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PAPER ON EDUCATION

Progress in Chemistry Studies for Students of Industrial Pharmacy Speciality with Different Learning Styles

Tetiana M. Derkach

Kyiv National University of Technologies and Design, Nemyrovycha-Danchenka St, 2, Kyiv, 01010, Ukraine.

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Abstract:

The paper goal was to analyse the actual learning preferences of students in the speciality "Industrial Pharmacy" and find correlations between the learning styles and academic success in the study of chemistry. The Indices of Learning Styles by Felder-Soloman's model were investigated for 1st to 5th-year students. The preferred learning styles do not change in the course of 4-years undergraduate studies and are described by the propensity to active (65-79% out of all students), sensitive (82-92%), visual (75-81%) and sequential (64-73%) manners of study. Master students are more susceptible to the reflective (43% of graduates vs 29% of undergraduates), intuitive (29% vs 12%) and verbal styles (43% vs 23%). No significant changes take place in the sequential-global dimension. The change in the general profile of a group of master students occurs at a stage of additional selection of graduates when they enter their master's course. Progress in studies of eight chemistry and chemical technology disciplines was compared for students with typical and non-typical profiles. The higher the number of typical styles in learning preferences, the more definite distinction is observed in the academic performance. Students with typical learning profiles usually demonstrate better academic performance in studying chemical disciplines, but the difference becomes statistically significant with increasing the number of typical styles in learning preferences.

Keywords: correlation between learning styles and progress in chemistry studies; Index of Learning Style; industrial pharmacy speciality; typical learning profile

1. Introduction

Individualisation of education and the increasing use of electronic learning resources (e-resources) on the base of information and communication technologies (ICTs) are the mainstream of modern development of higher education. However, extensive use of ICT-based e-resources in teaching does not automatically improve the quality of education [1-3]. Determining the styles of learning for individual students and predominant profiles of student groups is an essential component of developing the best pedagogical approaches, building a training course and ensuring high-quality learning. The learning preferences of students are known to depend on the area of study [4] and change in a wide range of values. The origin of this phenomenon is still widely debated, but the vital role of the learning environment, including the used educational technology and resources, teaching methods and approaches, and other potentialities of educational institutions and teachers, are usually recognised as important factors affecting the learning styles [5, 6].

At the same time, learning preferences are relatively stable because they represent a cognitive, psychological and emotional behaviour of a person and identify the ways of a person's interaction with the learning environment. Such a definition considers a preferred learning style as an adaptive strategic response to a situation which depends on many different factors but simultaneously is a rather stable mode associated with personal characteristics. A variety of approaches are applied to characterise

*Corresponding author. E-mail: derkach.tm@knutd.edu.ua

the learning styles of individuals, but no standard procedures have been universally recognised so far [7]. The Index of Learning Style (ILS), developed in the works of R. Felder with co-authors more than 20 years ago, is still used among others to analyse learning styles [8, 9].

Correlations between the learning styles and the academic performance of students are often discussed, but the conclusions amaze at diversity [10, 11]. No statistically significant interdependences were found in some research [10, 12-14] while quite distinct interrelations were reported in other works [15-17]. The clarification of this question is vital to the successful implementation of modern ICTs into the educational process. The effective use of e-resources requires consideration of students' learning preferences because the perception of some resources depends on cognitive and learning styles of individuals, being effective for teaching some persons and simultaneously inefficient for others. In other words, some e-resources are sensitive to preferred learning style while other resources are equally apprehended by all students. This problem was studied in detail for the case of teaching university courses of basic chemical disciplines in some previous works [18, 19].

ICT-based means are progressively employed in the training of future pharmacists [14,20] while little information is known about students' preferences concerning both learning resources and learning styles [21-23]. On the one hand, some studies show [21,24] that learning profiles of pharmacy students are generally similar to those of medical students [25-27]. On the other hand, the learning preferences of students of the speciality "Industrial Pharmacy" are close to those of students of natural sciences, in particular, future chemists [23].

There is even less information about the correlation between academic performance and learning preferences of pharmacy students. For example, no statistically significant interdependence was found between the indicators of separate styles identified by the Felder-Solomon method and progress in studies [14]. In this work, all students were divided into a group with typical and non-typical learning profiles. The latter consisted of individuals, which demonstrated at least one preferred style different from the four typical styles.

It is worthy to note that a learning profile consists of a combination of person's preferences in several dimensions. In the Felder-Solomon method, four dimensions are used, each of which characterises a contribution of a particular style compared to its anti-style. Therefore, the analysis of a combination of individual styles rather than preferences in separate dimensions shows more promise for the establishment of correlations between learning styles and academic performance. Accordingly, the number of combinations increases significantly, making them difficult to analyse.

The current gap in knowledge requires additional studies focused on the understanding of students' learning styles and developing appropriate teaching technologies for adequate training of future pharmacists. The goal of this paper is to analyse the actual learning preferences of students in the speciality "Industrial Pharmacy" and to find possible correlations between the learning styles and academic success in the study of the cycle of chemical and chemical-technological disciplines during the baccalaureate. Particular attention is paid to the influence of various combinations of learning preferences when comparisons are made for student groups with different numbers of preferred styles.

2. Results and Discussion

The average percentages of respondents with particular learning styles are shown for 1st to 4th (Fig. 1a) and 5th (Fig. 1b) year students. The learning profiles of undergraduate students remain practically unchanged during the studies in baccalaureate, demonstrating the stability of the educational preferences gained. They show firm preferences for sensitivity (from 82% to 92% of students) and visibility (75-81%). The advantages of the actual (62-79%) and sequential (64-73%) learning styles are also strongly pronounced, but the share of students with such styles is somewhat lower than for sen and vis styles.

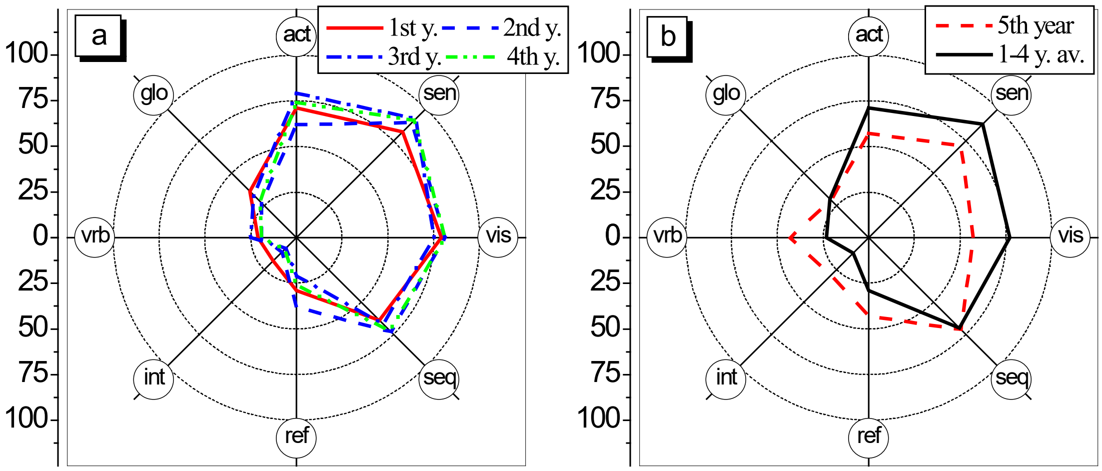

Figure 1. Preferred learning styles of students of different years of studies: a – 1st to 4th years, b – 5th year compared to the average value for 1st to 4th years.

At the same time, graduate students are more reflective, verbal and intuitive compared to undergraduates. No significant changes are observed for the dimension of glo-seq. The difference between undergraduate and graduate students varies between 14% and 20% for three dimensions and is within 2% for the fourth pair of styles (glo-seq). The origins of such behaviour have already been discussed [14]. Such a difference is likely to form at the stage of an additional selection of students entering their Master's course. Such students are prone to reflection and generalisation supported by reflective and intuitive learning styles. Also, they are characterised by a more balanced use of visual and verbal channels of perception of information.

The question of the existence of correlations between the preferred learning styles and academic performance is of high practical importance. However, the simplest analysis, namely the calculation of the Pearson correlation coefficients between the ILS and the results of examinations in eight chemistry and chemical technology disciplines, showed no interdependency because the calculated correlation coefficients do not exceed ±(0.05-0.2) values for all cases and combinations. In our opinion, this result indicates the complexity of possible relationships between learning styles and academic achievements. One may suppose that the analysis of combinations of learning styles rather than individual components can provide more information about their impact on the academic performance of students.

As follows from Fig. 1, the distribution of the number of students by the preferred components of learning styles, suggests the existence of advantages in four dimensions. However, this does not indicate that students simultaneously demonstrate all four preferences. Available learning profiles can be estimated more accurately by analysing the calculated ILS indices following their interpretation by the authors of the model used [8]. According to this interpretation, the balance between a style and corresponding anti-stylus is maintained if the ILS variable ranges from 4 to 7. In other cases, either moderate (ILS is equal 8 or 9) or pronounced (ILS is 10 or 11) preference is observed for a particular style. Table 1 illustrates the relative number of undergraduate students with zero (students with fully balanced styles) to four preferred styles in four dimensions. For students with one preferred style, the percentages are shown in detail for four typical styles (act, sen, vis and seq).

Only approximately 10% of students are characterised by either a fully balanced profile or concurrent preferences in all four dimensions. Therefore, a combination of balanced styles in some aspects with one to three evident favourites in others is typical for 90% of respondents.

Let us consider students whose learning profile is characterised by the presence of one preference. Students of industrial pharmacy prefer act, vis, seq and sen learning styles. Among students with one preferred style, approximately two-thirds (20% of all respondents) fall on the styles of vis and sen; one quarter is characterised by either seq or act styles (Table 1). Also, a small part (~8% or 4 persons, 2.5% of all students) demonstrates a non-standard for future pharmacist styles, such as ref, int, glo or vrb.

Students, demonstrating typical learning styles, are grouped into four groups according to their preferences. The results of examinations in eight disciplines are shown in Fig. 2 separately for students of each group. The number of students with non-typical styles is too small for statistical analysis.

The highest scores are usually demonstrated by students with pronounced vis and sen preferences, while respondents with active and sequential preferences are inferior to them. As follows from Fig. 2, students with active style demonstrate better results in the study of technological disciplines, in fact, at the level of students with styles vis and sen.

Table 1. The relative number of undergraduate students as a function of the number of preferred learning styles.

Number of preferred styles	The relative number of students, %
0	6.5
1 (act)	4.6
1 (vis)	10.2
1 (seq)	3.1
1 (sen)	10.4
1 (others)	2.5
2	36.1
3	22.5
4	4.1

In the case of two preferred styles (Fig. 3), despite the potentially large number of combinations, only four pairs of styles cover the leading share of all respondents (34 out of 43 students). The number of students with other combinations is insignificant that makes them impossible to analyse. A pair of act-sen is an explicit outsider regarding student success rates in all disciplines except pharmaceutical technology.

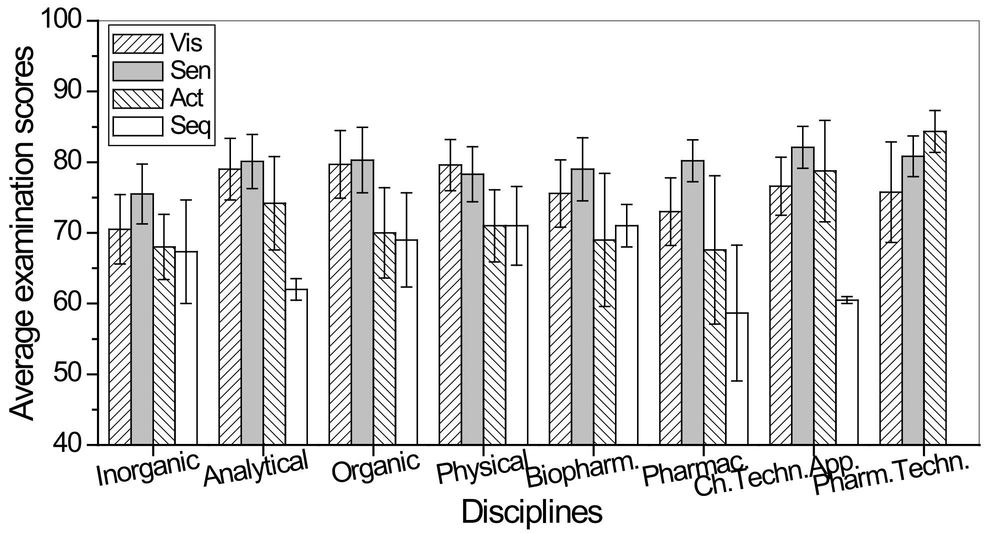

Figure 2. Average examination points for students with one preferred style.

Students with sen-seq and act-vis styles usually show the best results, the sen-vis pair is inferior to them but usually excels the act-sen pair. Thus, as in the case of one dominant style, the presence of a couple with either pronounced sensitive or visual styles usually characterises students with higher progress in chemistry learning. High activity, even with a pronounced sensitivity, is, in turn, distinctive for students with lower rates of academic performance. However, the ANOVA tests do not reveal the statistically significant difference between the studied four pairs of styles due to a limited number of respondents and high data spread. Therefore, the detected differences in academic progress between styles denote some trends rather than firmly facts.

The variety of learning profiles increases with increasing the number of preferences. Division of students into groups by individual style combinations is complicated because such groups are too small for convincing conclusions. For this reason, only two groups, each of which is characterised by the presence of three preferred styles and is numerous enough for analysis, were formed and shown in Fig. 4. The first group, named typical, combines respondents with any three of the four typical styles. The second group, labelled as others, is composed of students with any three non-typical preferences, such as ref, int, vrb or glo

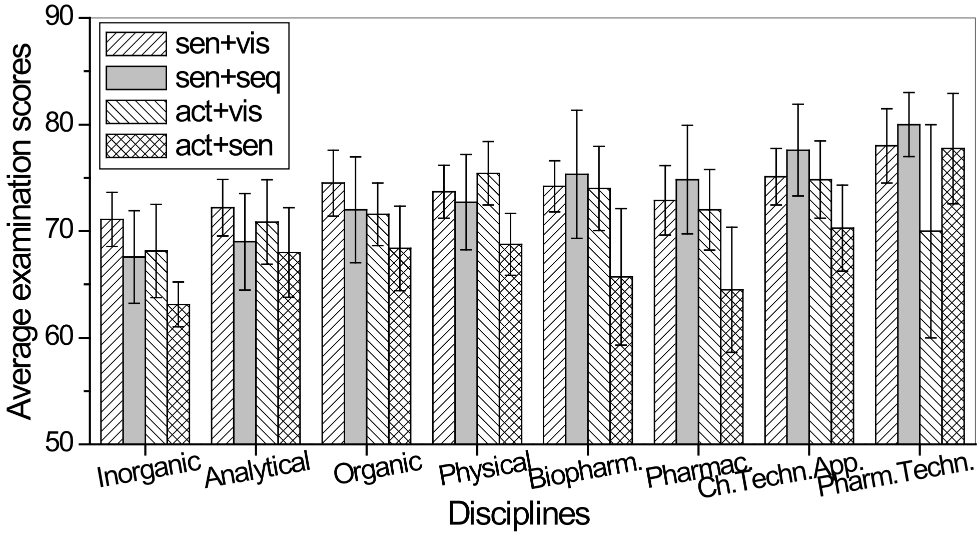

Figure 3. Average examination points for students with two preferred styles.

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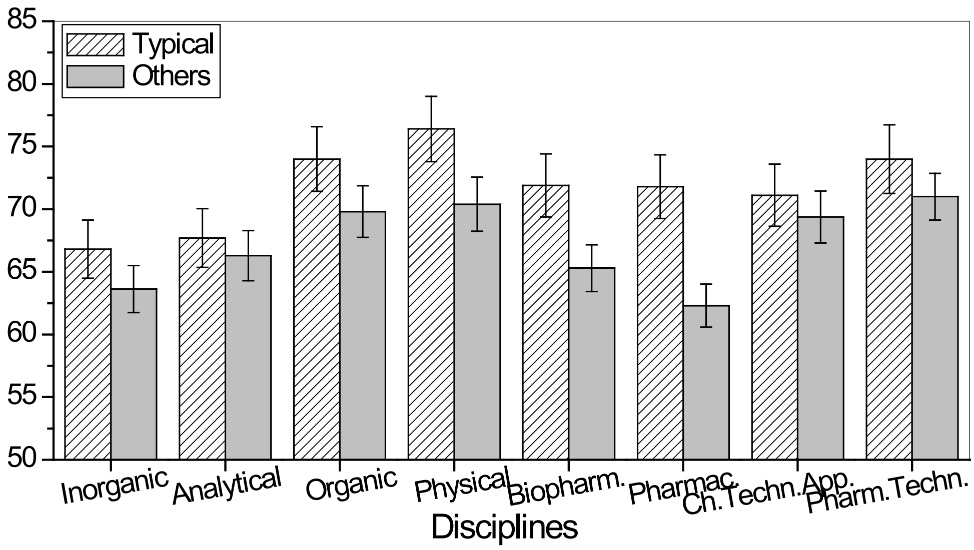

Figure 4. Average examination scores for students with three typical and other (non-typical) learning preferences.

In virtually all of the chemical disciplines, students with typical learning preferences show better performance than other students (Fig. 4). Moreover, in some cases (pharmacognosy, biopharmaceutical chemistry, and physical and colloid chemistry), the differences are statistically significant that was never observed for groups with one (Fig. 2) or two (Fig. 3) preferences. One can suppose that the difference in examination results between students with typical and non-typical learning profiles increases with the growing number of monitored styles.

The number of students with preferences in all four dimensions is limited (Table 1). The size of this group was enlarged to obtain statistically significant results. Students, who have pronounced preferences in three aspects and also score at least 6 or 7 points in a fourth dimension (i.e. being formally attributed to a group of balanced students in this dimension), were added to students with four preferences. The results of the analysis of such a united group are shown in Fig. 5 for students with typical and other (non-typical) profiles.

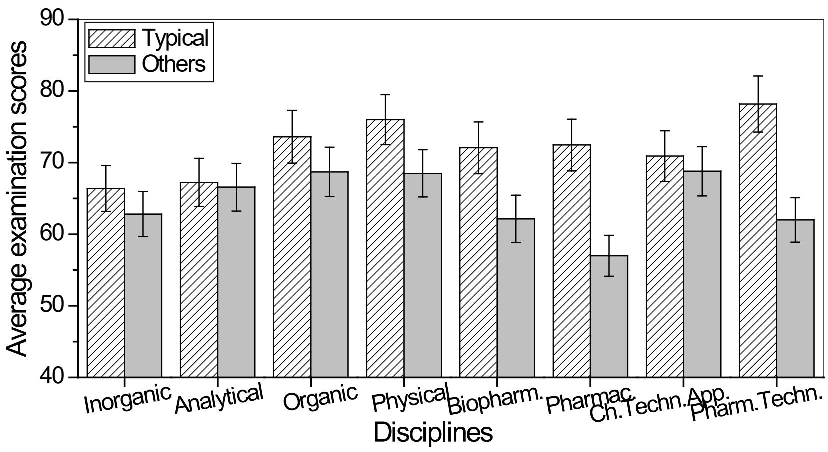

Figure 5. Comparison of average examination points for students with four typical and non-typical preferences.

Students with typical profiles demonstrate better results in all eight disciplines. Moreover, the difference in the points scored is statistically significant for four out of eight subjects. It confirms the supposition that the difference in the academic performance among students with typical and non-typical learning styles usually increases and becomes statistically significant with the increasing number of styles in groups.

The results of the examinations were averaged over all eight disciplines and shown as a function of the number of available preferences in the learning styles (Fig. 6). All participated students were divided into two groups with typical and non-typical styles by the principles outlined in the previous section. The average exam results were given separately for these groups.

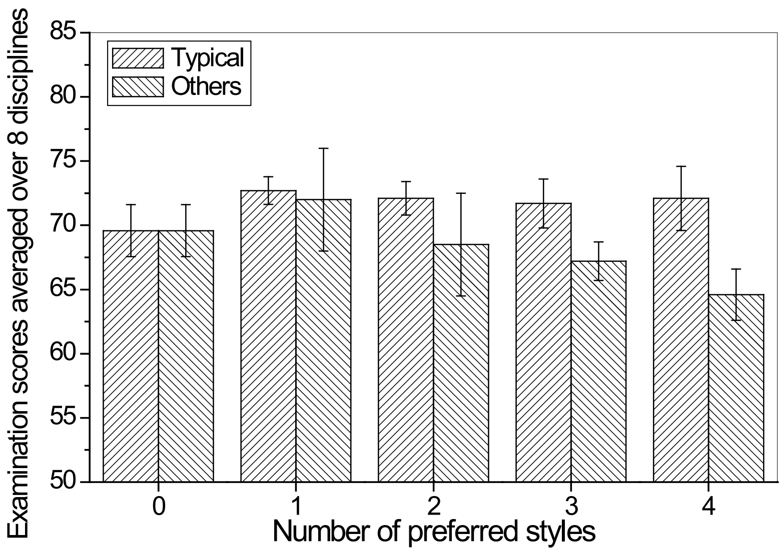

Figure 6. Average examination points as a function of the number of preferred styles for students with typical and non-typical preferences.

As a rule, students with standard learning profiles demonstrate better academic performance (Fig. 6). The difference in academic performance usually increases with the number of preferred styles. Such inequality is insignificant for groups with one preference but reaches a maximum for groups with four preferred styles. All four available dimensions are essential for a complete description of the student's learning profiles. Therefore, the analysis of the impact of prevailing styles on the progress in studies is ineffective if only some separate dimensions are analysed. This conclusion correlates with the results [14] where using Pearson's pair correlations, no statistically significant interdependences were found between the examination points and separate learning preferences for individual students.

Such an assumption is supported by the results of another experiment [28] where the correlation between the progress in studies of the course of "General and Inorganic Chemistry" taught with the use of multimedia presentations and the degree of advantage of their learning styles was found for students of the speciality “Chemistry”. Students with active and sequential styles and simultaneously balanced in the "visual-verbal" dimension demonstrated the most significant progress. The availability of at least one and no more than three preferences in learning styles was found to be another condition for good academic achievements. In the previous experiment [14], industrial pharmacy students were not divided into groups with typical and non-typical profiles; the difference in the progress in studies was rather small. The current research shows that the difference in academic achievements increases to statistically significant levels if the results are analysed separately for student groups with typical and non-typical preferences.

The origin of this phenomenon is not entirely clear. However, one can assume that the content of the disciplines being taught, the teaching methods used, and the teaching resources, including e-resources, create a more comfortable learning environment for students with typical learning preferences. Thus, all these factors contribute to a better understanding of chemical knowledge. Therefore, to increase the effectiveness of educational activities, lecturers must analyse the composition of groups and optimise methods, forms and resources for teaching in concord with established groups’ profiles. For the teaching of chemical disciplines at university chemical departments, an algorithm of the systematic selection of appropriate e-resources and teaching methods has been developed for each type of students [29]. The taxonomy is based on the results of student and university teacher surveys, as well as the analysis of the results of some published works [30-32].

The integration of style aspects, teaching methods and the optimal choice of e-resources allow one to change the teaching methodology, focusing on the characteristics of students. The point is not that each of the teacher's actions has to correspond to the student's learning preferences, but the real challenge is to find the optimal balance.

On the one hand, some methods, which do not fit students’ learning styles but are necessary for the formation of knowledge and qualifications of a future specialist, can provoke discomfort. Such discomfort should not be significant. On the other hand, teaching methods do not create pre-conditions for the development of individuals, if they are entirely coherent with their learning preferences.

The developed approach [29,30] includes the calculation of two quantitative characteristics for each e-resource. In particular, an average resource score is calculated on the base of estimations of students with different learning styles which compile a student group profile. Also, the differences between the teachers’ and students’ ratings are computed. The application of both characteristics allows one to rank available e-resources and determine the balance between discomfort when using inconvenient e-resources and depressed motivation for further development when the teaching is solely based on the fully coherent resources.

2. Material and Methods

Students of the Faculty of Chemical and Biopharmaceutical Technologies participated in the survey at Kyiv National University of Technologies and Design (Ukraine) during 2017-2018 years (Table 2). Totally 160 persons are first- to fourth-year students; they take an undergraduate course in the speciality “Industrial Pharmacy”. On completion, they are given the Bachelor’s qualification "Technician-Technologist". The rest 14 students take a one-year graduate course upon completion of a Bachelor’s Degree in the speciality “Pharmaceutical Technologies”. Their future diploma qualification is "Master of Industrial Pharmacy."

Table 2. Number of students participated in the survey.

Speciality	Year	Number of students
Industrial Pharmacy	1	28
Industrial Pharmacy	2	37
Industrial Pharmacy	3	48
Industrial Pharmacy	4	47
Pharmaceutical Technologies	5	14
	Total	174

The survey was conducted to identify the preferred learning styles of all participated students. The instrument, known as Index of Learning Style (ILS) and developed by R. Felder and B. Soloman (thereinafter Felder-Soloman's model) [8] was used. All respondents were interviewed, and their responses to 44 questions were analysed to estimate available preferences in four complementary dimensions. The instrument categorises individuals in line with their preferences in perception - sensitive (sen in short) or intuitive (int), input - visual (vis) or verbal (vrb), processing - active (act) or reflective (ref)) and understanding of information - sequential (seq) or global (glo).

Each dimension has a 12 point scale; 0 to 11 points were divided between style and anti-style on the base of student answers. Estimation of learning preferences is based on the distribution of 11 points between two opposite styles. The range of 4-7 points gives evidence to an existing balance between styles, 8-9 points indicate a moderate advantage of a particular style, and 10-11 points prove the presence of substantial advantage.

The revealed learning preferences and their combinations were compared with the results of students’ academic performance in learning eight chemistry and chemical technology disciplines during undergraduate studies. They are as follows: inorganic, organic, analytical, physical and colloid, and biopharmaceutical (biopharm.) chemistry; pharmacognosy (pharmac.); pharmaceutical technology (pharm. techn.) and chemical technology apparatus (ch. techn. app.). All disciplines were taught using various e-resources, including static and dynamic presentations, virtual laboratories, educational databases, ready-to-use tests for various topics, information assistance means, etc. The results of examinations in all subjects were scored on a 100-point scale. Comparison of learning profiles and academic achievements was conducted for 3rd to 5th-year students, a total of 109 people completed all disciplines and passed ILS tests.

Statistical methods with the use of IBM SPSS-19 software were applied to analyse the data obtained. The results were presented in plots as the mean values with standard errors of the mean. Pearson’s correlation coefficients examined possible correlations between individual data. The Levene and Shapiro–Wilk tests were applied to investigate variance homogeneity and distribution normality, respectively. One-way analysis of variance (ANOVA) was applied to study possible differences between the mean values. The significance level was defined at $\alpha \leq 0.05$. If the mean values display significant differences, post hoc pairwise multiple comparisons were applied to determine which means differ. The least significant difference method was applied for equal variances in post hoc comparisons, and Tamhane’s T2 model was employed for unequal variances.

4. Conclusions

Students of the speciality “Industrial Pharmacy” are characterised by active (65-79% of all respondents), sensitive (82-92%), visual (75-81%) and sequential (64-73%) learning styles which exceed reflective, intuitive, verbal and global styles, respectively. During the four-year undergraduate study, students' preferences do not change, indicating their relative stability.

Masters students of the same speciality differ significantly from undergraduate students, demonstrating more reflective (43% of graduates vs 29% of undergraduates), verbal (43% vs 23%)

and intuitive (29% vs 12%) styles. No significant difference is observed in the global-sequential dimension.

The difference in learning preferences between undergraduate and graduate students is not connected to changes in the preferences of personalities. It is most likely caused by different profiles of student groups which appear on the stage of additional selection of students when master's groups are formed.

Progress in studies of eight chemistry and chemical technology disciplines was compared for industrial pharmacy students with typical (active, sensitive, visual and sequential) and non-typical (other combinations) profiles. The higher the number of typical styles in learning preferences, the more definite advantage is observed in the academic performance. For example, students with four and three standard preferences usually demonstrate better progress in studies of all eight disciplines compared to students with non-typical profiles; the difference is statistically significant for six and three subjects, respectively. Students with one or two preferred typical styles still show better progress in studies, but the difference is always within the statistical error.)

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