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THE DEGREE OF NEWTON'S THINKING IN FUTURE STUDENTS

Abstract: *This paper presents the results of a six-year project, where one of the goals was to observe the conceptual understanding of Newtonian mechanics with which students enrol in undergraduate studies* where they study physics courses from the very beginning. As an example of such study programs, the research included *977 undergraduate freshman students of university studies: Pharmacy (N = 152); Chemistry and Chemical Technology (N=563); Food technology (N=123) and professional study of Material Protection and Recovery (N=139). The measuring instrument used to assess the student's level of knowledge of Newtonian mechanics is the Force Concept Inventory (FCI test). In all teaching programs of the observed undergraduate studies, physics courses are core courses and therefore require significant students' engagement and knowledge in order to be mastered successfully. Results show that enrolled students arrive to these studies with extremely poor knowledge of Newtonian mechanics. Among the undergraduate students of Pharmacy, 9.9 % of students are at the level of Newtonian thinking; in the undergraduate study of Chemistry and Chemical Technology, 0.9 %; in the undergraduate study of Food Technology, 4%; while in the undergraduate professional study of Material Protection and Recovery, there are no enrolled students who have adopted Newtonian mechanics. These results point to significant problems in high school physics teaching, as well as to problems in the quality mastery of physics course material at the observed studies.*

Key words: *physics, freshmen, conceptual understanding, Newtonian mechanics, FCI test*

INTRODUCTION

Today's students significantly differ from the students of the last decades of the 20th century. Due to the advancement of technology, information has become more accessible and widespread. Students are looking for quick answers to their problems, and their attention span is quite low. This is certainly one of the reasons why the traditional teaching method is less effective in teaching physics than active learning methods.

Traditional way of teaching is the most common form of teaching that has been used for many years. In the middle of the 20th century, it was noticed that it was impossible to achieve high-quality and permanent scientific literacy. At the same time, most of the changes or turns in teaching occurred precisely in some science-based subjects, physics being among them. First one to notice the need for a different way of teaching was a Swiss psychologist Jean Piaget. In his theory of cognitive development, he emphasizes the validity of students' intuitive ideas and constructive role of consciousness in the creation and interpretation of experience. For experts who teach physics, J. Piaget's theory is important because he mostly used physical approach to questions and tests to explain his theory (Krsnik, 2008). In this theory, the most important thing is the mental structure that shapes and determines the overall knowledge and human behaviour in the environment. J. Piaget distinguishes two types of reaction, and thus two processes of mental structure development: assimilation and accommodation (Krsnik, 2008). Assimilation is a process in which new information is in accordance with the existing mental structure. During this process, a person acquires information without noticeably changing their mental structure. Accommodation is the process of restructuring and upgrading mental structure for the purpose of a new equilibrium state. In this process, a child builds new mental structures adapt to new situations, which enable a better relationship and balance with the outside world. The overall process of adaptation and extension of mental structures, which includes both assimilation and accommodation, is called self-regulation. According to Piaget's model of cognitive development, students go through different stages of development until they achieve the highest level of scientific thinking, formal-operational thinking (Renner and Lawson, 1973). Students reach the level of concrete-operational activity [Lawson (1995) calls it "empirical-inductive"] between the ages of 6 and 11. At this stage, students can classify objects and understand conservation (of numbers, weights, and continuous sizes), but they are still unable to think hypothetically (Inhelder and Piaget, 1958). Students are able to think hypothetically in the last stage in the development of thinking, formal-operational reasoning [Lawson (1995) calls it "hypothetic-deductive"]. Only then can they isolate and control variables and model their interrelationships, for example, proportional reasoning (Lawson, 2000). According to Piaget, students should reach this stage between the ages of 11 and 15. However, many researchers have shown that a large number of high school and college students have not reached the level of formal operations (Marušić and Sliško, 2012). For example, Arons and Karplus (1976) cite evidence showing that only one-third of the US population aged 13 to15 reaches the formal-operational level of thinking. The majority of students are at the concrete operational or transitional phase of thinking, i.e. they are partially capable of formal-operational thinking. In other studies, focusing on physics students, similar results were obtained (Cohen et al., 1978; Lawson and Renner, 1974). In his study, Maloney (1981) showed that in basic physics courses for science majors at Creighton University, two-thirds of the students were at the formal thinking level, while in physics courses, taught as a part of education and health sciences majors, barely a third of the students reached that level. This is something that is understandable because physics is conceptually more difficult than the sciences of education and health, and thus it is chosen by students who have previously achieved higher cognitive development. On the other hand, extensive research conducted on a representative sample of 10,000 students between the ages of 10 and 16 showed that the development of early formal thinking was achieved in a maximum of 20 % of students. Furthermore, the data also show that most of their development has already occurred by the age of 14.5 years (Shayer et al., 1976; Shayer and Wylam, 1978).

When it comes to teaching physics, which starts from the 7th grade of elementary school, students come with premade concepts about some phenomena in nature that surround them. These concepts are often incorrect, which is why we call them preconceptions. Physical concepts are developed in students by observing and perceiving the world around them. However, students' conceptualization of the world and physical phenomena often does not fit into physical theory and concepts, and it develops and changes over time. Preconceptions are simple and comprehensible for students in explaining physical phenomena, and it is difficult for students to abandon them, which makes teaching physics difficult (Krsnik, 2001).

In constructivist teaching, preconceptions are endeavoured to be corrected and are taken into account. On the contrary, in traditional teaching, they are ignored and do not affect the course of the lesson. The traditional way of teaching is also easier for teachers because they themselves have preconceptions and do not know how to correct them even though they are aware of them. The teacher should first find out what preconceptions the students have, and correct them by giving them new ideas that will be comprehensible and logical to them. The teacher's conversation with students is the most common and easiest way to discover and identify students' preconceptions, during which he can see how students think and understand physical ideas and concepts. The teacher chooses the way and method of correcting student preconceptions according to the frequency, origin and resistance of the preconceptions themselves. In traditional teaching, students will not abandon their more comprehensible and clear concepts or preconceptions, because of the illogical and hard-to-understand physical concepts and theories that the teacher teaches them. In constructivist teaching - active learning, it is easier to correct students' intuitive ideas due to the application of correct physical concepts and ideas to real problems. The teacher directs the students towards the correct concepts, then the students come to the teacher themselves, and thus the preconceptions are changed. By setting up problem situations, students are motivated to participate, work and to independently find solutions. Students should be given enough time to think because of the importance of coming to a solution independently.

At the beginning, educational research was most often conducted using interviews and tests with open-end questions. In such tests, the respondents answered in their own words, i.e. they were not offered answers. Therefore, they required a very difficult and complex analysis. Examinations (interviews and tests), conducted among students of different ages and levels of education in physics in different countries, showed that students' ideas about some physical concepts are very similar. This prompted educational physics researchers to develop a multiple-choice test. At the same time, the most frequently offered answers were precisely the alternative conceptions that appeared during earlier tests conducted using interviews and open-end tests. Some of the most well-known and commonly used concept tests in physics are tests from:

- mechanics: Force Concept Inventory (FCI) (Hestenes et al., 1992), Mechanics Diagnostics Test (MDT) (Halloun and Hestenes, 1985), Mechanics Baseline Test (MBT) (Hestenes and Wells, 1992), Test of Understanding Graphs in Kinematics (TUG-K) (Beichner, 1994)
- electromagnetism: Conceptual Survey in Electricity and Magnetism (CSEM) (Maloney et al., 2001)
- waves: Wave Concept Inventory (WCI) (Roedel et al., 1998)
- understanding of simple circuits: Determining and Interpreting Resistive Electric Circuits Concepts Test (DIRECT) (Engelhardt and Beichner, 2004) and others.

Most of the conceptual tests are in the field of mechanics. Mechanics is the fundamental area of physics in which preconceptions occur that need to be identified in time and corrected as soon as possible. That way, in further areas of physics based on mechanics, students can understand physical concepts, theories and ideas with less effort.

Currently, the FCI is the most reliable and useful test which demonstrates effectiveness of the teaching method used in general physics courses. Heller and Huffman (1995) suggest that a score of 60 % on the FCI test corresponds to the Newtonian thinking threshold. Students with results lower than 60 % are considered to mainly use pre-Newtonian ideas in their answers, while those with results of 85 % and above have adopted Newton's laws (Planinić et al., 2010).

Inspired by Heller and Huffman’s research and results (1995), Richard Hake (1998) compared the FCI scores of students who took physics courses with different teachers. He concluded that regardless of who the teacher was, teaching using a traditional learning method resulted in fairly similar pre-test and post-test results and was twice as effective in developing conceptual understanding as when active learning methods were used. Moreover, the FCI test was the key to the great teaching reform that has taken place in physics in the last twenty years. It is used worldwide and has contributed significantly to the development of other concept tests in physics and other STEM disciplines (Sands et al., 2018).

This paper analyses the results of entrance FCI tests for students of three undergraduate university studies and one undergraduate professional study at the Faculty of Chemistry and Technology in Split.

ABOUT UNIVERSITIES

This six-year study was conducted at three undergraduate studies and one professional study where physics courses are studied from the first semester. These are: Undergraduate Study in Pharmacy; Undergraduate University Study in Chemistry and Chemical Technology; Undergraduate Study in Food Technology and Professional Study in Material Protection and Recovery.

All studies are conducted at the Faculty of Chemical Technology, University of Split, Republic of Croatia. Basic information about the studies can be found in Table 1.

Table 1.

About the undergraduate university studies and professional study

Integrated Study of Pharmacy	
Study program provider	Faculty of Chemistry and Technology Faculty of Medicine
Academic/vocational title earned at the completion of study	Master of Pharmacy
Duration of the study programme	5 years (10 semesters)
The minimum number of ECTS required for completion of study	300
Enrolment requirements and admission procedure	Completed 4-year secondary school and secondary school graduation exam.
Undergraduate University Study of Chemistry and Chemical Technology	
Study program provider	Faculty of Chemistry and Technology
Academic/vocational title earned at the completion of study	University Bachelor of Chemistry and Chemical Engineering
Duration of the study programme	3 years (6 semesters)
The minimum number of ECTS required for completion of study	180
Enrolment requirements and admission procedure	Completed 4-year secondary school and secondary school graduation exam.
Undergraduate Study of Food Technology	
Study program provider	Faculty of Chemistry and Technology
Academic/vocational title earned at the completion of study	Bachelor of Food Technology
Duration of the study programme	3 years (6 semesters)
The minimum number of ECTS required for completion of study	180
Enrolment requirements and admission procedure	Completed 4-year secondary school and secondary school graduation exam.
Professional Study of Material Protection and Recovery	
Study program provider	Faculty of Chemistry and Technology
Academic/vocational title earned at the completion of study	Vocational Bachelor of Chemical Engineering
Duration of the study programme	3 years (6 semesters)
The minimum number of ECTS required for completion of study	180
Enrolment requirements and admission procedure	Completed 4-year secondary school and secondary school graduation exam.

INTEGRATED STUDY OF PHARMACY

Integrated study of pharmacy lasts five years and ends with the defence of a diploma thesis where students acquire the academic title of Master of Pharmacy.

Once a student finishes the study of pharmacy, he can continue his studies at the post-graduate course lasting 3 years (180 points) in the field of biomedicine and health care. Students may also choose to pursue postgraduate education in another related field provided they can meet individual study requirements.

UNDERGRADUATE STUDY OF CHEMISTRY AND CHEMICAL TECHNOLOGY

After completing the university undergraduate studies, students acquire the academic title of university bachelor of chemistry and chemical engineering, and can continue their education at university graduate studies at the Faculty of Chemical Technology or at other university graduate studies at related faculties.

All programs of this study are based on scientific knowledge in the scientific fields of chemistry and chemical engineering, which significantly contributes to the modern education of the young generation.

UNDERGRADUATE STUDY FOOD TECHNOLOGY

The Undergraduate Study of Food Technology educates experts who, upon completion of the studies, acquire the professional title of University Bachelor of Food Technology, which makes them significantly recognizable on the labour market. Adequately educated staff is a necessary prerequisite for success in the field of food technology.

UNDERGRADUATE PROFESSIONAL STUDY OF MATERIAL PROTECTION AND RECOVERY

Once they complete their studies, professional bachelors, are trained to get involved in solving the problem of disposal of various waste materials and thus balance the relationship between technological development and the environment.

The basic goal and purpose of the studies is to develop professional skills necessary for the fastest possible inclusion in the work process in various economic branches of industry, in small and medium-sized enterprises.

PHYSICAL COURSES AT STUDIES

a) Integrated Undergraduate Study in Pharmacy
Physics for Pharmacists is a compulsory subject which students take in the first year of undergraduate studies. This course is fundamental in developing the student's scientific view of the world and increasing the skill of scientific reasoning. The Faculty of Pharmacy has a Physics course organized as an intensive three-week course held in January. The curriculum is presented at
https://www.ktf.unist.hr/images/stories/repozitorij/Nastava/IPDSF_2014_22_1.pdf

b) Undergraduate University Studies in Chemistry and Chemical Technology

According to the curriculum, students of the Undergraduate University Studies in Chemistry and Chemical Technology take mandatory physics courses in the first two semesters. In the first semester, students have the courses Physics 1 and Exercises in Physics 1. In the second semester, they have the courses Physics 2 and Exercises in Physics 2. Curricula and programs of all physics courses are shown on
https://nastava.ktf-split.hr/studij.php?lang=hr&kod=PK
https://nastava.ktf-split.hr/studij.php?lang=hr&kod=PKT-KI

c) Undergraduate Study in Food Technology and

d) Undergraduate Professional Study in Material Protection and Recovery

Students of these two studies study Physics together. Physics is a compulsory subject which all students take in their first year of study. The course Physics is organized in the first semester of the Undergraduate Study of Food Technology and the Professional Study of Material Protection and Recovery. The curriculum is presented at
https://nastava.ktf-split.hr/studij.php?lang=hr&kod=PPT
https://nastava.ktf-split.hr/studij.php?lang=hr&kod=SZOM

The most important goals of all presented physics courses can be reduced to the following:
- Formation of a correct view on the interpretation and application of physical phenomena and laws.
- Acquiring theoretical knowledge and developing the ability to distinguish the properties and concepts of classical and modern physics.
- Mastering the scientific physical approach to experimental observation and measurement methods necessary for laboratory work and the use of modern measuring equipment.

All observed courses require strong activity and prior knowledge of students in order to be successfully mastered. Since Newton's mechanics is the basis of physical thinking in mechanics but also in other areas of physics, the question "What knowledge of mechanics do freshmen come to the demanding physics courses presented in undergraduate university and professional studies with?"

METHODOLOGY

RESEARCH GOAL

The goal of the research was to examine the level of knowledge of Newton’s mechanics of future students for whom knowledge of physics is a condition for successful studies.

RESPONDENTS

Research included 977 students of the first year of university studies: Pharmacy (N = 152); Chemistry and Chemical Technology (N = 563); Food technology (N = 123); Material Protection and Recovery (N = 139) (Table 2).

Table 2 shows that there is no statistically significant difference in the average age among the students of the observed different studies.
Before the FCI test, respondents were asked for information about their high school and their physics program at that school. At the same time, respondents had to provide information about the way of learning physics in high school: active learning or traditional learning of physics. Data is provided in the Results section.

Table 2.

Number of students and their average age by academic years and observed undergraduate studies.

	2013/2014	2014/2015	2015/2016	2016/2017	2017/2018	∑
Integrated Undergraduate Study in Pharmacy						
Number of students	30	31	31	30	30	**152**
Average age	19.1	18.9	19.3	19.4	19.1	**19.2**

	2014/2015	2015/2016	2016/2017	2017/2018	2018/2019	∑
Undergraduate University Studies in Chemistry and Chemical Technology						
Number of students	118	112	113	108	113	**563**
Average age	19.3	19.1	19.4	19.2	19.1	**19.3**
Undergraduate Study in Food Technology						
Number of students	24	24	24	24	27	**123**
Average age	19.1	18.9	19.3	19.4	19.1	**19.2**
Undergraduate Professional Study in Material Protection and Recovery						
Number of students	48	23	23	23	22	**139**
Average age	19.3	19.1	19.4	19.2	19.3	**19.3**

MEASURING INSTRUMENT: THE FORCE CONCEPT INVENTORY (FCI)

The Force Concept Inventory (FCI) test was designed to assess students' conceptual understanding of Newtonian mechanics (Hestenes et al, 1992) (Table 3). It is considered the most reliable and well-established concept test and is widely used to assess physics courses (Hake, 1998). The test consists of 30 multiple-choice questions to be answered in 30 minutes. Each question results in one point and the maximum number of points at the test is 30. Each question is associated with one or more conceptual errors through the proposed answers. The "Newton threshold" is considered reached when the result exceeds 60 % of correct answers, i.e. when a student achieves 18 correct answers.
The used version of the FCI test (translated into Croatian) can be found at https://www.talkphysics.org/wp-content/uploads/2015/07/fci-rv95_1.pdf .

Table 3.

Newtonian Concepts in the Force Concept Inventory

	Newtonian Concepts	Question
Kinematics	Velocity discriminated from position	20
	Acceleration discriminated from velocity	21
	Constant acceleration entails	
	Parabolic orbit	23, 24
	Changing speed	25
	Vector addition of velocities	7
First Law	With no force	4, 6, 10
	Velocity direction constant	26
	Speed constant	8, 27
	With cancelling forces	18,28
Second Law	Impulsive force	6, 7
	Constant force implies constant acceleration	24, 25
Third Law	For impulsive forces	2, 11
	For continuous forces	13, 14
Superposition Principle	Vector sum	19
	Cancelling forces	9, 18, 28
Kinds of Force	Solid contact	
	Passive	9, 12
	Impulsive	15
	Friction opposes motion	29
	Fluid contact	
	Air resistance	22
	Buoyant (air pressure)	12

Gravitation	5, 9, 12, 17, 18, 22
Acceleration independent of weight	1, 3
Parabolic trajectory	16, 23

After the test, the students were informed about the result they achieved. They were also told that the results are used only for diagnostics and do not affect the final grade in physics courses.

Data analysis was performed using IBM SPSS Statistics 22.0 (Armonk, New York). The Wilcoxon T-test was used to assess possible statistical difference. This statistical test is a non-parametric test, and the p value is set at 0.001 a priori.

RESULTS AND DISCUSSION

In addition to information about the secondary schools which the students attended prior to study, it is also interesting to observe data about the physics program they had and the method of learning physics (A – active learning, T – traditional learning method) (Table 4). This information was given by the respondents before the FCI test itself.

Table 4.

Schools which the students of undergraduate studies attended (0-curriculum without physics, 1 – one-year physics program; 2 – two-year physics program; 3 – three-year physics program; 4 – four year physics program). Physics learning methods (A – active learning, T – traditional learning method)

	Learning method	**High school (%)**		**Vocational school (%)**				
		2	**4**	**0**	**1**	**2**	**3**	**∑**
Integrated Undergraduate Study in Pharmacy (N=152)	T	4	65	/	/	/	14	83
	A	0	14	/	/	/	3	17
	∑	4	79				17	100
Undergraduate University Studies in Chemistry and Chemical Technology (N=563)	T	/	51	2	3	11	17	84
	A	/	11	0	0	3	2	16
	∑		62	2	3	14	19	100
Undergraduate Study in Food Technology (N=123)	T	/	45	4	1	19	18	87
	A	/	7	0	0	4	2	13
	∑		52	4	1	23	20	100
Undergraduate Professional Study in Material Protection and Recovery (N=139)	T	/	7	12	4	31	39	93
	A	/	0	0	0	5	2	7
	∑		7	12	4	36	41	100

Most students arrive to the Integrated Undergraduate Course in Pharmacy from high schools (83 %): 4 % with a two-year and 79 % with a four-year physics program. This study also enrols 17 % of students from vocational schools that have a three-year physics program. Active learning of physics in high school was used by 17 % of students (14 % from high school, 3 % from vocational schools).

62 % of students in the Undergraduate University Study of Chemistry and Chemical Technology come from four-year high schools while 38 % come from vocational schools, 2 % without studying physics, 3 % with a one-year program, 14 % with a two-year and 19 % with a

three-year physics program. The active method of learning physics was used by 16 % of students (11 % from high school, 5 % from vocational schools).

52 % of high school students with a four-year physics program and 48 % of students with a completed vocational school (4 % program without physics, 1 % with a one-year, 23 % with a two-year and 20 % with a three-year physics program) enrol in the Undergraduate Study of Food Technology. The active method of learning high school physics was used by 13 % of students (7 % from high school, 6 % from vocational schools).

Table 5.

Average resolution (and standard deviation) of the FCI test by observed undergraduate studies.

	N	FCI test (%)
Integrated Undergraduate Study in Pharmacy	152	29,7 ± 10,7
Undergraduate University Studies in Chemistry and Chemical Technology	563	23,9 ± 9,0
Undergraduate Study in Food Technology	123	21,1 ± 9,2
Undergraduate Professional Study Material Protection and Recovery	139	17,0 ± 8,7

7 % of students from high school and 93 % of students from vocational schools choose the Undergraduate Professional Study in Material Protection and Recovery: 12 % without a physics program, 4 % with a one-year, 31 % with a two-year and 39 % with a three-year physics program. Of these enrolled students, active learning of physics in high school was used by only 7 % of vocational school students.

The results of the FCI testing of the freshmen of all observed studies are shown in Table 5. All enrolled students have an average score of less than 30 % on the FCI test. The highest percentage of solutions is achieved by Pharmacy students (29.7 %), which is not surprising because students with the maximum number of points from high school are enrolled in this course. Chemistry and Chemical Technology students achieve 23.9 % of FCI test scores, while Food Technology students have a slightly lower score of 21.1 %. Finally, it is not surprising that the students of the Professional Study in Material Protection and Recovery achieved the worst result of 17.0 %.

These results indicate a major problem in high school physics teaching and the lack of methods aimed at increasing the conceptual understanding of Newtonian mechanics as well as increasing the scientific way of thinking. It can be safely concluded that a very small number of freshmen went through some of the active learning methods of high school physics, which would surely be recognized through better results on FCI testing.

Table 6 shows the achieved score list on the FCI test for the observed studies. A summary of the data from the Table 6 is given in Table 7 and Figure 1, where the number and percentage of students of individual undergraduate studies below and above the threshold of Newtonian thinking are shown.

It can be seen that 9.9 % of students enrolling in Pharmacy studies exceed the threshold of Newton's thinking. In the study of Chemistry and Chemical Technology only 0.9 % of students achieve the score of 60 % on the FCI-test. This is also achieved by 4.4 % of students who enrol in the Food Technology course. None of the students enrolling in the professional study of Material Protection and Recovery has crossed Newton's thinking threshold.

Table 6.

Number of students who achieved a certain number of points on the FCI test for the observed undergraduate studies. Number and percentage of students of individual undergraduate studies below and above the threshold of Newtonian thinking.

NUMBER OF POINTS ACHIEVED	Pharmacy N=152	Chemistry and Chemical Technology N=563	Food Technology N=123	Material Protection and Recovery N=139
0	0	0	0	0
1	0	5	0	2
2	0	17	10	8
3	5	38	16	6
4	9	57	14	25
5	25	95	12	32
6	26	62	10	27
7	9	65	16	9
8	15	70	9	13
9	11	54	7	4
10	10	34	6	4
11	5	16	5	5
12	4	10	4	4
13	3	3	3	0
14	4	7	1	0
15	2	6	3	0
16	5	5	1	0
17	4	5	1	0
0-17	137 (90,1%)	549 (99,1%)	118 (96%)	139 (100%)
18	6	4	2	0
19	4	5	0	0
20	3	2	1	0
21	2	2	2	0
22	0	1	0	0
23	0	0	0	0
24	0	0	0	0
25	0	0	0	0
26	0	0	0	0
27	0	0	0	0
28	0	0	0	0
29	0	0	0	0
30	0	0	0	0
18-30	15 (9,9%)	14 (0,9%)	5 (4%)	0 (0%)

Table 7.

Number and percentage of students in individual undregraduate study below and above the treshold of Newtonian thinking

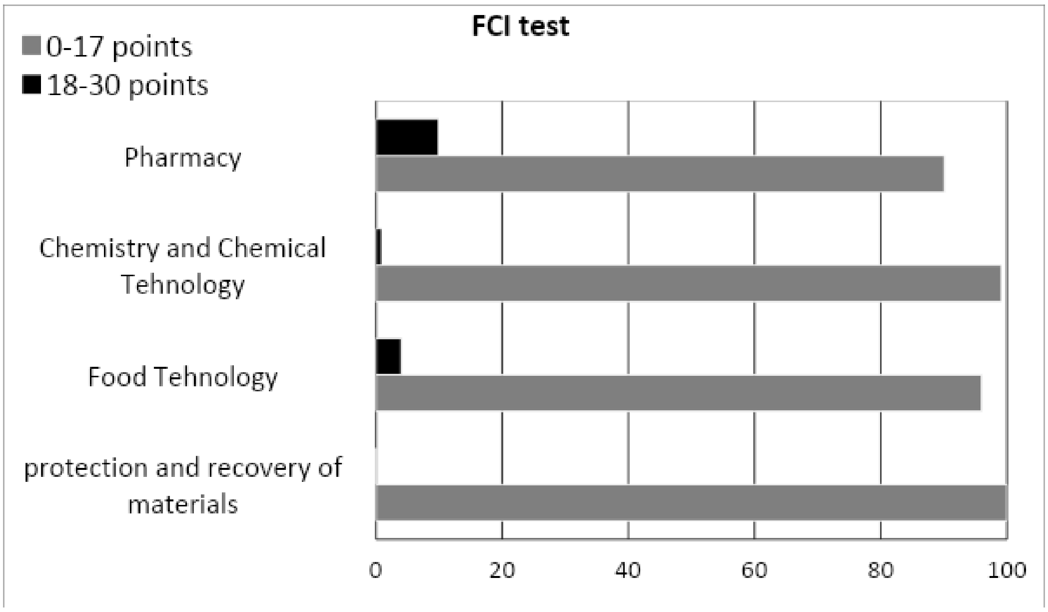
FCI -TEST	Pharmacy		Chemistry and Chemical Technology		Food Technology		Material Protection and Recovery	
	N	%	N	%	N	%	N	%
	152	100	563	100	123	100	139	100
0 – 17	137	90.1	549	99.1	118	96	139	100
18 - 30	15	**9.9**	14	**0.9**	5	**4.0**	0	**0.0**

It should be emphasized that the students of all observed studies who crossed Newton's threshold come to study from high schools that had a four-year physics program. This supports the fact that it takes a considerable amount of time for Newton's concepts to be implemented in the way of thinking when solving problems in mechanics. Therefore, a four-year high school physics program with an active learning method can be a good way to achieve a higher percentage of students who will adopt Newtonian mechanics.

Mechanics is the field of physics in which there are many preconceptions. That is why this area is the most common area of testing or research. Mechanics is the fundamental field of physics. Its understanding is important in order to acquire better understanding of other scientific fields. If a student has preconceptions in the field of mechanics, there is a high probability of preconceptions appearing in other areas of physics as well. The majority of teachers hold lectures in physics, which contributes to the creation of preconceptions or makes it difficult to correct existing ones. Therefore, students have problems in understanding some physical concepts in mechanics even though they formally know mathematical formulas, laws and calculations.

Figure 1.

Diagram showing percentages of students of individual undergraduate studies below and above the threshold of Newtonian thinking.



One of the goals of any physics course is to eliminate misconceptions, improve understanding of fundamental concepts and develop procedural knowledge. For the last forty years, research has been continuously carried out in the field of physics in education with the aim of improving the teaching itself and the teaching of physics. It was pointed out that the existence of misconceptions does not disappear after attending physics courses with the traditional teaching method. Therefore, it is necessary to change the way lectures are held. What all active methods of teaching physics have in common is the emphasis on student-teacher interaction, as well as student-student interaction. Teaching physics is based on encouraging students to draw conclusions and solve problems based on their own experience. Students gain the necessary experience by conducting experiments, measuring, processing and displaying data, exchanging ideas, and finally, discussing and critically judging. Through physics lessons, students also develop the ability to work in a team and cooperate, as well as respect other people's ideas and opinions. (MZO, 2019)

Students with very different experiences of learning methods and duration of physics lessons come to the observed studies. Let's remember that all elementary school students study physics in the seventh and eighth grade, two hours a week. According to the curriculum, there are two high school programs with the four-year study of physics. One model includes two physics lessons per week, and the other one includes three physics lessons per week in all four years of study. Some four-year secondary schools also work according to these models, while some seconary schools have a smaller total number of physics lessons, so they work according to the adapted models. Curricula for vocational schools are given in separate documents that describe the curriculum with the number of of physics classes and elaborated outcomes. These documents can be found on the website of the Ministry of Science and Education (MZO, 2019).

„In addition to encouraging interest in physics and acquiring basic knowledge necessary for understanding physical phenomena and laws, as well as developing communication skills when exchanging ideas and results, the educational goals of the Physics course are also the development of scientific-research approach, the development of critical-logical thinking and development of skills needed when using mathematical and computer tools and the development of problem-solving skills and evaluation of results" (MZO, 2019).

As part of the official "views" on the Physics as a subject, observing the presented results, an important question arises: To what extent have the students adopted the basic characteristics of the Physics subject and what knowledge, abilities and experiences do they bring to their studies? Physics teaching in secondary schools should be more thoroughly changed by introducing active learning methods with the aim of improving the understanding of basic physics concepts and possibly preparing students for future studies better.

CONCLUSION

In this study, students' initial conceptual understanding of Newtonian mechanics was observed as measured by the FCI test. The research lasted for six academic years and was conducted on 977 students of three undergraduate universities and one undergraduate professional study: Pharmacy Undergraduate University Studies - Undergraduate University Studies in Chemistry and Chemical Technology; Undergraduate Study in Food Technology and Undergraduate Professional Study in Material Protection and Recovery.

The results of the research confirmed the fact that students come to the observed studies with extremely little knowledge of Newtonian mechanics. Although the best results are achieved by students of Pharmacy, only 9.9 % of them exceed Newton's thinking threshold. On the other hand, none of the students enrolled in the Undergraduate Professional Study of Materials Protection and Recovery crossed Newton's threshold. This is a very big problem because the Physics courses at the observed studies are very demanding and often serve as a filter for continuing studies.

However, it should be emphasized that all the students of these observed studies who achieved a score of over 60 % on the FCI test actively studied physics in their secondary schooll, which was high school with a four-year physics program. The results indicate significant problems in secondary school physics teaching, which is still largely traditional. The results indicate the necessity of much better conceptual knowledge and skills that should be developed through high school education, which could be the basis for future research. On the other hand, the results also offer an obligation to organize the learning of physics courses at the university level through active learning methods.

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