THE IMPACT OF ACTIVE LEARNING OF PHYSICS ON STUDENT SCIENTIFIC REASONING

EL IMPACTO DEL APRENDIZAJE ACTIVO DE LA FÍSICA EN EL RAZONAMIENTO CIENTÍFICO DEL ESTUDIANTE

M. Marušić, L. Gujinović†

Department of Physics, Faculty of Chemistry and Technology, University of Split, Croatia; lukag@ktf-split.hr†
† corresponding author

Recibido 14/4/2022; Aceptado 15/3/2023

In this work, the results of a five-year project are presented. The changes in scientific reasoning level of first-year students, from the Undergraduate Study of Food Technology (N=122) and Professional Study of Materials protection and recycling (N=118), were evaluated within a one-semester course in Physics. The efficiency evaluation of the physics active learning method "Experimenting and discussion", used to increase the level of scientific reasoning (intervention group – IG), was carried out in a relation to a traditional learning method (control group – CG). "Lawson's Classroom Test of Scientific Reasoning" (LCTSR) was used as a measurement instrument. 57.8 % of IG group students from the Undergraduate Study of Food Technology achieved a positive shift towards higher levels of scientific reasoning. For Materials protection and recycling students, that percentage was 52.6 %. A statistically significant difference was found between the Pre-test and Post-test results for both studies.

En este trabajo se presentan los resultados de un proyecto de cinco años. Se estimaron los cambios en el nivel de razonamiento científico de los estudiantes de primer año, de la Licenciatura en Tecnología de Alimentos (N=122) y del Estudio Profesional de Protección y Reciclaje de Materiales (N=118), dentro de un curso de un semestre de Física. La estimación de la eficiencia del método de aprendizaje activo de física "Experimentación y discusión", utilizado para aumentar el nivel de razonamiento científico (grupo de intervención – GI), se realizó en relación a un método de aprendizaje tradicional (grupo control – GC). Como instrumento de medida se utilizó la "Prueba de Razonamiento Científico en el Aula de Lawson" (LCTSR). En la Tecnología de los Alimentos, el 57,8 % de los estudiantes del grupo IG lograron un cambio positivo hacia niveles más altos de razonamiento científico. Para los estudiantes de Protección y reciclaje de materiales, ese porcentaje fue del 52,6 %. Se encontraron diferencias estadísticamente significativas entre los resultados de la prueba previa y la prueba posterior para ambos estudios.

PACS: Education (educación), 01.40.-d; Teaching methods and strategies (Métodos y estrategias de enseñanza), 01.40.gb; Demostration experiments and apparatus (Demostraciones experimentales y aparatos), 01.50.My; General physics (Física general), 01.55.+b.

I. INTRODUCTION

Since everything proven is based on scientific reasoning, it is necessary to consider the views on that type of reasoning in detail. It has been primarily described as a capability of solving scientific problems and a process of collecting data, with a goal of acquiring theoretical or hypothetical knowledge, possibly used in knowledge generalization [1,2]. As an extended description of scientific reasoning, mental processes occurring while thinking about scientific field topics and during participating in typical scientific activities are also mentioned [3].

The development of scientific reasoning is a complex process, including various cognitive skills used for detecting and evaluating findings, drawing conclusions, and argumentation. All these skills have a role in increasing scientific understanding or creating and changing concepts and theories about the natural and social world [4]. Understanding the essential scientific terms is related to an achieved level of scientific reasoning [5]. Due to that, an improvement of scientific reasoning and understanding of the foundational scientific concepts should be a primary goal of scientific education.

In classrooms, the way that scientists develop their reasoning skills, draw a conclusion, or offer an alternative explanation, is often missing. The most common reasons for that are organizational problems, poor equipment, inadequate education of teachers and a dominant and traditional method of teaching science [6].

Researchers indicated that there is a large number of high school and faculty students, without the reached level of formal reasoning. Extensive research, carried out on a representative sample of 10000 students, aged 10 to 16, showed that the highest percentage of all examinees with a developed formal level of scientific reasoning was 20 %. The data also showed that the majority of students completed their development at the age of 14.5 years [7]. Arons and Karplus claimed that only one-third of the American population, aged 13 to 15, reach the formal-operative level of reasoning [8]. Maloney presented the data for two student groups: two-thirds of students, taking computer and algebraic courses in physics at Creighton University, achieved the level of formal reasoning, while only one-third of students in educational and scientific fields achieved that level [9].

A large study, carried out on 5760 students of technology and science from four U.S. and three Chinese universities, showed that quite different educational systems in U.S and China did not result in a large difference in the development of student scientific reasoning skills [10]. The results of tests showed that, regardless of university and study program, student development over the years was not noticed, and cognitive abilities developed in the first year were not developing during the remaining years of studying. However, teachings focused on research offered an improvement in students' scientific and logical reasoning [11]. Due to these facts, the development of scientific reasoning skills became a specific and explicit objective in many study programmes [12].

Furthermore, exposure to multiple situations, that demand applied scientific reasoning skills, even without teaching directly, results in scientific reasoning level progress [13, 14]. Active learning includes these educational experiences and enhances higher-order thought processes, such as analysis, synthesis and evaluation [15].

In this research, the active learning method in physics was examined, characterized by simple experiment performances and discussion participation. More precisely, the influence of this active learning method on the shift in scientific reasoning level among the students from the Undergraduate Study of Food Technology (FT) and Professional Study of Materials Protection and Recycling (MPR). Hence, our hypothesis is that the active learning method through experimenting and discussion significantly improves the level of scientific reasoning among the students, while our variable is the level of scientific reasoning.

II. STUDY DESIGN

Participants

This five-year research was carried out at the Undergraduate study of Food Technology and the Professional study of Materials protection and recycling, from the Faculty of Chemistry and Technology, University of Split, through five generations. The research included 122 first-year students of Food Technology (FT) and 118 first-year students of Materials protection and recycling (MPR) in total and was conducted during a one-semester Physics course per generation. At the start of the course the students were given the Pre-test, and at the end the Post-test, which measured their level of scientific reasoning before and after the course (see measuring instrument section). Between the Pre-test and Post-test, only 1 FT student quit his studies, while that number was significant at MPR (21). Those students were not included in the analysis (Table 1).

Physics course curriculum

The regular version of the Physics course included traditional learning methods, which consisted of typical lectures (30 hours), solving exercises (15 hours) and laboratory exercises (30 hours). Their laboratory exercises were organized through the introductory lecture of the teacher, a short test on the given exercise topic and measurements with the analysis of the results. Curriculum and course content are present at https://nastava.ktf-split.hr/predmet.php?lang=en&kod =KTK102 and in Supplementary Table 1. Students from the academic years of 2017/2018 and 2018/2019 were taught traditionally and formed control groups (CG) (see Table 1). On the other hand, in the academic years of 2014/2015, 2015/2016 and 2016/2017, students were taught with the active learning method in the following manner. While the lectures and solving exercises were unchanged, the duration of laboratory exercises was decreased by 30 minutes. As a result, that time was compensated by the active learning methods of experimenting and discussion. These students formed the intervention groups (**IG**) (see Table 1).

FT and MPR students were taking a Physics course together, but their improvement was followed separately since they belonged to different studies.

The schedule of applying the active learning methods instead of traditional ones was decided by the Ethical committee. That is also the reason why IG and CG groups were never found within the same generation since the approach would not be equal for the students from the same generation.

Since IG and CG groups were always in separate academic years, there was no physical connection among them, but they were connected with the same curriculum, enrollment conditions and most importantly, their similar knowledge that was not significantly different at the Pre-test results within the same study (shown in the Results section).

Teaching intervention

Teaching intervention performed only in IG groups is characterized by the active learning method of physics through experimenting and discussion and with "collective learning" and "cognitive conflict" included in their laboratory exercises. The students are active participants in a process of acquisition and renewal of their knowledge. The main used initiator of cognitive development is the predict-observe-explain [16] or observe-explain-predict-test [17] learning sequence (Supplementary Table 2).

With these sequences, students activate their acquired knowledge and put it in a testing process through a comparison of predicted and observed. This testing process involves analysis and observation of simple experiments, with the physical phenomena, about which the students already had their well-known "alternative conceptions" [18]. These phenomena are covered in physical topics such as Force and the concept of motion, Pressure (hydrostatic, hydraulic, atmospheric, hydrodynamic), Heat, and Sound waves. Chosen examples among 20 experiments, divided into 10 sessions, are shown in Table 2. The full list of experiments is present in Supplementary Table 3.

All the experiments had a surprising effect on the students. Visualizations of these experiments are shown: Crumpled can (Fig. 1), Strange balance (Fig. 2), Chimney (Fig. 3). The IG group students were divided into smaller subgroups of 9 to 12 students, resulting in 6 IG subgroups for FT and 8 groups for MPR. The cycle of active learning of physics, using simple experiments, for one of the IG groups is shown in Fig. 4. After the group laboratory exercises were carried out, a simple experiment(s) was described to the students of a group, but without its execution. The students were asked to predict the possible outcome of the experiment and offer an explanation of the expected result, sharing their ideas with the group. Then, they were involved in a discussion and tried to explain why they expected those outcomes [19].

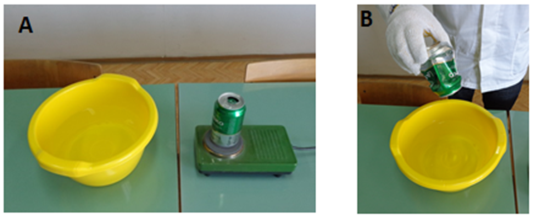

Figure 1. An example of a simple experiment – “Crumpled can”. (A) heating up the can on a stove. (B) display of the can after contact with cold water.

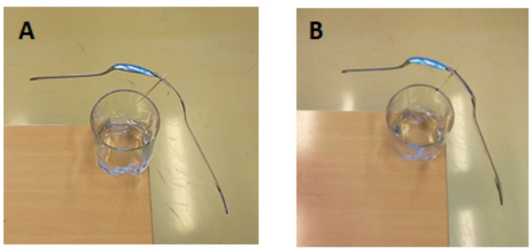

Figure 2. An example of a simple experiment – “Strange balance” (A) setting up a balanced system; (B) display of the system after combustion of both ends of the toothpick.

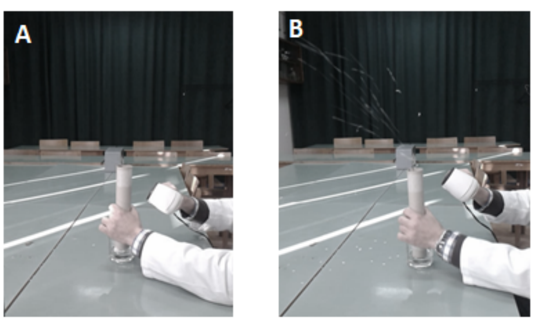

Figure 3. An example of a simple experiment – “Chimney”. (A) before starting the hairdryer. (B) during the blowing of the hairdryer.

Through discussion, misconceptions in physics, as well as the level of scientific reasoning were recognized. After discussion, the teacher performed the experiment, while the students observed and made notes about the outcome. The students often asked the teacher to repeat the experiment because of their positive emotions. They could directly engage during the experiment by reacting to what was observed and offering their own explanations, this way improving their predictions. During the final discussion, with the teacher involved, the group achieved the right physical interpretation of an observed phenomenon [19].

Measuring Instrument

The instrument for measuring gains of different groups was the ”Lawson’s Classroom Test of Scientific Reasoning” (LCTSR) [20]. We applied it at the beginning and at the end of the project. The test consists of 24 questions. The questions refer to several areas: inferences about conservation, concluding about proportions, identification and control of variables, understanding the probability and hypothetical-deductive reasoning. All of the above-mentioned areas determine the level of students’ scientific reasoning. The questions in the LCTSR are grouped in such a way that the student scores one whole point only when the answers to both questions, i.e. the outcome and the explanation for the outcome, are consistent with formal-operational reasoning [21]. This way, the total score on the test is 12. Considering the total score, the following classification is given by Lawson [22]: concrete thinkers (0-4 points), transitional thinkers (5-8 points), and formal thinkers (9-12 points).

Data analysis was performed using IBM SPSS Statistics 22.0 (Armonk, New York). Mann-Whitney U-test was used to assess the possible statistical difference in LCTSR Pre-test results for the IG and CG student groups. Wilcoxon Signed-Rank Test was used to determine statistical differences in the Pre- to Post-LCTSR results so we could evaluate how two different teaching methods of physics for the IG and CG group affect the change in the level of scientific reasoning. Both statistical tests are non-parametric tests and the p-value was established at 0.05 a priori.

Furthermore, the effect size was calculated as Cohen’s **d** value [23] using the following formula:

$$d = \frac{(< Post >)- < Pre >}{SD} \tag{1}$$

where SD is the pooled standard deviation of the Pre- and Post-test scores, while <Post> and <Pre> are the average Pre- and Post-test scores of the group (IG or CG). The suggested values for effect sizes are 0.2 for small, 0.5 for medium and 0.8 for large effect sizes.

Because of its proven value in research and the study of teaching, LCTSR has been widely accepted in many empirical studies at various academic levels. LCTSR is often used to assess the reasoning abilities of university students in relation to their academic achievements [10, 11, 24, 25]. Many studies have also used LCTSR as a standard to assess the success of undergraduate studies in terms of educational outcomes beyond the knowledge of the content [19, 26–28].

III. RESULTS

Pre-test LCTSR results were analyzed and the number of students at different scientific reasoning levels was observed by academic years. Table 3 indicates that the lowest percentage of FT students from the IG and CG groups achieved the formal reasoning level before the Physics course (9.9 %, 9.8 %). Among the MPR students, there were no students from both the IG and CG groups who reached the formal reasoning level before the course. IG and CG groups of both studies did not show a statistically significant difference in LCTSR Pre-test results ($p>0.05$). The percentages of students achieving different reasoning levels on Lawson's Pre- and Post-test, are shown in Table 4. The IG groups of FT students achieved a significant shift in reasoning level, unlike the students from CG groups. LCTSR results from IG groups indicated a decrease in concrete reasoning level percentage from 64.8 % to 25.4 %, with increased percentages of students at the transitional (from 25.3 % to 47.9 %) and formal reasoning level (from 9.9 % to 26.7 %). On the other hand, these improvements in reasoning level were not noticed in CG groups. With only a slight decrease of 1.9 % among the concrete and an increase of 1.9 % among the formal thinkers, these changes were insignificant (see Table 4). The IG groups of MPR also achieved significant improvements in formal reasoning when compared to the CG groups. What should be emphasized is that there were no students with the highest, formal reasoning level on the Pre-test. The Pre-test result for IG groups, counting 83.3 % of concrete thinkers and 16.7 % of transitional thinkers, differed considerably from the Post-test results. Again, a statistically significant shift in scientific reasoning level was noticed, with 42.3 % of concrete, 41.0 % transitional, and 16.7 % of formal thinkers, respectively. CG groups did not achieve a statistically significant shift as well, being almost inconsiderable (see Table 4). The exact number of students at different scientific reasoning levels between the Pre- and Post-test results of IG and CG groups from both study programmes are shown in Table 5, giving an insight into migrations among reasoning levels.

In addition, the exact average Pre- and Post-test results with the standard deviations for IG and CG groups are given in Table 6, as well as the effect size (**d**), which is interpreted as large. FT students significantly improved their average test result, which increased from 3.88 to 6.54 on the Post-test, with a large effect size of 0.99. For MPR students, this improvement was even greater with an effect size of 1.33 and a significant average result increase from 2.94 to 5.78. These values corroborate our hypothesis.

IV. DISCUSSION AND CONCLUSIONS

The initiative for this research was the connection between the learning/teaching methods and cognitive changes occurring among students. Two different physics teaching methods were examined: the traditional teaching method used in control groups (CG), and Experimenting and discussion (discussing classical physics topics), used in intervention groups (IG). This research basis was the analysis of learning methods impact on reasoning level and cognitive changes among students from Undergraduate university study of Food Technology (FT) and Professional study of Materials protection and recycling (MPR).

The Pre-test results showed that less than 10 % of FT students had the formal level of reasoning achieved, while there were no students with this reasoning level at the MPR. This fact presents a major issue for students with a desire for learning physics thoroughly since formal reasoning level is considered essential for an adequate understanding of physics. Such an approach to learning demands understanding of fundamental physical concepts, as well as applying and recognizing them in everyday situations.

The CG results for both studies confirmed a well-known fact, showing that traditional teaching methods do not result in significant changes in the average scientific reasoning level of students.

The IG results showed that the active learning method of physics through Experimenting and discussion (IG groups), applied within one semester, provided significant improvement in scientific reasoning level. Among FT students, 57.8 % achieved a transition towards higher reasoning levels, while that percentage was 52.6 % for MPR students. For both studies, the average test score was significantly improved on the Post-test, with a large effect size, calculated as Cohen's d value.

Although the control and intervention groups belong to different academic years, such an improvement and the difference between them is the effect of teaching intervention. Taking a look at the percentages of students at different reasoning levels on the Pre-test (Table 3) shows that there were no statistically significant differences between the IG and CG groups of the same study. Therefore, the students from different groups and generations could be considered as equal examinee samples at the beginning of the research, while the statistically significant shifts in scientific reasoning of IG groups were shown at the end. Moreover, the same teacher was in charge of teaching through all these generations, without any changes being made among generations of CG and IG groups (except for the intervention).

From previous studies, it was shown that a maximum of 20 % of high school-age students reach the formal reasoning level [7], which coincides with the Pre-test results of high school students from Croatia [27], where considerable benefits of active learning of physics were shown on the Post-test. A similar trend was observed with Pharmacy students [19]. Apart from these results, this research offers an insight into the development of scientific reasoning among the students with noticeably worse Pre-test results. Nevertheless, with the use of active learning methods of physics their results improved significantly, while the traditionally taught students showed indistinguishable progress on Lawson's Post-test. This fact encourages the use of such methods in teaching since it could provoke progress in reasoning capabilities.

Using the previously mentioned sequences: predict-observe-explain, or observe-explain-predict-test, stated progress is achievable through simple experiments with a surprising effect, encouraging students to think creatively and search for a physical solution to observed phenomena. During that process, students mutually communicate and embrace the basic values of teamwork, that way developing social and teamwork skills necessary for future professional work.

Although significant improvements in scientific reasoning levels were achieved in IG groups, this research has certain limitations. Firstly, it is necessary to verify if other teachers would accomplish similar improvements by using these active learning methods. Secondly, the duration of the Physics course may be not long enough to create the habit of using these learning methods among students. And finally, it is necessary to insist that other teachers enrich their scientific courses with this method. Taking into account and resolving all these limitations, in the future we could completely estimate the full potential of this active learning method.

REFERENCES

[1] D. Klahr and K. Dunbar, Cognitive Sci. **12**, 1 (1988).

[2] D. Klahr, Exploring Science: The Cognition and Development of Discovery Processes (MA: MIT Press, Cambridge, UK, 2000).

[3] K. Dunbar and J. Fugelsang, The Cambridge Handbook of Thinking and Reasoning (Cambridge University Press, Cambridge, UK, 2005).

[4] C. Zimmerman, The Development of Scientific Reasoning Skills: What Psychologists Contribute to an Understanding of Elementary Science Learning (National Research Council, Washington DC, 2005).

[5] A. L. Glaze, Educ. Sci. **8**, 12 (2018).

[6] F. Abd-El-Khalick, S. Boujaoude, R. Duschl, N.G. Lederman, R. Mamlok-Naaman, A. Hofstein, M. Niaz, D. Treagust and H. Lin Tuan, Sci. Educ. **88**, 3 (2004).

[7] M. Shayer and H. Wylam, Brit. J. Educ. Psychol. **48**, 1 (1978).

[8] A. B. Arons, and R. Karplus, Am. J. Phys. **44**, 4 (1976).

[9] D. P. Maloney, Am. J. Phys. **49**, 8 (1981).

[10] L. Bao, T. Cai, K. M. Koenig, K. Fang, J. Han, J. Wang, Q. Liu, L. Ding, L. Cui, Y. Luo, Y. Wang, L. Li and N. Wu, Science **323**, 5914 (2009).

[11] V. P. Coletta and J.A. Phillips, Am. J. Phys. **73**, 12 (2005).

[12] V. P. Coletta, and J.A. Phillips, Physics Education Research Conference **1179**, (2009).

[13] D. Kuhn, Mechanisms of Cognitive Development: Behavioral and Neural Perspectives (Lawrence Erlbaum Associates Inc., Mahwah, NJ, 2001).

[14] B. Bettina, M. Pesa and M. Braunmuller, Rev. Bras. Ensino Fis. **44**, e20210326 (2022).

[15] I. Araujo, T. Espinosa, K. Miller and E. Mazur, Rev. Bras. Ensino Fis. **43**, e20210222 (2021).

[16] R. White and R. Gunstone, Probing Understanding (The Falmer Press, London, UK, 1992).

[17] A. Van Heuvelen and E. Etkina, The Physics Active Learning Guide (Addison Wewley, San Francisco, CA, 2006).

[18] H. Pfundt and R. Duit, Bibliography. Students alternative frameworks and science education (Institute for Science Education, Kiel, DE, 2006).

[19] M. Marušič and A. Dragojevič, Am. J. Pharm. Educ. **84**, 8 (2020).

[20] A.E. Lawson, Classroom test of scientific reasoning (revised pencil paper version; Arizona State University, Tempe, AZ, 1996). http://www.public.asu.edu/ anton1/AssessArticles/ Assessments/Mathematics %20Assessments/Scientific % 20Reasoning %20Test.pdf

[21] L. Bao, Y. Xiao, K. Koenig and J. Han, Phys. Rev. Phys. Educ. **14**, 2 (2018).

[22] A.E. Lawson, Science Teaching and the Development of Thinking (Wadsworth Publishing Company, Belmont, CA, 1995).

[23] J. Cohen, Statistical power analysis for the behavioral sciences (Hillsdale, NJ: Lawrence Erlbaum, 2nd ed., 1988).

[24] S.N. Zhou, Q.Y. Liu, K. Koenig, Q.Y. Li, Y. Xiao and L. Bao, J. Balt. Sci. Educ. **20**, 1 (2021).

[25] L. Richterek and T. Hrouzková, Lawson classroom test of scientific reasoning at entrance university level (Presentation at BalticSTE ’21 symposium: https://balticste.com) (2021).

[26] T. Abate, K. Michael and C. Angell, Eurasia J. Math. Sci. Technol. Educ. **16**, 12 (2020).

[27] M. Marušič and J. Sliško, Int. J. Sci. Educ. **34**, 2 (2012).

[28] Z.A. Zulkipli, M. M. M. Yusof, N. Ibrahim and S.F. Dalim, Asian J. Univ. Educ. **16**, 3 (2020).

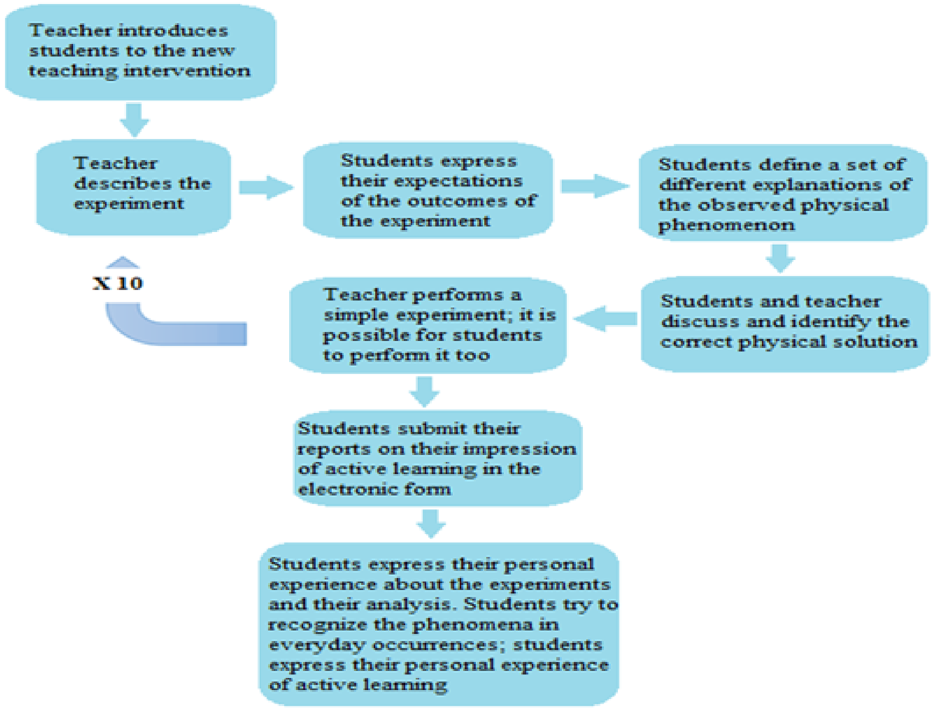

Figure 4. The cycle of active learning of physics, using simple experiments for one IG group.

Table 1. The number of students at the Pre-test and Post-test, and the average age by academic year-comparison of active learning (intervention) and traditional (control) learning groups.

Undergraduate university study of Food Technology								
		Intervention group				Control group		
		2014/2015	2015/2016	2016/2017	Sum	2017/2018	2018/2019	∑
Number of students	Pre	24	24	24	72	24	27	51
	Post	23	24	24	71	24	27	51
Average age on the LCSTR Pre-test		19.1	18.9	19.3	19.1[1]	19.4	19.1	19.3
Professional study of Materials protection and recycling								
		Intervention group				Control group		
		2014/2015	2015/2016	2016/2017	Sum	2017/2018	2018/2019	∑
Number of students	Pre	48	23	23	94	23	22	45
	Post	40	20	18	78	20	20	40
Average age on the LCSTR Pre-test		19.6	19.1	19.4	19.4[1]	19.2	19.3	19.3

[1]Statistically no different from the CG group, p<0.05

Table 2. List of three simple experiments with a short description.

Experiment	Description of the experiment
Strange balance	A fork is fixed on a spoon. A toothpick is threaded through the joint of the spoon and the fork. The balance should be established, and the system is placed on the edge of a glass with the other end of the toothpick, so that everything is at rest. Finally, both ends of the toothpick are lit with a lighter.
Crumpled can	A little water is poured into a beverage can and the can is placed on a heat source. After the water boils, the can is immersed in a bowl of cold water with its upper part.
Chimmey	A cardboard tube is placed above the bottom of a cup containing finely cut paper. The top of the cardboard tube is horizontally blown with a hair dryer. The goal is to make the pieces of paper move towards the top of the tube and come out of it.

Table 3. Lawson Classroom Test of Scientific Reasoning (LCTSR) - Pre-Test Results by Academic Year.

Undergraduate university study of Food Technology (Pre-test)									
	Intervention Group (N = 71)					Control group (N = 51)			
Pre-test level	2014/2015	2015/2016	2016/2017	Sum	%	2017/2018	2018/2019	Sum	%
Concrete	15	17	14	46	64.8[1]	14	18	32	62.7
Transational	5	6	7	18	25.3[1]	9	5	14	27.5
Formal	3	1	3	7	9.9[1]	1	4	5	9.8
Professional study of Materials protection and recycling (Pre-test)									
	Intervention Group (N = 78)					Control group (N = 40)			
Pre-test level	2014/2015	2015/2016	2016/2017	Sum	%	2017/2018	2018/2019	Sum	%
Concrete	34	16	15	65	83.3[1]	16	17	33	82.5
Transational	6	4	3	13	16.7[1]	4	3	7	17.5
Formal	0	0	0	0	0	0	0	0	0

Table 4. Percentages of students in concrete, transitional, and formal reasoning categories, calculated from the Pre-test and Post-test scores on the Lawson classroom test of scientific reasoning (LCTSR).

Undergraduate study of Food Technology				
		Concrete (%)	Transational (%)	Formal (%)
Intervention group N = 71	Pre	64.8	25.3	9.9
	Post	25.4	47.9	26.7
	Shift	-39.4[2]	22.6[2]	16.8[2]
Control group N = 51	Pre	62.7	27.5	9.8
	Post	60.8	27.5	11.7
	Shift	-1.9[3]	0.0	1.9[3]
Professional study of Materials protection and recycling				
		Concrete (%)	Transational (%)	Formal (%)
Intervention group N = 78	Pre	83.3	16.7	0.0
	Post	42.3	41.0	16.7
	Shift	-41.0[2]	24.3[2]	16.7[2]
Control group N = 40	Pre	82.5	17.5	0.0
	Post	80.0	20.0	0.0
	Shift	-2.5[3]	2.5[3]	0.0

[2]Statistically significant shifts, <0.05
[3]Statistically significant shifts, >0.05

Table 5. Undergraduate university study of Food Technology

Undergraduate university study of Food Technology							
Intervention group (N=71)				Control Group (N=51)			
Pre		Post		Pre		Post	
Concrete	46	Concrete	18	Concrete	32	Concrete	31
		Transational	25[4]			Transational	1[5]
		Formal	3[4]			Formal	0
Transational	18	Concrete	0	Transational	14	Concrete	0
		Transational	9			Transational	13
		Formal	9[4]			Formal	1[5]
Formal	7	Concrete	0	Formal	5	Concrete	0
		Transational	0			Transational	0
		Formal	7			Formal	5
Professional study of Materials protection and recycling							
Intervention group (N=78)				Control Group (N=40)			
Pre		Post		Pre		Post	
Concrete	65	Concrete	33	Concrete	33	Concrete	32
		Transational	28[4]			Transational	1[5]
		Formal	4[4]			Formal	0
Transational		Concrete	0	Transational	7	Concrete	0
		Transational	4			Transational	7
		Formal	9[4]			Formal	0

Table 6. Pre- and Post-test average on the Lawson test with the effect size.

Undergraduate university study of Food Technology				
Group	N	<Pre> ∓ SD	<Post> ∓ SD	Effect Size
Intervention group IG	71	3.88 ∓ 2.47	6.54[6] ∓ 2.89	0.99[7]
Control group CG	51	4.11 ∓ 2.61	4.39 ∓ 2.61	0.11
Professional study of Materials protection and recycling				
Group	N	<Pre> ∓ SD	<Post> ∓ SD	Effect Size
Intervention group IG	78	2.94 ∓ 1.52	5.78[6] ∓ 2.60	1.33[7]
Control group CG	40	3.20 ∓ 1.25	3.60 ∓ 1.24	0.03

[4]Statistically significantly migrations, $p<0.05$
[5]Statistically significantly migrations, $p>0.05$
[6]Statistically significantly different from the <Pre> value
[7]Large effect size