	28.99
WC_SPRO	Writing communication	67.50	25.49
CR_PRO	Critical reading	53.70	30.00
FEP_SPRO	Formulation of engineering projects	145.48	40.12

Table 1: Study variables, 2009-2018 (source: Delahoz-Dominguez, Zuluaga and Fontalvo-Herrera, 2020)

Academic Competences

SABER 11 is an evaluation of the level of secondary education in Colombia to provide educational institutions information on the development of basic skills that a student must develop during their time in school (ICFES, 2020). On the other hand, SABER PRO is an assessment aimed at higher education students close to graduation. Both evaluations are carried out by the Colombian Institute for the Evaluation of Education (ICFES) to measure the quality of all public or private educational institutions. The SABER PRO assessment is a mandatory requirement for all students who wish to acquire a professional degree in Colombia (ICFES, 2020). A student can also take the assessment only if they have passed 75% of the academic credits.

Cluster Analysis

For the development of the first phase of the proposed method, a non-hierarchical cluster analysis was carried out through the k-means algorithm (Clayman, Srinivasan and Sangwan, 2020; Oyelade et al., 2019). This algorithm randomly selects *k* points from the original data set to add as the initial clustering center. First, each unit in the data set is considered a point. Then, the distance between the data points and the core of the group is determined using the Euclidean equation, and the data set is preliminarily grouped by distance. Finally, the average distance of the observations in each group is calculated, the center of mass of the group is adjusted, and the final result of the grouping is obtained through multiple iterations. The Silhouette test (Menardi, 2011) assesses the quality of the membership of the observations, providing weights that oscillate between values of -1 and 1, where -1 is the evaluation of the observations better represented in another group; observations that are in the boundary between two clusters take the value of 0 and those that are well matched to the current group take the value of 1.

Data Envelopment Analysis

The key concept of DEA is the evaluation of the efficiency of the decision-making units that interact within a competition and development sector. Also known as border analysis, DEA has become the standard for the development of processes for comparing, measuring, and evaluating efficiency in productive organizations (Pawsey, Ananda and Hoque, 2018). Different approaches can be taken from the viewpoint of DEA analysis for educational purposes, for example, Amara, Rhaiem and Halilem (2020) evaluated research efficiency of Canadian scholars, considering aspects such as public funding seniority and university reputation.

The DEA-CCR model, known in the literature as technical efficiency, is the relationship between the weighted sum of the outputs and that of the inputs. The CCR model seeks to maximize the efficiency of a decision-making unit, within a group of reference organizations, through the optimal weights related to the input and output variables (Benicio and Mello, 2015). The optimization model associated with the DEA-CCR model endogenously calculates the weighting of the performance criteria and the result of the variables to achieve the maximum or minimum value of the objective function (Sinuany-Stern, Mehrez and Hadad, 2000). In addition, the result of the academic program results in the sum of the scores of the students who take the test for each institution adjusted by the arithmetic mean. However, the arithmetic mean is affected by outliers and, in particular, in the case of standardized tests, by the number of students taking the test. Therefore, when hypothetically considering two university programs A and B, with the same average results in the exams, different behaviors of the variability can be classified in the same technical efficiency category.

It should be noted that the DEA models assume that the input information of the models is accurate. However, in most cases, the input and output variables are imprecise, wrong, and biased. For example, when evaluating an individual student's performance through a standardized test, which was designed by experts who select the questions for each topic and dimension, adjusting the order and quantity of the questions according to standardized criteria of reading speed, comprehension, and analysis (Wolszczak-Derlacz, 2017). In summary, the process of creating the standardized test is a summation of subjective decision processes, which together generate noise in the final result. This is aligned with the main objective of this research to compare levels of efficiency among equals. Thus, although the exams are the same for all, the students do not come from the same context and, at a certain point, a university can be efficient in generating knowledge for its students, considering the student's initial learning inputs in relation to other universities (Duan, 2019; Ghasemi et al., 2020). Finally, the research model is presented below:

$$\max_{u,v} h_o = \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{io}} \tag{1}$$

subject to

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1,\ j = 1,\ldots,\ n \tag{2}$$

where

n : Each of which uses the same inputs (in different quantities) to obtain the same outputs (in different quantities).

x_{ij} : Input quantities *i* consumed by the *j*-th DMU.

x_{io} : Amount of input *i* consumed by the DMU *o*.

y_{rj} : Observed quantities of outputs *r* produced by the *j*-th DMU.

y_{ro} : The observed quantity of the output *r* produced by the DMU *o*.

u_r : Weighting of the virtual output.

v_i : Weighting of the virtual input.

On the other hand, for the application of the DEA model, we start from the construction of the conceptual scheme that relates the input and output variables of the model. The inputs of the DEA model correspond to the competencies evaluated in SABER 11 (Math_S11, ENG_S11, NS_S11, CS_S11, and CR_S11) and the outputs of the model are the competences evaluated in SABER PRO (QR_SPRO, CS_SPRO, ENG_SPRO, WC_SPRO, CR_PRO, and FEP_SPRO).

Random Forest

The RF model is an assembly-type method based on the recurring and growing construction of multiple DTs through a bootstrapping aggregation process (Breiman, 2001). That is, multiple DTs are created with different composition of variables in such a way that each tree produces an independent result. A democratic process is then carried out where a category is assigned according to the resulting class with the most votes in general. This characteristic of generating separate responses for each Decision Tree and then joining them in a general prediction produces robust models that are less susceptible to extreme values and overfitting than a simple Decision Tree, thus improving the model's predictability and classification. The RF model presents a variable selection technique; in this way, it is possible to handle data sets with a large number of variables without using previous processes to reduce dimensions. The model also identifies the importance of the variables for the correct classification of the observations through a permutations test.

The success of the classification process occurs by minimizing the difference between the predicted value and the actual value. This relationship is described by the metrics True Positive (TP), True Negative (TN), False Positive (FP), False Negative (FN), and F1 Score. The metrics used to assess performance will be correct classification rate (C), positive predictive value (PPV), negative predictive value (NPV), sensitivity (S) and specificity (E), and Area under ROC. It should be noted that: specificity indicates the ability of the estimator to detect negative cases; sensitivity indicates the ability of the estimator to detect positive cases; F1 score is the harmonic mean between precision and recall (Sun, Liu and Wang, 2020), the optimal value is 1, this indicates that there is a perfect precision and recall; and the Area under ROC represents the rate of PT and FP at various discrimination thresholds. A model with a perfect classification will have Area under ROC = 1. On the other hand, a totally random model will return a value of Area under ROC = 0.5.

Finally, for the training of the model, the cross-validation (10-folds) method was used and 70% of the data set, on the other hand, 30% of the data set is used for the evaluation of the model. The inputs of this model are the academic competencies of SABER 11 and SABER PRO, the output is the category of the efficiency group (Group 1 efficient, Group 1 Non-efficient, Group 2 efficient, Group 2 Non-efficient).

RESULTS

The proposed methodology consists of three phases. Detailed results for each phase are presented below.

First phase: Cluster Analysis

For the first phase of academic profiling, the k-means algorithm was used, varying the number of centroids from two to ten, to identify the optimal number of groups to which the university programs belonged. The test's highest value corresponds to the formation of two groups with a Silhouette test value of 0.49 (see Figure 2).

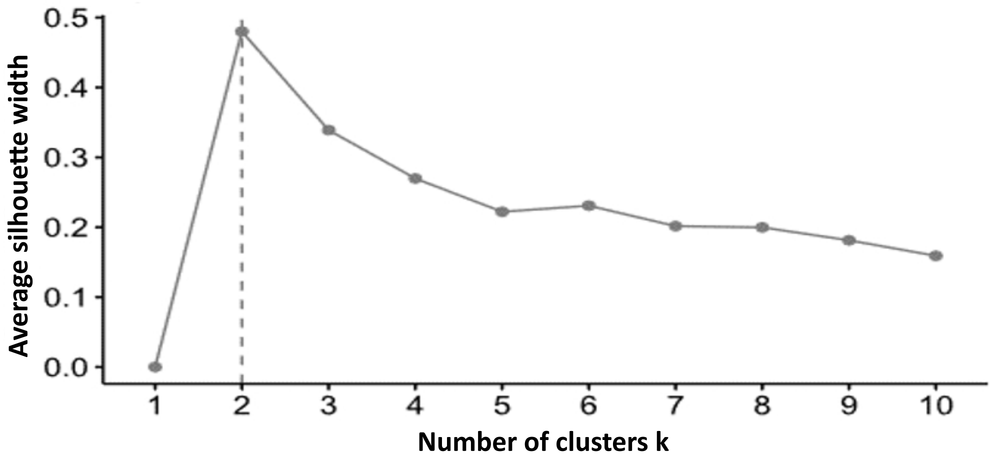

Figure 2: Analysis of the Silhouette test for optimal group conformation

Consequently, the representative elements of each profile are analyzed as shown in Figure 3. The university programs of cluster 1 are observed to have on average a higher score in all academic competences than the programs of Group 2. Thus, the competencies that will characterize Group 1 are those with an average higher than 70 points: ENG_SPRO, CS_SPRO, CR_SPRO, QR_SPRO, and MATH_S11. On the other hand, the characterizing competencies of Group 2 are those with an average higher than 55 points: QR_SPRO, MATH_S11, CR_S11, CS_S11, and NS_S11. Therefore, profile one can be contextualized as university programs with a high level of university entrance competencies and profile two as those with a medium-low level of university entrance competencies.

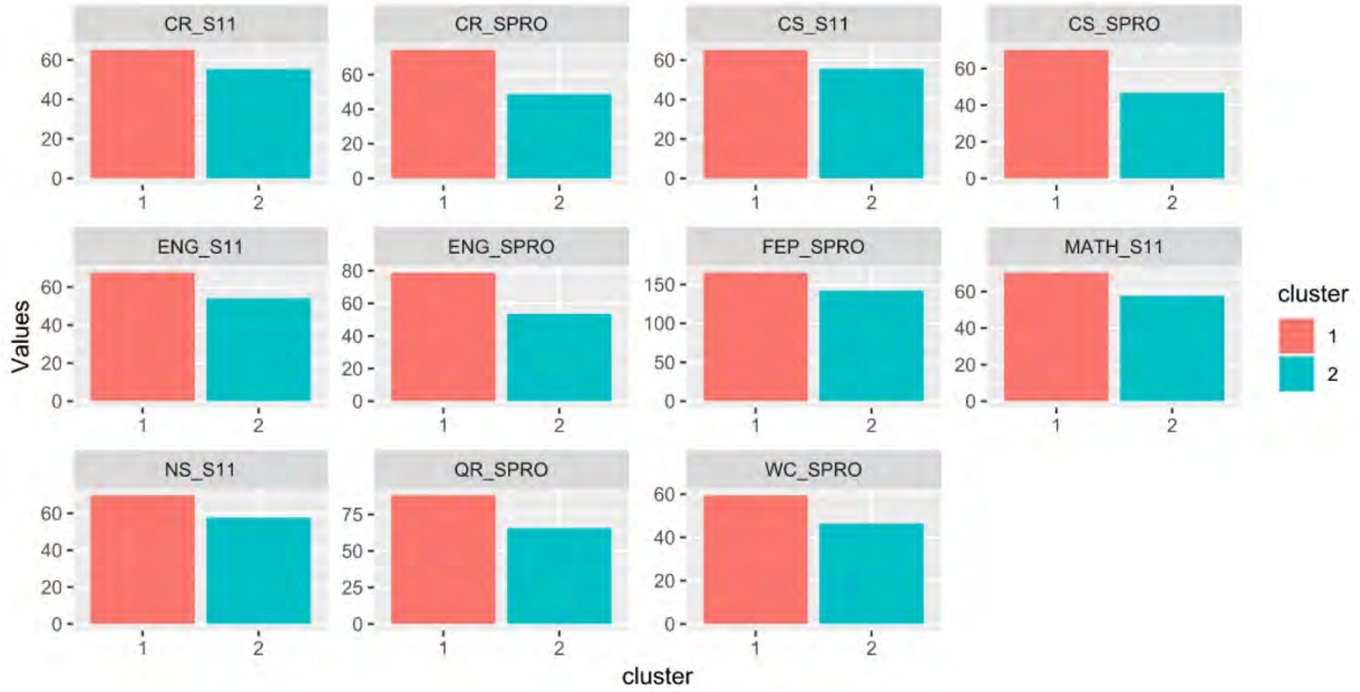

Figure 3: Contribution of academic competencies in clusters

Results by Cluster

In this phase, to improve the interpretation of academic profiles, the two-dimensional representation of the groups generated by the k-means algorithm was developed (see Figure 4). There is a wide separation of both groups, cluster 1 located on the left side is represented as a homogeneous group, showing low variability in the results of the SABER tests among its members. Group 2 is located on the right side of the map and presents greater variability among its members, represented in the area they occupy.

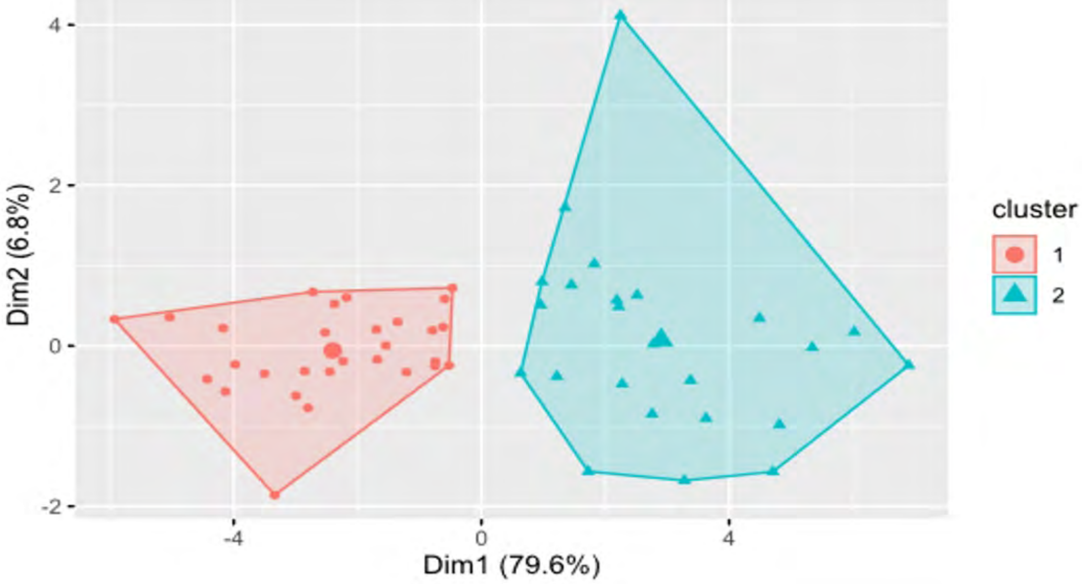

Figure 4: Graphic representation of the *k*-means cluster

Second phase: Efficiency Analysis

For the second phase of the method, the efficiency of the academic programs was calculated, adjusted by the previously determined efficiency profiles. The efficiency results by groups are presented in Table 2. The average efficiency of Profile 1 is 0.973 with a standard deviation of 0.029, 28 programs are determined as efficient out of a total of 111 members of this profile. In contrast, the average efficiency of Profile 1 is 0.941, with a deviation of 0.052, considering 34 university programs out of 154 members of this profile as efficient. The average efficiency for institutions without clustering by the cluster is 0.832, and the number of inefficient academic programs ranges from 223 in the global analysis to 203 in the group-adjusted analysis.

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Variable	No cluster	Clustering	
	General	Profile 1	Profile 2
Efficient programs	42 (15.85%)	28 (25.23%)	34 (22.08%)
Non-efficient programs	223 (84.15%)	83 (74.77%)	120 (77.92%)
Minimum level of efficiency	0.681	0.853	0.731
Average efficiency	0.832	0.973	0.941
Standard deviation	0.097	0.029	0.052
Number of programs (DMUs)	265	111	154

Table 2: Summary of the efficiency model

The integration of the results of phase one and two allows the creation of four AEP: 1) Efficient institutions in group one, 2) Non-Efficient institutions in group one, 3) Efficient institutions in group two, 4) Non-Efficient institutions in group two. Table 3 presents the value of the efficiency of some units of the study concerning the group to which they belong. The institutions that present a value equal to one in their level of efficiency are be classified as efficient and the rest as "Non-efficient.".

No cluster		Cluster			
		G1		G2	
DMU	Efficiency	DMU	Efficiency	DMU	Efficiency
U1	0.94	U24	1	U1	1.00
U2	0.91	U36	0.99	U2	0.99
U3	0.82	U37	0.98	U3	0.82
U4	0.85	U68	0.97	U4	0.87
U5	1.00	U69	0.99	U5	1.00
U6	0.86	U70	0.99	U6	0.91
U7	0.89	U71	1.00	U7	0.91
U8	0.93	U72	1.00	U8	0.96
U9	0.88	U73	0.99	U9	0.91
U10	1.00	U83	0.96	U10	1.00
U11	0.89	U84	1.00	U11	0.91
U12	0.93	U87	0.95	U12	1.00
U13	0.87	U88	0.98	U13	0.90
U14	0.87	U90	1.00	U14	0.91
U15	0.95	U105	1.00	U15	0.98

Table 3: Selected DMU Efficiencies

To contextualize the results, the variable "High-quality accreditation" of the academic program is used as an adjustment factor to provide tools to justify the differences in the levels of efficiency between the profiles. In Table 4, when comparing the results of the global efficiency analysis with the program accreditation variable, there is a higher proportion of accredited universities in the efficient universities profile.

Group	Quality Accreditation		
	Not	Yes	Total
Efficient	30.95%	69.05%	42 (15.85%)
Non-Efficient	60.09%	39.91%	223 (84.15%)

Table 4: Distribution of efficient DMUs without adjusting for academic profiles

Results of the efficiency levels adjusted by the quality accreditation variable are presented in Table 5. The results reveal a difference in the behavior of the groups. In the AEP of efficient units of Group 1, 92.86% of the programs are accredited, while in the AEP of efficient units of Group 2, only 15.83% have the accreditation.

AEP	Group distribution	Quality Accreditation	
		No	Yes
Group 1 Efficient	10.57%	7.14%	92.86%
Group 1 Non-efficient	31.32%	22.89%	77.11%
Group 2 Efficient	12.83%	73.53%	26.47%
Group 2 Non-efficient	45.28%	84.17%	15.83%

Table 5: Efficiency distribution for DMUs adjusted by academic profiles

A similar analysis is presented in Table 6. The academic program, considering the distribution by type of specific program, is taken into account using the global estimate of efficiency.

Engineering program	Efficient	Non-efficient	Total
Civil	13.04%	86.96%	17.36%
Electromechanical	20.00%	40.00%	1.89%
Electrical	22.22%	77.78%	3.40%
Electronic	22.64%	77.36%	20.00%
Industrial	13.54%	86.46%	36.23%
Industrial automation	8.57%	91.43%	13.21%
Mechatronic	25.00%	75.00%	3.02%
Chemistry	7.69%	92.31%	4.91%

Table 6: Distribution of DMUs in efficient groups by program without adjustment for profiles

Table 7 reports the distribution considering the adjustment by academic group. There are differences in the distribution of efficiency categories concerning the results of Table 6, for example, the Industrial Engineering program went from having a total of 13.54% of efficient units under the total efficiency measurement scheme to 22.92% considering the sum of the categories of efficient units of Profiles 1 and 2.

One of the greatest advantages of the DEA model is determining the number of resource units that a DMU will increase/decrease to reach the efficiency frontier. In Tables 8 and 9, these values are presented as objectives that an academic program should achieve to reach the efficiency frontier established by proposed model. For example, in Table 8, which reports the results for the global efficiency model, the most significant opportunity for improvement is associated with proficiency in the English language. On the other hand, when analyzing the results of the model adjusted by profiles (Table 9), the most significant opportunity for improvement is different for each of the groups.

Engineering program	Group 1 Efficient	Group 1 Non-Efficient	Group 2 Efficient	Group 2 Non-Efficient	Total
Civil	10.87%	34.78%	4.35%	50.00%	17.36%
Electromechanical	0.00%	20.00%	40.00%	40.00%	1.89%
Electrical	22.22%	55.56%	0.00%	22.22%	3.40%
Electronic	15.09%	30.19%	18.87%	35.85%	20.00%
Industrial	6.25%	20.83%	16.67%	56.25%	36.23%
Industrial automation	8.57%	42.86%	2.86%	45.71%	13.21%
Mechatronic	12.50%	12.50%	25.00%	50.00%	3.02%
Chemistry	15.38%	76.92%	7.69%	0.00%	4.91%

Table 7: Distribution of DMUs in efficient groups by academic program adjusted by profiles

	MATH_S11	ENG_S11	NS_S11	CS_S11	CR_S11
Mean	1.92	2.24	1.55	1.50	1.11
Standard deviation	1.77	1.96	1.61	1.50	1.22
Number of programs	150	124	110	76	104
Maximum	9.55	11.4	7.74	9.77	6.77

Table 8: Improvement targets for input variables under full efficiency estimation

Cluster 1					
	MATH_S11	ENG_S11	NS_S11	CS_S11	CR_S11
Mean	2.28	1.55	1.28	1.50	0.93
Standard deviation	1.87	1.91	1.76	1.91	1.37
Number of programs	85	46	44	44	33
Maximum	7.44	7.57	8.43	11.61	5.65
Cluster 2					
	MATH_S11	ENG_S11	NS_S11	CS_S11	CR_S11
Mean	1.10	2.07	1.41	1.41	1.23
Standard deviation	1.41	2.51	1.39	1.85	1.21
Number of programs	30	71	76	31	72
Maximum	6.97	16.89	7.17	9.84	6.48

Table 9: Improvement objectives for input variables under adjustment for academic profile

Group 1 presents more significant opportunities for improvement in mathematical competence. In Group 2, the improvement is mainly due to mastery of English, with mathematics being only the fourth competence with the most significant room for improvement for this profile. These results indicate that the comparison between equals allows a better conceptualization of the efficiency results and, therefore, objective, and specific tools for developing improvement strategies in the higher education sector.

Third phase: Machine Learning

In the third phase, the RF model predicts the academic efficiency profile to which an academic program belongs. The predictors of the model are the results of academic competencies and the result will correspond to one of the four AEPs. Thus, the model obtained a mean precision of (0.833) during the training phase using 10-folds in cross-validation. Consequently, Table 10 shows the performance metrics of the RF model training, the mean, lower limit of the confidence interval (LL.CI – 5% significance) and upper limit of the confidence interval (UL.IC – 5% significance) of Sensitivity, Specificity and F1 Score.

	RF Model								
	Sensitivity			Specificity			F1 Score		
1	0.76	0.75	0.77	0.93	0.92	0.94	0.73	0.71	0.74
2	0.56	0.55	0.57	0.9	0.89	0.91	0.67	0.65	0.68
3	0.75	0.74	0.76	0.96	0.95	0.97	0.78	0.77	0.80
4	0.58	0.57	0.59	0.91	0.90	0.92	0.68	0.66	0.70
5	0.57	0.56	0.58	0.90	0.89	0.91	0.61	0.6	0.63
6	0.58	0.57	0.59	0.92	0.91	0.93	0.68	0.66	0.70
7	0.75	0.74	0.76	0.96	0.95	0.97	0.78	0.77	0.80
8	0.88	0.87	0.89	0.98	0.97	0.99	0.93	0.91	0.94
9	0.63	0.62	0.64	0.94	0.93	0.95	0.71	0.7	0.73
10	0.75	0.74	0.76	0.95	0.94	0.96	0.83	0.82	0.85

Table 10: Improvement objectives for input variables under adjustment for academic profiles

Then, the Area under ROC value was equal to 95.8% for the RF predictions (ROC curve). Consequently, cross-validation is performed to generate coherence on the model. In this case, Table 10 shows a reduction in the standard deviation measurement for the precision and Area under ROC metric results with values of 0.739 and 0.035, respectively (see Table 11).

Based on the model results, the importance of the predictors can be determined (see Table 12). Thus, what role academic competencies play in efficiency can be observed for each group. For example, in cluster 1, to detect the efficient study units, the variables that have a positive relationship in the model correspond to QR_SPRO, CR_SPRO, CS_SPRO, WC_SPRO, and FEP_SPRO. On the other hand, the variables that have a negative relationship with the model correspond to MATH_S11, CR_S11, CS_S11, NS_S11, ENG_S11, and ENG_SPRO.

On the other hand, Table 13 presents the Random Forest model's performance metrics, evaluating the model's ability to identify group membership and associated efficiency accordingly. The results show that the model can mainly identify the academic efficiency profile to which each program belongs.

Model	Accuracy				Area under ROC			
	Min	Mean	Max	sd	Min	Mean	Max	sd
RF Model	0.737	0.833	1	0.073	0.896	0.958	1	0.035

Table 11: Performance metrics for cross-validation training

Competence	Importance			
	Group 1 efficient	Group 1 Non efficient	Group 2 efficient	Group 2 Non efficient
MATH_11	-0.062	0.178	-0.011	0.070
CR_11	-0.034	0.172	-0.016	0.127
CS_11	-0.067	0.166	0.014	0.030
NS_11	-0.042	0.175	0.017	0.054
ENG_11	-0.043	0.099	0.012	0.017
QR_PRO	0.023	0.047	-0.039	0.127
CR_PRO	0.071	0.042	-0.044	0.223
CS_PRO	0.011	0.061	-0.034	0.162
ENG_PRO	-0.012	0.030	-0.031	0.135
WC_PRO	0.007	0.003	0.004	0.075
FEP_PRO	0.079	0.010	-0.019	0.068

Table 12: Importance of variables for the Random Forest classification

Metric	Group 1 efficient	Group 1 Non efficient	Group 2 efficient	Group 2 Non efficient
Sensitivity	0.250	0.960	0.250	0.829
Specificity	0.986	0.818	0.941	0.844
F1 Score	0.364	0.814	0.315	0.817

Table 13: Summary of the test process metrics

Finally, this research consists of three phases: cluster analysis, efficiency analysis, and machine learning. Exploratory cluster analysis analyzes the data by identifying clustering patterns between programs and characterizing academic profiles between university degrees. The efficiency measurement phases are performed for the profiles resulting from the cluster analysis and also for the raw data to provide a basis for comparison and contrast. The findings in Table 2 reveal the highest efficiency for non-group analysis, but this restricts the scope and complexity of the analyses that can be performed. It is also challenging to compare a university with a high level of reputation, popularity, experience, and positioning with a university for which these characteristics are low.

The efficiency analysis was carried out considering the academic program and its quality accreditations, allowing estimation of how the accreditations influence the level of efficiency in both study groups. The results highlighted how efficient Group 1 (G1_EFF) is made up of 92.86% of accredited universities, in contrast to efficient Group 2 (G2_EFF), with only 26.47% of accredited universities (see Table 5). Finally, in this phase, it is possible to determine the weak and strong competencies of each efficient group. In addition, the score that must be increased to reach the efficiency threshold for each study unit can be established (see Table 9). This makes it possible to identify the competencies that higher education institutions must strengthen within their teaching curriculum to improve academic performance and, consequently, the level of efficiency.

In the third phase, an RF model predicts the membership of an efficiency profile (G1_EFF, G1_Not_EFF, G2_EFF, G2_Not_EFF) of the academic programs studied. This is very useful because if the university predicts a student's performance in advance, it could take steps to improve or maintain their efficiency.

DISCUSSION

It is essential to compare the results with other studies that use machine learning and artificial intelligence techniques to predict the efficient group (Group 1, Group 2, etc.) and/or the type of efficiency (efficient or not efficient). The Random

Forest model output used to classify academic efficiency levels was Area under curve ROC=0.94; this value is at the same level in another educational research. For example, the authors Durairaj and Vijitha (2014) presented a group analysis using k-means and predicting students' performance from the probabilistic algorithm and Naïve Bayes DT, obtaining a sensitivity of 0.94, a specificity of 0.47, and an F1 score of 0.93. On the other hand, de Morais, Araújo and Costa (2014) developed a methodology that consists of analyzing groups using k-means and then generating academic performance prediction through multivariate regression, obtaining a significant adjustment of 99%. Torabi, Moradi and Khantaimoori (2012) predicted the results of student evaluations using Bayesian networks, obtaining a precision of 66%. Kolo, Adepoju Solomon and Alhassan (2015) used a DT algorithm and obtained an accuracy of 66.8% in academic evaluations. Singh, Sabitha and Bansal (2016) used the k-means group analysis algorithm, showing an excellent performance of up to 80% precision in the academic evaluation results.

Consequently, Alsabawy, Cater-Steel and Soar (2016), points out that the improvement of efficiency levels is not an easy task, since there are no "automatisms" for efficiency, identifying that it is made to believe that the improvement in the educational contexts is associated with technological change. Considering the previous approach, our research uses the outputs of the DEA linear programming model, specifically the slack variables as an objective element to objectively identify potential areas for improvement in the institutions.

The comparison of institutions with similar characteristics was one of the objectives of our study, this aspect can be understood by the total range of the efficiency scores, as presented in Table 4, the minimum value of the efficiency score for Cluster 1 and 2 is 85.3% and 73.1% respectively, these values are higher than the minimum score in the global scenario without grouping, which was 68.1%. When comparing with the research (Johnes, 2006), where they analyze 130 universities in the UK using six inputs and three outputs, the minimum efficiency score was estimated at around 60%. Similarly, Klumpp (2018) in the research of 17 European universities identified a minimum efficiency score of 61.60%; The minimum threshold of 60% for the efficiency score increases in our research when institutions are grouped by similarity factors.

Kuah and Wong (2011) evaluated universities' efficiency through a DEA model. They affirm that the efficiency of a university is made up of two dimensions: teaching efficiency and research efficiency. Their research indicates an alternative to measure efficiency. However, our research's advantage is that it uses standardized tests as inputs, which are objective measures. However, one limitation of our study is that only one aspect of a university's efficiency is measured. Ramzi, Afonso and Ayadi (2016) developed an efficiency analysis of primary and secondary education in Tunisia using a DEA model, highlighting the need for clustering (cluster) and the importance of calculating the educational efficiency. By comparison, our research measures the relative impact colleges have on students when evaluating high school and college exam results. Like Agasisti, Munda and Hippe (2019), our study evaluates the university's contribution to students' professional achievement. Therefore, the proposed methodology produces good results and is relevant for the educational context when comparing our research results with similar approaches.

The results of our work become an objective tool to evaluate the academic performance of university institutions. In university management, it could be useful for independent regulatory entities as a mechanism to identify representative institutions and determine objective evaluation criteria. In the specific case of university decision-makers, the structure proposed in the research allows strategically mapping the position of a program or university in an academic context, thus supporting decision-making in investments, curricular designs, and new academic programs. Finally, students have a tool to support the career's decision to study, associating their interests with the efficiency results delivered by our efficiency analysis structure. The results indicate that Quality Accreditations support higher academic efficiency for engineering programs. However, the cluster analysis isolates the quality accreditation effect, evidencing that quality accreditations have a greater impact on universities that receive students with better abilities from high school.

CONCLUSIONS

This study comprehensively evaluated the educational efficiency of 265 academic engineering programs. A three-phase method was proposed that assesses the effect that large universities have on the sector's overall efficiency performance. This research's key contribution is the specific description of a method to evaluate and forecast academic efficiency in university education. The first phase (cluster analysis) groups universities with similar academic characteristics in clearly defined profiles. Consequently, the efficiency analysis is carried out through DEA (second phase), first without considering cluster analysis and then calculating each profile's efficiency. The evaluation of homogeneous universities makes it possible to correctly determine academic performance. Finally, the third phase corresponds to the machine learning model's application to predict an academic efficiency profile.

From the empirical evidence, the following criteria are the research findings. The first phase results show the formation of two groups: the first with high results in basic professional skills and the second group with high results in secondary basic skills. The second phase reveals that the average efficiency value for Groups 1 and 2 is 0.973 and 0.941, respectively. Finally, in the third phase, the RF model was trained and validated, which obtained a high percentage of success for predicting the academic efficiency category. A structured method for analyzing, measuring, and forecasting efficiency in engineering education is presented to the scientific community and the education sector internationally. The proposed structure enables a decision-making process for continuous improvement in educational contexts.

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Full research paper

A STUDY OF STUDENTS' PREFERENCES IN THE INFORMATION RESOURCES OF THE DIGITAL LEARNING ENVIRONMENT

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ABSTRACT

The digital learning environment comprises various resources - didactically transformed and untransformed information, and mediated communication. Students' information behaviour combines both actions characteristic of the traditional educational process and specific for the digital environment, based on digital tools and user interactions. Students' information behaviour in the digital environment is considered as an indicator of their engagement in various educational activities that contribute to the personalisation of learning. The results of a survey on students' preferences of information resources in the digital environment show that learners use a variety of information sources, but they mainly apply the methods of work in the "traditional" learning paradigm. They insufficiently use the digital environment potential of collaboration, knowledge exchange, and knowledge extraction from authentic sources. Obtained data indicates problems in students' information culture and shortcomings in the methodological support of students' autonomous work. Based on the results, recommendations on creating conditions for developing students' prospective strategies of interaction with digital resources are proposed. These recommendations include a gradual increase of the authentic digital learning resources, an account of students' information preferences, and a particular attention to the management issues in the digital learning environment.

KEYWORDS

Information behaviour, information resources, digital learning environment, information culture, preferences, student

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Highlights

- *Information behaviour reflects a personal information culture.*
- *Students are familiar with the capabilities of digital educational content, but they do not use the entire potential of the digital learning environment - collaboration, knowledge exchange, and knowledge extraction from authentic sources.*
- *Students prefer interactivity and gamification in learning.*

INTRODUCTION

Modern education prepares students for effective activities in the knowledge society, based on the possession of knowledge and the ability to use it. Drucker (2017: 298) emphasised the importance of 'universal skills to use and systematically acquire knowledge as the basis for efficiency, qualifications, and achievements…'. The digital learning environment comprises social experience, scientific knowledge, and educational resources that work efficiently due to the capabilities of multimedia, interactivity, customisation, and productivity. Consequently, methods and technologies of "traditional" education should change to serve students' productivity in the digital learning environment. Educational resources of the progressing digital environment have significant features in comparison with traditional, mainly printed sources of information:

- various information channels in the educational environment;

- variable technologies for organising, storing, and providing students with educational content;
- functional digital resources pedagogical design which contributes to educational process activation and personalisation;
- strengthened role of open educational resources and resources for self-education;
- capabilities of learning content processing with the use of digital tools;
- personalised learning objects.

We need to connect the innovative digital content opportunities to the current knowledge trends in the emerging knowledge society and the long-term demands of the labour market of the digital economy. This problem and the general digitalisation of education objectives are closely interrelated. New meaningful educational goals arise with the influence of changing technological structure, the need to master new digital tools; solve new cognitive problems in the learning process, and further self-development. Constructing a personal evaluative knowledge system, finding personally effective ways to interact with information, and acquiring skills in the digital environment becomes increasingly important for students. Achieving these new goals is impossible without taking into account the individual preferences, opportunities, interests, and initiative of students.

One of the most important educational goals is shaping students' active learning position concerning available information resources. Such a position presumes perception of educational, cultural, and professional information sources not only from the sight of assimilation for solving particular learning problems, but also as a means of self-development that ensures success and competitiveness in the contemporary labour market. Particularly important become such learning skills as a self-directed information search and knowledge extraction, an acquisition of prospective ways to apply knowledge in various situations, creative and research activities in the extensive digital environment. In this context, students' autonomous learning plays an important role and ensures self-education and self-organisation, which are demanded for lifelong learning.

In a complex, rapidly changing world, a comprehensive support of a person as a "full-fledged" author of his life is significant for education, because it helps to expand the range of learning outcomes (Wannemacher, 2016). We need a focused transition from traditional reproductive students' interaction with educational resources, to the production methods that provide the ability to construct knowledge in personal or joint activities and to produce new information products. The implementation of such a paradigm is impossible without the personalisation of learning activities.

Publications on e-learning and digital learning technologies often focus on the content and formats of learning resources (Lafuente, 2017; Lopez-Rosenfeld, 2017; Nau, 2017). However, internal psychological factors (attitudes, motivations, and aspirations of a learner) also determine the effectiveness of a knowledge extraction. Accordingly, in the digital environment, not only a diversity of content, resource presentation modes, and teaching methods should be considered by a teacher, but also a "cognising subject" (a learner) and his information behaviour (Noskova et al., 2018).

The following issues of the design of the digital resources are problematic:

- the core changes in the representation of knowledge in the educational computer systems;
- the ways to get the most advantages of the open digital educational environment;
- the new types of learning tasks that can be solved with digital resources and tools;
- personalised learning activities considering professional digital transformation and human information behaviour;
- students' engagement in the implementation of the lifelong learning strategy, which is a prerequisite for the success of upcoming professional activities.

The main objective of the paper is to study the diversity of students' information preferences in the digital learning environment. We hypothesise that students use a variety of information sources, but they mainly apply the methods of work that they have mastered in the "traditional" (face-to-face) learning paradigm. To a lesser extent, they use the potential of the digital environment associated with collaboration, knowledge exchange, and knowledge extraction from non-adapted (authentic) sources. In other words, students do not use the entire potential of the digital learning environment, which may indicate problems in students' information culture and shortcomings in the methodological support of students' autonomous work.

The paper comprises several sections that describe a theoretical background of the study (what is information behaviour and which sources are available for students in the reach digital environment), methods and materials of the research (aims and structure of the questionnaire for bachelor students), analysis of the obtained results and further discussion of the main issues revealed.

The paper presents an extended and updated version of the report "Diversity of students' information behaviour within a digital learning environment" presented at the 17th International Conference "Efficiency and Responsibility in Education – ERIE 2020" (Noskova, Pavlova and Yakovleva, 2020).

THEORETICAL BACKGROUND

By student's information behaviour, we understand the entirety of human efforts and actions that ensure the search, assimilation, use, and creation of new knowledge, together with its transmission and dissemination in the society (Spink and Cole, 2006; Wilson, 2000). Information behaviour is also considered as a reflection of a personal information culture.

Students and lecturers are increasingly connected by diverse, versatile communication capabilities and digitisation (Huijbers, Sprang and Groen, 2018). Existing pedagogical practices in the digital environment need to be enriched with personality-oriented non-linear educational technologies, providing students a sufficient freedom of learning actions and a possibility of personally understood educational results with satisfaction in the learning process (Laptev and Noskova, 2013). Digital environment instructional design should take into account students' information behaviour models, because the larger part of current learners are digital natives (Noskova, Pavlova and Yakovleva, 2016;.Hayman, Smith and Storrs, 2019; Smith, 2017). Such practices require both technological and methodological restructuring of resource equipment for students' autonomous work. To promote a productive information behaviour of students within a particular learning task framework, a teacher can arrange various learning activities based on the choice of resources, learning methods, and digital tools. At the same time, a teacher needs to reveal and analyse students' preferences in a wide range of information activities. A necessary condition for the students' demand for learning resources new functionality is an open cognitive position purposefully shaped in the educational process. Kholodnaya (2002: 133) defines an open cognitive position as 'a special type of attitude in which individual contemplation is characterised by variability and a variety of subjective ways of understanding the same event, as well as by an adequate susceptibility to unusual aspects of what is happening'. Kholodnaya and Gelfman (2016) stressed that the learning content should have a developing effect and solve the problems of intellectual upbringing. The authors identified learning content features that contribute to a student's open cognitive position shaping. Among these features, a specific information structure is named, which allows integrating declarative and procedural knowledge, contracted and expanded content, contradictions, alternative points of view, complex situations, instructions, cases, etc. The identified relationship between the learning content structure and a personal learning position should find new implementations in the resources of the digital educational environment.

Digital learning resources are considered as the basic component of students' independent activity in an enriched, expanded information space. The pedagogical support priority comprises a personal educational request, personal learning strategy design, and self-realisation in learning activities. Tracking the changing information request of young people who are growing up in a rich media environment is coherent with the idea of a personal digital learning environment. In this context, we rely on the main features of a personal learning environment (Downes, 2010; Attwell, 2007), which allow students to 'regain control of their learning process by being able to choose and mix from several alternatives for (among other actions) capturing, storing, classifying, analysing, creating, sharing, disseminating and processing information, thus creating knowledge' (Kompen et al., 2019: 194).

In the digital learning environment, the principles of connectivity formulated by Siemens (2005) are reflected, which has a significant impact on students' information behaviour. The following provisions may be mentioned as an example:

- 'Learning and knowledge rests in diversity of opinions.
- Learning is a process of connecting specialised nodes or information sources.
- Learning may reside in non-human appliances.
- The capacity to know more is more critical than what is currently known
- Nurturing and maintaining connections is needed to facilitate continual learning.
- Ability to see connections between fields, ideas, and concepts is a core skill.
- Currency (accurate, up-to-date knowledge) is the intent of all connectivist learning activities.
- Decision-making is itself a learning process. Choosing what to learn and the meaning of incoming information is seen through the lens of a shifting reality. While there is a right answer now, it may be wrong tomorrow due to alterations in the information climate affecting the decision' (Siemens, 2005: 5-6).

The study of students' information behaviour is especially relevant in the context of the strengthening trend of blended learning, which is noted in the Educause Horizon Report (2019: 12): 'students report a preference for blended learning, citing flexibility, ease of access, and the integration of sophisticated multimedia'. Therefore, blended learning implementation presumes a special complex of pedagogical methods, digital teaching tools, and providing interaction with digital learning content, educational communication, and learning activities management.

Students' information behaviour analysis in the digital environment denotes new opportunities for interaction with information and people in the process of solving educational problems. A multilevel resource environment of a contemporary student, incorporating both didactically transformed and untransformed ("raw") information, traditional and network communication models. Accordingly, the information behaviour of a student combines actions characteristic of the traditional educational process and new actions, based on the specifics of the digital information space, the possibilities of digital tools, and user interactions. In the open, accessible, and frequently updated digital environment, the ability to correctly formulate search queries and quickly extract the necessary knowledge becomes a priority. These ideas are international trends. They are reflected in the competency frameworks for citizens in general and representatives of specific professions in particular.

For example, in the Russian educational standards of teacher education, there is a category of "systematic and critical thinking" that comprises such competencies as search, critical analysis, and synthesis of information (Order on the approval of the Federal state educational standard of the higher education, a bachelor degree in training 44.03.01 Pedagogical education, Ministry of Science and Higher Education of the Russian Federation, 2018). The Digital Competence Framework for Educators – DigCompEdu – also introduces a category of "digital resources" as one of the important objects of teacher activities (Redecker, 2017). That means that a teacher needs to be ken at identifying, assessing, and selecting digital resources for teaching and learning. The "Europass" initiative relevant for any European citizen offers a digital competences self-assessment grid that includes the "information processing" category reflecting the ongoing development of competencies from basic online search to proficient search strategies, assessment of information validity, and credibility, and advanced techniques of information retrieval.

The report "Future Work Skills 2020", published in 2011 by the Institute for the Future in Palo Alto (USA) presented a map of professional skills of the future (Future Work Skills Summary Map, 2011). The map along with many important skills (transdisciplinarity, project thinking, intercultural competence, innovative adaptive thinking, the definition of meaning and social intelligence), highlighted the information skills - literacy in the new media environment, cognitive loading management, virtual collaboration, and computational thinking.

In the course of a large-scale study "Competence Foresight 2030" (Skolkovo), in which more than 2500 Russian and international experts took part, a list of "over-professional skills and abilities" was presented (Agency for Strategic Initiatives, 2015). This list as discussed above examples contains the competencies of an information nature. Among them are systemic thinking, programming of IT solutions (management of complex automated systems, interaction with artificial intelligence), project management (the ability to design, plan and organise projects and processes), readiness to work in the mode of high uncertainty and a quick change of conditions (the ability to quickly make decisions, respond to changing working conditions, the ability to allocate resources and manage time).

MATERIALS AND METHODS

Sample of Research

To identify a diversity of students' information behaviour in the digital learning environment, a survey was conducted for the first-year bachelor students of the Herzen State Pedagogical University of Russia. The sample included 500 respondents: age-balanced sample (17-19 years), specifically, 433 (86.6%) female and 67 (13.4%) male students. The gender distribution is not surprising since for many years in Russia there has been a tendency for girls to prevail as students of teacher education. The experimental work was carried out in the frame of the "Infocommunication Technology" course for the first-year bachelor students of the Herzen University (2019-2020 academic year). This is a mandatory course for all first-year students, and it restarts every semester. In this particular study, students from two areas of training took part - future teachers of primary school (300 students, 60%) and future teachers of history, social sciences, and philosophy (200 students, 40%).

The sample was chosen for several reasons. Firstly, during the first year, students are adapting to the university (e.g., they understand the organisation of the learning process, requirements, rules, and recommended sources of information). Secondly, in further learning, they will make use of an autonomous work with information sources even more; therefore, it is necessary to identify problematic aspects that should be analysed. We assumed that students' preferences in the information resources of the digital learning environment could vary for the groups of students in different areas of training.

Research materials

A questionnaire was elaborated to reveal students' understanding of various strategies to interact with digital learning resources and to assess their preferences in digital tools. Respondents were asked to relate statements connected to their behaviour strategies and use of digital resources to a 5-point scale (1 point – never, 2 points – once or twice, 3 – rarely, 4 – often, 5 – constantly). The questionnaire consisted of several sections, combining questions related to the following aspects.

Knowledge acquisition:

- Students' preferences in terms of digital learning content (digitised printed publications, video lectures recorded by teachers, digital presentations and visualisations, interactive content, etc.);
- Selection of reliable, relevant information in various formats;
- Memorisation;
- Comprehension;

A sample question: "Evaluate your preferences in the ways of memorising the necessary terms and facts: tests for training and self-control, flashcard applications, interactive timelines, traditional memorisation".

Knowledge application:

- Processing of digital learning information;
- Analytical and synthetic processing of digital learning information extracted from multiple information sources;
- Attitude to gamification.

A sample question: "Evaluate your preferences in the ways of applying the acquired knowledge: traditional assignments; discussions; peer assessment; compilation of tests, crosswords, quizzes, games; scribing".

Designing a personal information environment:

- Use of MOOCs, micro-learning, mobile resources;
- Personal learning resources database;
- Demand to improve skills in determining effective interaction with digital educational information.

A sample question: "Evaluate your preferences regarding the use of MOOCs in the process of study: tests, lecture fragments, MOOCs to obtain a certificate, MOOCs for self-education".

Joint network activities with digital learning content:

- Collaborate learning;
- Discussions;
- Collaborate digital products;
- Virtual labs, gaming environments.

A sample question: "Evaluate your preferences regarding joint network activities with digital learning content: co-editing documents, online discussion, joint development of digital products, interaction in digital environments".

Pedagogical support of learners' information behaviour:

- Assessment criteria;
- Deadlines;
- Reminders;
- Penalty points;
- Progress bar;
- Rating;
- Badges.

A sample question: "Evaluate your preferences in teachers' management of your learning activities: clear assessment criteria, strict deadlines, reminders, penalty points, progress bar, rating, badges".

Overall, the data on 42 variables were collected and analysed. The answers underwent statistical analysis: descriptive statistics for all questions, including the distribution of answers to questions for all respondents. Due to the nature of survey data, non-parametric tests were used in the analysis. Differences in questionnaire answers between the respondents were detected by Mann-Whitney U-test. All the participants were conditionally divided into two groups according to the features of training – the area of scientific knowledge and future professional activities. Students of the Institute of Childhood (future teachers of primary school) formed the first group and the second group comprised students of the Faculty of History and Social Sciences and the Institute of Human Philosophy (future teachers of history, social sciences, and philosophy). Differences in nominal data among groups were tested Chi-square test or Fisher's exact test. The relationship between the survey questions was analysed with Spearman's rank correlation coefficient. All results were considered significant at $p < 0.05$. The analysis was performed with the statistical package STATISTICA v. 12.0 (StatSoft. Inc., Tulsa, Oklahoma, USA).

RESULTS

General trends in students' preferences in the information resources of the digital learning environment

At the first stage of the study, the data of the whole sample was analysed to identify general trends in students' preferences in the information resources of the digital learning environment. The respondents rated all sources of information and strategies for working with them above the average level of significance (the median of none of the variables was lower than 3). However, the most interesting are the variables that students rated the highest (Me=5) and the lowest (Me=3). They are presented in Figure 1.

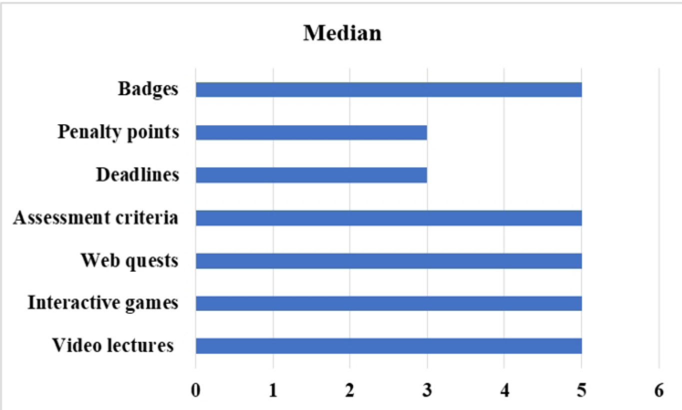

Figure 1: Students' preferences in the interactions with digital educational content (source: own calculation)

The generalised histogram shows a relatively even distribution of students' attitudes to various techniques that organise the interaction with digital educational content. We see that the most highly rated are interactive, gaming, multimedia tools, and methods. Consequently, students prefer high-quality educational videos and interactive training programmes. Besides, students gave a low evaluation of the "hard" methods of pedagogical support (ratings, strict deadlines, and penalty points), feeling that these methods are discrepant from the information behaviour freedom in the digital learning environment. The deeper analysis showed that students do not highly appreciate peer-to-peer evaluation in the process of interacting with digital educational content. This probably indicates a lack of experience and an inadequate understanding of the opportunities for such techniques. The study particularly analysed data on students' preferences regarding sources of digital educational information (Table 1).

The data demonstrates that traditional digitised printed publications still occupy a leading position among the sources of educational information, but learners realise a variety of digital alternatives. However, at the same time, more troubling is that almost 48% of students noted they often use information from unreliable sources. These findings indicate both a low information culture of students and shortcomings in the methodological support of students' autonomous work.

The correlation analysis helped to find relations between the significance of the variables. In the first block of the questionnaire (knowledge acquisition), the closest correlation was found between the variables "tests for self-control" and "tests for training" ($r = 0.6$). In the second block (knowledge application), the correlations between the variables "flashcards" and "interactive timelines" ($r = 0.7$), "interactive games" and "mindmaps" ($r = 0.6$), "infographics" and "quiz making" ($r = 0.4$) were found. In the third block (designing a personal information environment), the correlation between the variables "MOOC lectures" and "MOOC

Sources of information \ Scoring	1	2	3	4	5
Digitised educational publications within an e-course	14	21	20	33	16
E-libraries	3	7	21	32	41
Portals and databases	1	9	21	34	39
Educational video channels and podcasts	6	6	22	23	47
Official scientific and educational sites	2	4	16	38	44
Mass media	3	10	31	29	31
Reputable professionals and scientists personal sites	7	13	25	39	30
Information sites of unspecified affiliation	28	24	8	25	19
Open digital educational resources	2	7	12	28	55
File hosting and torrent trackers	19	14	23	22	26

Table 1: A variety of digital educational information sources used by students, in % (source: own calculation)

tests" (r = 0.7) was revealed. In the fourth block (joint network activities with digital learning content), the correlation between the variables "network discussions" and "virtual labs, gaming environments" was found (r = 0.5), together with the correlation between "web quests" and "didactic games with a virtual agent" (r = 0.8). In the last block (pedagogical support of learners' information behaviour), the correlations were found between the variables "progress bar" and "badges" (r = 0.6), "deadlines" and "penalty points" (r = 0.7).

We see that students perceive the digital learning environment as something created for them and objectively prepared for use. None of the variables related to the design of a personal information environment and joint network activities with digital learning content received the maximum scores.

The survey shows that students are familiar with a variety of capabilities that allow them to interact actively with digital educational content, process it, and create an individualised information product. Preferences regarding gamification are clearly expressed, and that indicates students' willingness to learn interactively. Students prefer educational video content, the source of which can be both open video channels and online courses (videos with a high level of static and dynamic visualisation, expert explanation, and emotional expressiveness). Nevertheless, encouraged to implement various computer practices, many still prefer traditional educational resources. Students demand interactive learning content almost equally with traditional texts, and teachers should not ignore this. Respective to the modern educational process, methods of interaction with digital educational content assume a variety of learning activities, and at the same time require special efforts of teachers and students to minimise risks of the digital information environment redundancy.

Some features of information resources preferences for students from different areas of education

At the second stage of the study, statistically significant differences in the responses of representatives of different areas of training were identified. It should be noted that no statistically significant differences in terms of gender were revealed. Perhaps this is due to the features of the sample, which will be described in the "Discussion" section. The answers will be further described following the structure of the questionnaire - knowledge acquisition, knowledge application, designing a personal information environment, joint network activities with digital learning content, and pedagogical support of learners' information behaviour (Tables 2-6). Answers that have statistically significant difference with $p < 0.05$ are marked in red.

We see (Table 2) that in students' preferences characterising their information behaviour related to knowledge acquisition in the digital educational environment, with many similar features, there are some differences in the groups. Students from the first group, future primary school teachers, prefer video lectures to a greater degree, which is the most traditional form of presenting new material (Q. 2). At the same time, students in this group are very interested in interactive tutorials (Q. 4). This is probably because students are aware that a large number of interactive educational and developmental programs for preschool and primary school age are being created and distributed. Future teachers want to understand and master this way of acquiring knowledge better.

Students from the second group, which brought together representatives of the Faculty of Social Sciences and the Institute of Human Philosophy (future teachers of history, social sciences, and philosophy), more clearly reflected in their preferences such ways of presenting educational information as timelines, interactive flashcards, spreadsheets, interactive exercises on the compilation and comparison of series (Q. 8, Q. 13, Q. 15, Q. 16). In both groups, students showed that they understand the need to improve their information behaviour in the process of acquiring knowledge (Q. 17). At the same time, it should be noted that the range of preferences is significant, i.e. some students express a sharp rejection of digital interactive forms of interaction with educational information or completely reject traditional methods. Nevertheless, a median of "4" for almost all questions in this section of the survey demonstrates students' desire to use all these forms in the educational process.

Students' preferences in terms of the digital techniques used for knowledge application did not show significant differences (Table 3). We can only note a few more preferences of students from the second group expressed about online discussions, which is associated with the peculiarities of the areas of learning, including the comprehension of a large number of complex ambiguous problems. In general, students show a high willingness to act in different ways and in different digital formats in the process of solving educational problems on the application of knowledge in new situations.

Questions	Descriptive statistics Me (IQR)*				p-value
	Group 1 *N*=300 (Institute of Childhood)		Group 1 *N*=200 (Faculty of History and Social Sciences; Institute of Human Philosophy)		
	Mean	Me (IQR)*	Mean	Me (IQR)*	
Q. 1 Traditional digitised printed publications	4.009	Me=4 (3 – 5)	4.429	Me=4 (1 – 5)	0.048
Q. 2 Video lectures	4.435	Me=5 (2 – 5)	4.364	Me=4 (3 – 5)	0.043
Q. 3 Digital presentations and visualisations	3.930	Me=4 (1 – 5)	3.860	Me=4 (1 – 5)	0.367
Q.4. Interactive training programmes	4.345	Me=4 (3 – 5)	3.730	Me=4 (1 – 5)	0.245
Q. 6. Tests for training and self-control	3.990	Me=4 (1 – 5)	3.970	Me=4 (3 – 5)	< 0.001
Q. 7. Flashcards (Quizlet, Flashcard Exchange, BrainFlips, etc.)	3.772	Me=4 (1 – 5)	3,405	Me=4 (2 – 5)	0.380
Q.8. Interactive timelines (Timegraphics)	3.376	Me=4 (1 – 5)	4.434	Me=4 (2 – 5)	0.254
Q. 9. Traditional memorisation	3.574	Me=4 (1 – 5)	4.011	Me=4 (2 – 5)	0.134
Q. 11. Mobile polls	3.931	Me=4 (1 – 5)	3.926	Me=4 (2 – 5)	0.044
Q. 12. Interactive didactic games	4.287	Me=5 (1 – 5)	4.101	Me=4 (2 – 5)	0.018
Q. 13. Mind maps	3.821	Me=4 (1 – 5)	4.223	Me= (2 – 5)	0.276
Q. 14. Tests	3.811	Me=4 (1 – 5)	3.827	Me=4 (2 – 5)	0.144
Q. 15. Filling in tables (conceptual, comparative, etc.)	3.611	Me=4 (1 – 5)	4.330	Me=4 (2 – 5)	0.132
Q. 16. Interactive exercises on the compilation and comparison of series	3.703	Me=4 (1 – 5)	4.630	Me=4 (2 – 5)	0.351
Q. 17. Intention to develop new ways of building knowledge	4.454	Me=4 (3 – 5)	4.433	Me=4 (3 – 5)	< 0.001

Table 2: Knowledge acquisition (*Me – median, IQR – interquartile range) (source: own calculation)

Questions	Descriptive statistics Me (IQR)*				p-value
	Group 1 *N*=300 (Institute of Childhood)		Group 1 *N*=200 (Faculty of History and Social Sciences; Institute of Human Philosophy)		
	Mean	Me (IQR)*	Mean	Me (IQR)*	
Q. 18. Traditional assignments	3.801	Me=4 (1 – 5)	3.821	Me=4 (2 – 5)	0.142
Q. 19. Discussions with peers (forum, discussion in the social network)	4.108	Me=4 (1 – 5)	4.444	Me=4 (2 – 5)	0.015
Q. 20. Joint development of information products (wiki, online documents, etc.)	3.703	Me=4 (1 – 5)	3.711	Me=4 (2 – 5)	0.212
Q. 21. Compilation of tests, crosswords, quizzes, games	3.851	Me=4 (1 – 5)	3.703	Me=4 (1 – 5)	0.648
Q. 22. Scribing (explanation through sketches, drawings), services like Sparkol (stylistics of drawing with a felt-tip pen)	3.584	Me=4 (1 – 5)	3.331	Me=4 (1 – 5)	0.439
Q. 23. Intention to improve the ability to apply knowledge in a digital environment	4.315	Me=5 (3 – 5)	4.431	Me=4 (3 – 5)	0.012

Table 3: Knowledge application (*Me – median, IQR – interquartile range) (source: own calculation)

Questions	Descriptive statistics Me (IQR)*				p-value
	Group 1 *N*=300 (Institute of Childhood)		Group 1 *N*=200 (Faculty of History and Social Sciences; Institute of Human Philosophy)		
	Mean	Me (IQR)*	Mean	Me (IQR)*	
Q. 24. Create a bookmarking system for educational Internet resources	3.801	Me=4 (1 – 5)	4.406	Me=4 (3 – 5)	0.317
Q. 25. Use subscriptions to updated educational online resources	4.158	Me=4 (1 – 5)	4.537	Me=4 (3 – 5)	0.081
Q. 26. Use the materials of MOOCs in the process of studying	3.403	Me=3 (1 – 5)	3.603	Me=3 (2 – 5)	0.031
Q. 27. Systematise educational information on a local computer or a portable device	4.851	Me=4 (3 – 5)	4.830	Me=4 (3 – 5)	0.126
Q. 28. Organise educational information in a cloud storage	3.384	Me=3 (1 – 5)	3.217	Me=3 (3 – 5)	0.219
Q. 29. Use the capabilities of file managers (colour marking, sorting and filtering files, synchronising directories, etc.)	3.102	Me=3 (1 – 5)	3.056	Me=3 (3 – 5)	0.311
Q. 30. Reliably ensure the safety of important educational information (backup, archiving, anti-virus protection, synchronisation of information on different devices and in cloud storage)	3.406	Me=4 (1 – 5)	3.468	Me=4 (2 – 5)	0.142
Q. 31. Intention to improve the skills of designing a personal information environment	4.283	Me=5 (3 – 5)	4.346	Me=5 (3 – 5)	0.024

Table 4: Designing a personal information environment (*Me – median, IQR – interquartile range) (source: own calculation)

The questions focused on identifying the features of students' information behaviour in terms of designing a personal information environment, pursued an obvious goal - to attract the attention of students and to emphasise the importance of their activity in this aspect (Table 4). The data corresponding to this section of the survey showed a number, albeit not very significant, of differences in students' attitudes to ways of organising, storing, updating useful and necessary digital resources in training. For example, students from the second group take the issues of interacting with relevant information resources and receiving updated information more seriously (Q. 24).

Students of the studied groups showed that they rather far from using the possibilities of ensuring security and information management in their personal information environment. The demand for materials from MOOCs in the process of learning is rather low (Q. 26: Me=3). A likely result of focusing on students' problems of the active formation of their personal information environments was the answer to the question about the intentions to improve the ability to design a personal information environment (Q. 31: Me=5; IQR=3-5).

Questions	Descriptive statistics Me (IQR)*				p-value
	Group 1 *N*=300 (Institute of Childhood)		Group 1 *N*=200 (Faculty of History and Social Sciences; Institute of Human Philosophy)		
	Mean	Me (IQR)*	Mean	Me (IQR)*	
Q. 32. Co-editing documents	3.881	Me=4 (1 – 5)	3.673	Me=4 (2 – 5)	0.041
Q. 33. Blogging, activity in online educational communities	4.089	Me=4 (1 – 5)	4.320	Me=4 (2 – 5)	0.244
Q. 34. Joint development of digital content	3.653	Me=4 (1 – 5)	3.549	Me=4 (2 – 5)	0.313
Q. 35. Interaction in digital environments (virtual laboratories, virtual worlds, gaming environments)	3.831	Me=4 (1 – 5)	3.852	Me=4 (2 – 5)	0.021
Q. 36. Intention to improve the skills of joint network learning activities	3.950	Me=4 (1 – 5)	3.778	Me=4 (2 – 5)	0.028

Table 5: Joint network learning activities (*Me – median, IQR – interquartile range) (source: own calculation)

Joint forms of work, communication, cooperation are the most significant advantages of the digital educational environment. The corresponding section of the survey was designed to identify students' preferences in terms of joint actions in the process of solving educational problems (Table 5). There were no significant differences in the studied groups, except for the last question, related to the desire to improve the skills of joint network learning activities (Q. 36). Future primary school teachers are more aware of the need to fully unfold the educational potential of network communication.

Questions	Descriptive statistics Me (IQR)*				*p*-value
	Group 1 *N*=300 (Institute of Childhood)		Group 1 N=200 (Faculty of History and Social Sciences; Institute of Human Philosophy)		
	Mean	Me (IQR)*	Mean	Me (IQR)*	
Q. 37. Assessment criteria	4.337	Me=5 (1 – 5)	4.427	Me=5 (2 – 5)	0.018
Q. 38. Deadlines	3.198	Me=3 (1 – 5)	3.185	Me=3 (2 – 5)	0.027
Q. 39. Penalty points	3.049	Me=3 (1 – 5)	3.117	Me=3 (2 – 5)	0.038
Q. 40 Visual progress bar	4.080	Me=4 (1 – 5)	4.169	Me=4 (2 – 5)	0.218
Q. 41. Ratings	4.059	Me=4 (1 – 5)	4.036	Me=4 (2 – 5)	0.421
Q. 42. Badges	4.119	Me=4 (1 – 5)	3.917	Me=4 (2 – 5)	0.287
Q. 43. Intention to improve the skills of self-management	4.256	Me=4 (1 – 5)	4.273	Me=4 (2 – 5)	0.349

Table 6: Pedagogical support of learners' information behaviour (*Me – median, IQR – interquartile range) (source: own calculation)

The results of the survey section on the pedagogical support of learners' information behaviour (Table 6) showed that students of both groups are positive about the fact that clear criteria for evaluating their actions with educational information resources are important (Q. 37). A negative attitude is shown by students concerning "hard" management practices, which reflects their correct understanding of the basic capabilities of the open digital learning environment, which is designed to expand the freedom of information and educational activities (Q. 38, Q. 39: Me=3). Students of the first group showed great interest in using the reward system, which corresponds to their general preferences in the application of gamification techniques (Q. 42). A median of "4", obtained for most of the answers to the questions in this section, indicates that students understand the need to not only increase the saturation of their information environment, to make it more structured, but also strive for manageability of the information space and educational activities. Quite high values of the average score for answers to the question about the desire to improve self-management skills while working with educational resources indicate the correct vector for improving students' information behaviour (Q. 43).

Summing up, when building the educational process in the digital environment, it is necessary to take into account students' information preferences. There might be some differences in the information behaviour of students studying in different directions. The range of results also indicates the need to take into account different requests, which is impossible without providing the greatest possible freedom of information. This does not mean that electronic courses and digital content, in general, should be provided in all possible formats. Nevertheless, this means that students should be able to use as many digital techniques and tools as possible for the interaction with educational information and processing it while developing new competencies.

DISCUSSION

Issues of students' educational preferences in the information resources of the digital learning environment are considered today in different contexts. In a global context, Skalaban et al. (2020) note that analysis of students' preferences is closely related to the competition of universities in the educational services market. For example, the revealed interest of students in open educational resources is an incentive for their creation by universities. This makes the university more attractive, open, and modern.

The digital learning environment gives the ground for the personalisation of learning. Personalisation provides such a curriculum design when a learner follows a personal learning path (Nabizadeh et al., 2020). It is important to review the indicators of efficient information behaviour and make efforts to support students' self-management, initiative in learning, and personal productivity. Personalisation affects the quality and cost of education (Iatrellis et al., 2020).

Personalisation of information behaviour in the digital learning environment is one of the problems of education (Han and Ellis, 2020). Personalisation requires simultaneous consideration of many factors, e.g., risks of dripping out (Xing and Du, 2019), need for emotional support, and behavioural regulation (Zojaji and Peters, 2019). Quantities and correlations of these factors are not constant and alter in the educational process. Personalisation of learning is ensured by both an active student's position and a quality of digital learning environment (information, communication, management conditions).

In this paper, we propose five directions to reveal students' understanding of various strategies to interact with digital learning resources and to assess their preferences in digital tools - knowledge acquisition, knowledge application, designing a personal information environment, joint network activities with digital learning content, and pedagogical support of learners' information behaviour.

Referring to similar studies in the listed areas, we can note that the questions of students' preferences in knowledge acquisition, knowledge application are closely connected. Thus, Bates (2015) found that "at a university level we need strategies to gradually move students from concrete learning based on personal experience to abstract, reflective learning that can then be applied to new contexts and situations. Technology can be particularly helpful for that". For example, when designing an e-course, it is advisable to provide learners with variable media resources, ensuring "'richness' of possible content". Therefore, if we strive to design a diverse digital environment and provide students with a choice of learning activities, we need to be aware that by the means of a "manual control", it is not feasible to support students' interaction with "redundant" learning resources. The digital learning environment has special tools for a dynamic data analysis (users' input and their so-called "digital footprints") to provide deeper information on learners' decisions and activities.

To enrich the capabilities and functionality of digital educational activities, a granular digital learning content approach is promising. It assumes multiple, varied methods for its inclusion in the learning process. The diverse students' information behaviour prerequisites are not at the level of available digital tools, but at the level of the teaching methodology in the digital environment. This methodology reflects the specifics of the digital educational environment in the following key areas:

- Expanded range of educational goals, with the focus on prospective cognitive, social, digital skills (Mayer, 2019);
- Extended and varied digital learning content (Jagušt and Botički, 2019);
- Various semiotic systems and information structures of digital learning content (Sansone et al., 2020);
- Techniques and technologies for enhancing and personalising interaction with learning content and digital educational communication (Segal et al., 2019).

Belyakova and Zakharova (2019) studied some features of university students' interaction with educational content. They identified typological groups of learners in terms of general activity of referring to educational resources, as well as in terms of resource content - "passive", "active", "advanced", "professionally-oriented" and "humanities". In the study, students of all courses showed high activity in using digital and printed educational resources (preferably in text format) and low activity in working with such educational content as audio lectures, electronic simulators, and open e-courses (including MOOCs). Resembling results were obtained by Wilhelm-Chapin and Koszalka (2020), who showed that e-text and video tutorials were the most demanded sources of information within the e-course. Johnston and Salaz (2019) proved students' remaining demand for printed learning materials. However, the main reasons for that along with eyestrain, tactile features were the ability to highlight and take notes. That might mean that it is important for students to actively master new knowledge. Perhaps, they need not just digitised textbooks, but interactive materials with the ability to adapt them to their thinking process. Information technology development demonstrates a proactive influence on educational environment design that enables new forms, methods, and technologies of learning activities. The learning activity shifts toward interactivity, variability, and ambiguity of learning contexts. This trend is reflected in the educational science research (Takev, Rodriguez-Artacho and Somova, 2019; Farrow, De Los Arcos and Pitt, 2016).

Designing a personal information environment is an important area of research. To acquire prospective competencies in terms of interaction with information, from the very beginning of training a student needs to be in a gradually expanding information environment. This is possible due to a systematic transition from working with digital resources selected by the teacher to resources from the ubiquitous information environment, including interdisciplinary and foreign resources. An authentic learning approach also highlights these ideas of "meaningful, real-life situations" for acquiring new skills (Iucu and Marin, 2014: 410).

Performing such sometimes-difficult tasks as analysis of digital libraries, work with bibliographic lists and annotated catalogues, systematisation of links to information sources on a personal website, mind mapping, and visualisation, a student becomes aware of personal preferences of information sources, develops an individual style of activity, personal strategy of information behaviour. This will become the basis of a personalised educational path based on open educational resources (e.g., MOOC platforms) for lifelong learning. Prospects are individualised educational products that meet the needs of both students and employers.

Along with the study of new information, the modern learning process is impossible without interaction and co-working - joint network activities with digital learning content. Therefore, of interest are also questions of students' preferences in communication resources that support collaborative knowledge building (Duvall, Matranga and Silverman, 2020). Kent and Rechavi (2020) propose several types of interactions among learners: "digitally speaking" (learners who contribute content), "digitally listening" (learners who prefer consuming content), and "organisation of digital content". This discovery confirms the relevance of the study of students' preferences in joint network activities with digital learning content. Thus, Sleeman, Lang and Dakich (2020) showed that students' involvement in collaboration and communication via social media contributes to their engagement in learning and co-working with their peers, which is particularly important for international students' academic learning and social adjustment.

Pedagogical support of learners' information behaviour was researched by Hegarty and Thompson (2019) in the context of student-centred learning. The authors observed that regular feedback from the teacher (e.g., with the help of mobile technologies) contributes to the development of learner capability (critical thinking, social justice awareness, reasoning). Somyürek, Brusilovsky and Guerra (2020) went deeper into the issues of feedback and described several models of assessment that could be used in e-courses - open learner modelling (when a learner assesses himself) and open social learner modelling (when a learner can compare his outcomes with other learners). Both models help to improve students' self-assessment skills, however, the second model contributes to the relative knowledge assessment that is very important for understanding the reasons for being superior or inferior. This understanding is connected with social comparison as a mechanism of self-knowledge. The findings of our study also lie in this context because students showed preferences in such digital tools that help to improve the skills of self-management - visual progress bar, rating, etc. Kuzmanović, Andjelković-Labrović and Nikodijević (2019) revealed two typological groups of students according to their attitude to pedagogical support within an e-course – "results-oriented" (who prefer to study more at their own pace and have prepared content-on-demand) and "process-oriented" (who prefer to be "in the process of learning" through classroom live broadcasting).

There are several limitations of the particular study described in the paper. The first limitation emerges from the research sample that involved mostly female young participants from the humanitarian area of education. The second limitation is related to the learners' ICT experience. First-year students effectively apply technology to solve everyday problems, but they have not yet acquired enough experience in their application in solving educational and future professional problems. The third limitation is associated with the national and socio-cultural conditions of higher education in Russia, together with the particular case of the pedagogical university. Nevertheless, the findings can be beneficial for other universities in terms of e-learning practices, digital content design, facilitation, and support of students' autonomy in the learning process. The listed limitations help to see the prospects for further research.

CONCLUSION

Summing up, we can offer recommendations on creating conditions for students to master prospective strategies for interacting with digital resources. These approaches apply to the development of e-learning courses.

It is necessary to implement a gradual change in the ratio of selected, didactically transformed, and untransformed information, including foreign language sources. Along with this, attention should be paid to digital tools that facilitate the solution of information processing tasks: automated intellectual translation, work with knowledge bases, conceptual mind maps, etc. This will allow students to master the competencies of critical thinking, systemic thinking, and intercultural communication.

The preferences of students in the field of digital resources should be taken into account: the digital environment should offer them not only numerous text materials, but also multimedia, video lectures, interactive tasks, and tests. Productive is the use of gamification techniques to increase motivation and enhance the learning process. It is important that students not only can receive ready-made resources, but also take part in creating their information products, share them with peers, and discuss.

Particular attention should be paid to management issues in the digital environment. The priority of flexible management approaches is needed, as students feel the possibilities of educational freedom in the digital environment. However, the teacher can use many tools to monitor student activity. We are talking about persisting and accumulating "traces" of students' educational activities. Digital footprints in the accumulative mode allow us to track personal indicators of students' development and learning outcomes (electronic portfolio), to analyse students' activity, information, and communication and technological preferences in the learning process. The study of different types of educational activity of students (their frequency and rhythm) in the digital environment, comparing the values with the average indicator in the group allows us to assess the regularity of educational activity, the ability to work independently, to determine an individual learning style.

The issues of students' information behaviour, capabilities, interests, aspirations, and initiatives in the digital learning environment, need further reflection. This complex problem leads to the new pedagogical design of the digital learning environment and its methodological and technological transformation. Students' open learning positions and innovative ways of productive interaction with information are of particular importance because knowledge and technology change rapidly. The value of the ability to learn independently, to choose optimal resources, strategies, and tools increases significantly. On the one hand, diverse activities with digital content are highly demanded by students, but their expectations are not always justified by real educational practices. On the other hand, students sometimes prefer to act in traditional ways, having insufficient experience of an autonomous learning activity in an open digital environment.

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