JOURNAL OF BALTIC SCIENCE EDUCATION

ISSN 1648-3898 /Print/
ISSN 2538-7138 /Online/

EFFECTIVENESS OF THE CONCEPTUAL CHANGE METHOD ON UNDERSTANDING PLANT MASS INCREASE

Katja Gobec,
Jelka Strgar

Abstract. *This research aimed to assess the influence of the method of conceptual change on understanding the concept of increasing the mass of plants among 414 students in agricultural education in Slovenia. In photosynthesis, biomass is produced, so understanding these processes is essential for successful agriculture. Data were collected using a knowledge test and a questionnaire that were administered before and after the traditional and experimental teaching units. The results allowed the conclusion that the method of the conceptual change (experimental teaching unit) was significantly more effective than the traditional method in improving the understanding of the contribution of solar energy and carbon dioxide to the increase in the mass of plants. There was no significant difference in the improvement of knowledge about the contribution of the minerals that plants receive through their roots. Understanding the contribution of water to the increase of the mass should be tested further because of the unexpected misconception that influenced the results that was found among students. Students' attitudes toward biology and photosynthesis were significantly better after the experimental teaching unit. Considering these findings, other topics should be prepared using the method of the conceptual change to assist biology and science teachers in agricultural education.*

Keywords: *agricultural education, biology education, conceptual change, photosynthesis, plant mass.*

Katja Gobec
Vocational College, School Centre Šentjur, Slovenia
Jelka Strgar
University of Ljubljana, Slovenia

Introduction

Photosynthesis is an essential biochemical process in which energy-rich organic nutrients for photosynthetic as well as heterotrophic organisms are produced from simple inorganic molecules. It is one of the central topics in school biology and therefore included in most biology curricula. It provides a basis for understanding ecosystems (Eisen & Stavy, 1988; Stavy, Eisen, & Yaakobi, 1987; Taiz & Zeiger, 2006).

For students, photosynthesis is one of the most challenging biology topics (Gobec & Strgar, 2019; Marmaroti & Galanopolou, 2006; Stavy, Eisen, & Yaakobi, 1987; Svandova, 2014; Waheed & Lucas, 1992). One of the reasons for this is that it is an abstract process that cannot be observed with the naked eye (Brown & Schwartz, 2009; Russel, Netherwood, & Robinson, 2004). It is also a complex topic that requires understanding of several fundamental concepts (gas, transformation of energy, chemical transformation) and how they are interconnected (Helldén, 2005; Hogan & Fisherkeller, 1966; Magntorn & Helldén, 2007; Marmaroti & Galanopolou, 2006) which students find difficult to comprehend (Barker & Carr, 1989; Bell, 1985; Simpson & Arnold, 1982; Waheed & Lucas, 1992). As a consequence, students learn it by rote, which renders their knowledge of photosynthesis unusable (Cañal, 1999). Furthermore, this type of learning process does not influence students' misconceptions, so they do not develop their understanding of photosynthesis.

The traditional method of teaching photosynthesis usually involves describing the process while using a great deal of terminology not previously known to students. Often this process is taught only on a molecular level, despite the lack of chemical knowledge among many students (Ameway, 2016). It had become evident that for most students, traditional lessons were not effective in accomplishing educational objectives of photosynthesis as students were unable to understand this process even after a relatively long time of learning, (Anderson, Sheldon, & Dubay, 1990; Marmaroti & Galanopolou, 2006; Movahedzadeh, 2012; Näs, 2012).

Considering photosynthesis, students had difficulties understanding (1) reactants and products, (2) chemical changes (they lack the concept of substance transformation), and (3) chemical reactions involving gases (Anderson, 1986; Barker & Carr, 1989; Carlsson, 2002; Hesse & Anderson, 1992;

https://doi.org/10.33225/jbse/19.18.569

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Johnson, 2000; Marmaroti & Galanopolou, 2006). Students also confused photosynthesis and cellular respiration, and thought that photosynthesis took place during the day and cellular respiration at night (Amir & Tamir, 1994; Cañal, 1999; Eisen & Stavy, 1988; Haslam & Treagust, 1987; Köse, 2008; Radanović et al., 2016; Stavy, Eisen, & Yaakobi, 1987).

Carbon dioxide, as a gas that enters the process of photosynthesis, has a small mass. Students' naive conception was, therefore, that it could not contribute to the increased mass of plants (Eisen & Stavy, 1988; Parker et al., 2012). Students also believed that minerals received from the soil significantly added to the mass of plants (Parker et al., 2012). Many students classified sunlight as a reactant in photosynthesis (i.e., a substance that is incorporated into the mass of plants) and not as a source of energy for this process (Anderson, Sheldon, & Dubay, 1990; Barker & Carr, 1989; Carlsson, 2002; Eisen & Stavy, 1988; Parker et al., 2012; Marmaroti & Galanopolou, 2006; Stavy, Eisen, & Yaakobi, 1987; Waheed & Lucas, 1992).

Several suggestions have been made regarding how to improve the teaching of photosynthesis. Among them, Näs (2012) suggested that fewer formulas should be used in class, and when used, the formulas should be connected with specific living plant material. Helldén (2005), and Näs and Ottander (2008) also stressed the importance of the use of living plant material for understanding photosynthesis and the development of ecological understanding.

Problem of Research

Most of the research about the understanding of photosynthesis was done in the 1990s. It showed that people of all ages (from pupils to adults) held similar misconceptions about photosynthesis, and that the amount of science education they had received did not directly influence their misconceptions (Amir & Tamir, 1994; Anderson, Sheldon, & Dubay, 1990; Cañal, 1999; Eisen & Stavy, 1992; Waheed & Lucas; 1992). More recent research showed similar results about the knowledge of photosynthesis (Duschl, Schweingruber, & Shouse, 2007; Gobec & Strgar, 2019; Köse, 2008; Näs, 2012; Marmaroti & Galanopolou, 2006; Ross, Tronson, & Ritchie, 2006; Skribe Dimec & Strgar, 2017; Svandova, 2014; Yenilmez & Tekkaya, 2006). This showed that improvements that had been suggested as a consequence of findings in previous research were either not implemented in teaching and learning processes or were not effective.

Photosynthesis is essential in the food chain and, more broadly, it is connected to topics such as global climate change (Koba & Tweed, 2009). Understanding concepts related to photosynthesis (release of oxygen from plants, respiration, autotropism, nutrients, exploitation of sunlight energy) is a prerequisite for understanding relations between organisms in the ecosystem and the functioning of ecosystems (Eisen & Stavy, 1988) which is one of the main goals of biological education. Especially students in the field of agriculture should understand basics of biology to be able to cooperate fully in their workplace and make proper decisions about topics connected to agricultural production and processing (Warnick, Thompson, & Gummer, 2004), so they do not implement senseless measures that are detrimental to the environment, society, and human health.

In Slovenia, secondary school students in agricultural education (vocational programmes of Country Farmer and Gardener, and technical programmes of Agricultural-Entrepreneurial Technician and Horticultural Technician) lacked satisfactory knowledge of photosynthesis and also held characteristic misconceptions about it (Gobec & Strgar, 2019). One of their misconceptions that is of great importance for agricultural production was the concept of increasing the mass of plants. If this misconception could be effectively approached, then the method could be applied in teacher education programmes in agricultural education and further in educational settings (Clark, Threeton, & Ewing, 2010).

Research Focus

Yenilmez and Tekkaya (2006) reported that teaching using the method of conceptual change significantly improves the understanding of students on all levels of education and is especially effective in topics about which students hold misconceptions, which is true for photosynthesis. Based on this, the following research questions were formulated:

- Could teaching unit that includes the method of conceptual change bring about better understanding of the concept of increasing the mass of plants than traditional teaching unit could?
- Is the effectiveness of the method of conceptual change related to the students' attitudes toward biology and photosynthesis?

https://doi.org/10.33225/jbse/19.18.569

Research Methodology

General Background

The research design was quantitative and quasi-experimental in nature. Descriptive and correlational methods were used. Knowledge of Slovenian students in agricultural education about the factors that contribute to increasing the mass of plants and their attitudes toward biology and photosynthesis were explored by administering a knowledge test and a questionnaire. The research was conducted in the 2017-18 school year.

Sample

In the sample were included all the students from one agricultural school in Slovenia (School Centre Šentjur) who attended classes at the time this research was conducted (*N* = 414). There were 45.2% of female participants in the sample. Students involved in the research attended four types of educational programmes: first to fourth year of secondary technical programmes, first to third year of secondary vocational programmes, first to second year of vocational-technical programmes, and first to second year of vocational college (Table 1). In pre-test all 414 students took part. Then the students in each class were randomly allocated to either control (*n* = 202) or experimental (*n* = 211) group (with one student absent).

The research was anonymous. Approval to conduct it was secured from the School Centre Šentjur authorities, the parents of all underage participants, and the adult participants themselves.

Table 1. Distribution of participants according to the educational programme and year of study.

Educational programme	Participants			
	Year of study	Typical age	*N*	*f (%)*
Secondary technical and vocational	1	15	61	14.7
Secondary technical and vocational	2	16	64	15.5
Secondary technical and vocational	3	17	76	18.4
Secondary technical	4	18	20	4.8
Vocational-technical	1	18	31	7.5
Vocational-technical	2	19	21	5.1
Vocational college	1	19	87	21.0
Vocational college	2	20	54	13.0
Total			414	100.0

Instrument and Procedures

The knowledge test about photosynthesis contained seven questions:

1. How much does sunlight energy add to the mass of the plant?
2. How much do molecules of carbon dioxide add to the mass of the plant?
3. How much do molecules of minerals that a plant receives through roots add to the mass of the plant?
4. How much do molecules of water that a plant receives through roots add to the mass of the plant?
5. Which pair of substances are the reactants in photosynthesis?
6. Which pair of substances are the products of photosynthesis?
7. Which pair of substances is needed in photosynthesis, and which pair of substances are the products of photosynthesis?

With each questions the participants had to choose one answer out of three to five. Questions 1-4 were formed based on the results of prior research (Eisen & Stavy, 1988; Parker et al., 2012) that had shown misconcep-

https://doi.org/10.33225/jbse/19.18.569

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

tions about the concept of increasing the mass of plants. Questions 5 and 6 were used in the survey by Marmaroti and Galanopoulou (2006), and Gobec and Strgar (2019). Questions 5 and 6 were compiled into a new item (item 7) which acted as a control question. Cronbach's alphas for all seven questions on the pre-test, on the post-test for the control group, and on the post-test for the experimental group were between .84 and .88.

The survey questionnaire contained five statements, assessing students' attitudes towards biology and photosynthesis because attitudes are an essential factor in learning science (George, 2006; Nasr & Soltani, 2011; Osborne et al., 2003; Partin & Haney, 2012). These statements have already been used in The Relevance of Science Education study (The ROSE questionnaire, n.d.) and in the research of Gobec and Strgar (2019). The questionnaire used a 5-point Likert scale, ranging from strongly disagree (1) to strongly agree (5). Cronbach's alphas for all five statements on the pre-survey, on the post- survey for the control group, and on the post- survey for the experimental group were between .76 and .80.

Participants first completed the knowledge test and the questionnaire. Then each class was randomly divided into two groups, and each group participated in a different teaching unit about photosynthesis. Both teaching units followed the same objectives of the curriculum in agricultural education. One half of the students (211) participated in a traditional one-hour teaching unit (the control group) in which the topic about increasing the mass of plants was presented by the methods of explanation and discussion. The other half of students (202) participated in a two-hour teaching unit in which the method of conceptual change that was introduced by Strike and Posner (1992) was used (the experimental group). Students in this group conducted an experiment in small groups of three to four. In the first lesson, they prepared an experiment titled 'the impact of carbon dioxide on the increase in the mass of plants', which was a combination of experiments proposed by Albrechtová et al. (2007) and Ebert-May, Batzli, and Lim (2003). In the next lesson a few days later, students checked the results. They were given enough time to think about the results because to be able to understand such a complex concept as photosynthesis they have to construct their conceptual system (Koba, Tweed, 2009, Näs, 2012; Vosniadou, 2002). The experiment and presented theory were kept simple to avoid confusion and assist in understanding (Radanović et al., 2016).

The essential criteria for selecting the experiment were as follows: (1) materials for carrying out the experiment are simple and easily accessible in schools, (2) ease of implementation in time-limited frames, and (3) live organisms (plants) are included. In the experimental work, the conditions, strategies, and processes that various authors had proposed for the implementation of the method of conceptual change (Carey, 1991; Champagne, Gunstone, & Klopfer, 1983; Chinn & Brewer, 1993, Posner et al., 1982; Stepans, 1996) were combined. However, the implementation of the experimental work is best described by a four-stage strategy for the conceptual change proposed by Nussbaum & Novick (1982): (1) discovering misconceptions, (2) encouraging students to discuss and evaluate their misconceptions, (3) creating a conceptual conflict by an event that cannot be explained by the existing conception; once students are confronted with their own misconceptions, are aware of them, and dissatisfied with them, a conceptual conflict arises (Davis, 2001), (4) stimulating and guiding conceptual restructuring: the teacher presents a scientific explanation that must be understandable and credible, then students are encouraged to reconstruct their conceptions and replace them with biologically correct ones.

At the end of the teaching units, the control and the experimental group completed the same knowledge test and the questionnaire again to check whether the conceptual change in students actually took place and whether there were any changes in students' attitudes. After the teaching unit, the experimental group rated two more statements on a 5-point Likert scale to determine to what extent the students liked the experiment (1 - I did not like it at all; 5 - I liked it very much) and how helpful they found the experiment in promoting their understanding of the topic (1 - I did not understand anything; 5 - I understood a lot).

Data Analysis

The descriptive statistics (frequencies) was used on the knowledge test about photosynthesis. Data were tested for normal distribution with the Kolmogorov-Smirnov test for all seven questions; because the distribution of data was not normal (ps < 0.001), non-parametric testing was used. Statistical significance of differences in knowledge between the control and the experimental group on pre-test and post-test was established by a chi-square test or, where expected values were smaller than 5, by a Fisher's exact test. A Cramer's V was used to identify effect size.

The descriptive statistics (average, standard error) was used on the questionnaire data. The distribution of the data for all five statements was not normal (Kolmogorov-Smirnov test; ps < 0.001), so the non-parametric testing had to be used. Statistical significance of differences in attitudes between the control and the experimental

https://doi.org/10.33225/jbse/19.18.569

group on the pre-test and the post-test was established by a Mann-Whitney *U* test. Effect size *r* was calculated using equation $r = Z / \sqrt{N}$.

Correlations between students' knowledge and their attitudes toward biology and photosynthesis were established using Spearman's correlation coefficient (r_s). Comparisons of these correlations before the lesson and after the lesson were also calculated; it was then assessed, using equation $Z_{difference} = (z_{r1}\ z_{r2}) / \sqrt{\{[1/(N_{1-}\ 3)] + [1/(N_2 + 3)]\}}$ (Field, 2009, p 191), whether the differences between correlations were statistically significant.

Research Results

Students' Knowledge about Photosynthesis

The average level of knowledge of students on the seven items about photosynthesis on the pre-test was 48.1%. On the post-test, the average knowledge level of students in the control group was 57.0%; in the experimental group, it was 68.7%.

Concerning the reasons for the increased mass of the plants (items 1-4), students' knowledge of the pre-test was very diverse (5.6%-76.5%). On the post-test, it was better in the control group (10.6%-80.9%) and even better in the experimental group (43.4%-96.7%) There was only one exception to this pattern, namely item 4 (Molecules of water that plant receives through roots add to the mass of the plant a lot), for which knowledge in the experimental group dropped significantly from 76.5% on the pre-test to 43.9 % on the post-test. In the control group, it raised insignificantly from 76.5% to 80.9% (Figure 1).

Concerning reactants and products in photosynthesis (items 5-7), students achieved 54.2%-65.5% on the pre-test. On the post-test, the knowledge in the control group was better (63.0%-70.3%) and in the experimental group even better (80.7%-89.6%) (Figure 1).

There were three statistically significant differences (items 1, 2, 3) between the knowledge on the pre-test and the knowledge of the control group on the post-test; knowledge on the post-test was better in all three items. There were seven statistically significant differences between knowledge of students on the pre-test and the knowledge of the experimental group on the post-test; in six of these items, knowledge on the post-test was better, and in one item it was worse (item 4). Comparison of the knowledge of the control and the experimental group on post-test showed six significant differences; the control group had better knowledge in one item (4) while the experimental group had better knowledge in five items (1, 2, 5, 6, 7) (Table 2).

The effect sizes of changes of knowledge between the pre-test and the control group on the post-test were small (Cramer's V = .03-.23). The effect sizes of changes of knowledge between pre-test and the experimental group on post-test were small in items 3 and 6 (Cramer's V = .16-.18), medium in items 3, 4, and 7 (Cramer's V = .26-.32), and large in items 1 and 2 (Cramer's V = .46-.51). Effect sizes of differences between the control and the experimental groups on post-test were small in items 3, 5, 6, and 7 (Cramer's V = .07-.24), and medium in items 1, 2, and 4 (Cramer's V = .37-.38) (Table 2).

After the teaching unit, the students in the experimental group were asked to rate the experimental work about photosynthesis on the scale from 1 (low) to 5 (high). The results show that students liked the experiment (M = 4.04, SD = .772) and found that it helped them to understand better the concept of increasing the mass of plants (M = 3.97, SD = .840).

https://doi.org/10.33225/jbse/19.18.569

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

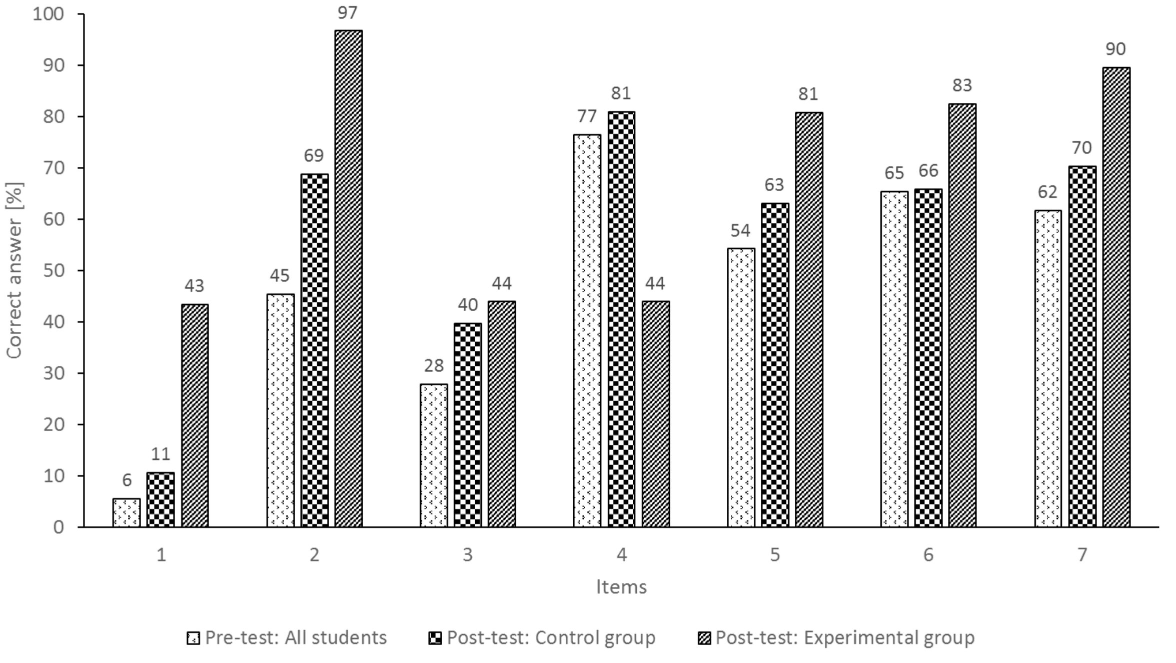

Figure 1. **Knowledge of photosynthesis among tested students (pre-test: *N* = 414; post-test control group: *n* = 202; post-test experimental group: *n* = 211).**

Table 2. **Differences in the knowledge of students, and effect sizes of differences (pre-test: *N* = 414; post-test control group: *n* = 202; post-test experimental group: *n* = 211; *df* = 2).**

		Difference								
		Pre-test/Post-test Control Group		Effect Size	Pre-test/Post-test Experimental Group		Effect Size	Post-test Control/ Experimental Group		Effect Size
Item	Correct answer	χ^2	*p*	Cramer's *V*	χ^2	*p*	Cramer's *V*	χ^2	*p*	Cramer's *V*
1	Sunlight energy does not add to the mass of the plant at all.	*7.864	.015	.12	*129.786	<.001	.46	*60.101	<.001	.37
2	Molecules of carbon dioxide add to the mass of the plant a lot.	*33.407	<.001	.23	*198.683	<.001	.51	*66.841	<.001	.38
3	Molecules of minerals that plant receives through the roots add a medium amount of mass to the plant.	*11.600	.001	.14	*16.842	<.001	.16	*1.850	.380	.07
4	Molecules of water that plant receives through roots add to the mass of the plant a lot.	*4.489	.084	.09	*64.372	<.001	.32	*61.795	<.001	.38
5	Carbon dioxide and water are the reactants in photosynthesis.	*4.692	.063	.09	*46.085	<.001	.26	*17.618	<.001	.21
6	Glucose and oxygen are the products of photosynthesis.	*0.486	.952	.03	*21.522	<.001	.18	**15.155	<.001	.19
7	Carbon dioxide and water are reactants in photosynthesis and glucose, and oxygen are the products of photosynthesis.	*4.818	.055	.09	*59.425	<.001	.29	**24.322	<.001	.24

*Note. Statistically significant values are shown in bold type. *Fisher's Exact Test; ***χ^2 *test.*

https://doi.org/10.33225/jbse/19.18.569

Students' Attitudes toward Biology and Photosynthesis

On the pre-survey about students' attitudes toward biology and photosynthesis, students' rating was the highest in Statement 3 (Photosynthesis is important for life on Earth; *M* = 4.33, *SD* = 1.126), followed by Statement 4 (Knowledge of photosynthesis is important for general knowledge; *M* = 3.44, *SD* = 1.042), Statement 2 (Photosynthesis is interesting; *M* = 3.32, *SD* = 1.077), Statement 1 (Biology is interesting; *M* = 3.04, *SD* = 1.186), and finally Statement 5 (Knowledge of photosynthesis is important for my personal career; *M* = 2.98, *SD* = 1.136) (Figure 2). On the post-survey, after having participated in teaching units about photosynthesis, the control group rated one statement insignificantly higher and four statements lower, two of them significantly lower (Statements 2 and 3). The experimental group rated all statements higher than before the teaching unit, four of them significantly higher (Statements 1, 2, 4, 5). The difference between ratings of the control and the experimental group after the teaching units was significant in all five statements (Table 3).

The effect sizes of changes in ratings of the control group before and after the teaching unit were mostly small. The effect sizes of changes in ratings of experimental group before and after the teaching unit were small to medium. The effect sizes of differences between the control and the experimental group on a post-survey after the teaching units were mostly medium (Table 3).

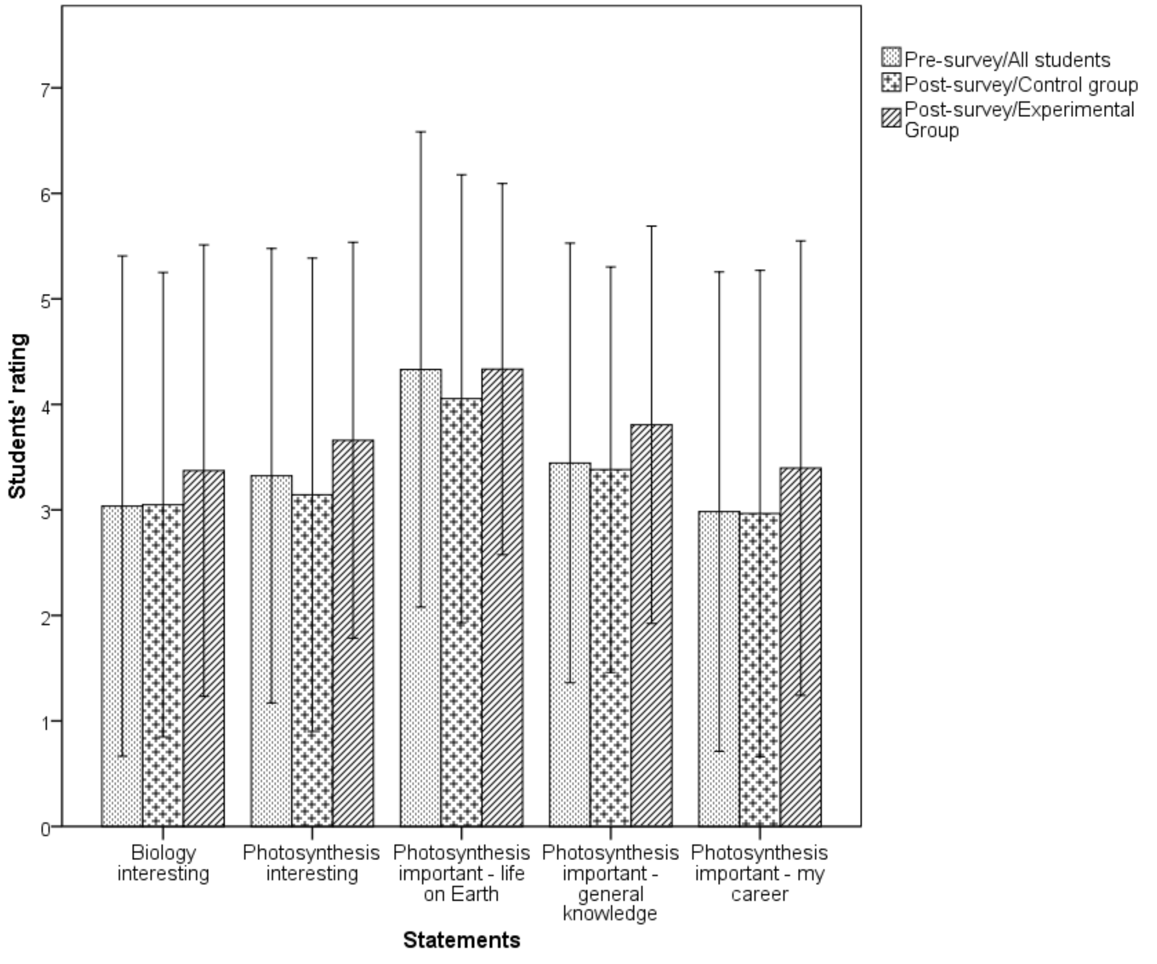

Figure 2. Attitudes of students toward biology and photosynthesis (*M* and *SD*) (pre- survey: *N* = 414; post-survey control group: *n* = 202; post-survey experiment group: *n* = 211) (Error Bars: +/- 2 *SD*).

https://doi.org/10.33225/jbse/19.18.569

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Table 3. Differences in attitudes of students toward biology and photosynthesis, and effect sizes of differences (pre-survey: *N* = 414; post-survey control group: *n* = 202; post-survey experiment group: *n* = 211).

	Difference (Mann-Whitney U test)											
	Pre-survey/Post-survey Control group			Effect Size	Pre-survey/Post-survey Experimental group			Effect Size	Post-survey Control/Experimental group			Effect Size
Statement	U	z	p	r	U	z	p	r	U	z	p	r
Biology is interesting.	41582.00	-0.116	.908	-.01	36937.500	-3.365	.001	-.14	17962.500	-2.968	.003	-.15
Photosynthesis is interesting.	37904.500	-1.969	.049	-.08	36503.000	3.627	<.001	-.16	15822.500	-4.817	<.001	-.24
Photosynthesis is important for life on Earth.	33104.000	-4.688	<.001	-.19	40360.500	-1.877	.060	-.08	18240.000	-2.826	.005	-.14
Knowledge of photosynthesis is important for general knowledge.	38918.000	-1.476	.140	-.06	35819.500	-4.021	<.001	-.16	15913.500	-4.754	<.001	-.23
Knowledge of photosynthesis is important for my personal career.	41678.500	-0.068	.946	-.00	35026.500	-4.282	<.001	-.17	17072.00	-3.692	<.001	-.18

Note. Statistically significant values are shown in bold type.

Correlations between Students' Knowledge about Photosynthesis and their Attitudes toward Biology and Photosynthesis

On the pre-test, 57.5% (23) of correlations between students' knowledge about photosynthesis and their attitudes toward biology and photosynthesis were statistically significant. There were 27.5% (11) significant correlations on the post-test in the control group and 15.0% (6) on the post-test in the experimental group. The correlations were predominantly (90%) weak. Most of them were positive; however, there was one negative correlation concerning the importance of the knowledge of photosynthesis for general knowledge, and three negative correlations concerning the importance of the knowledge of photosynthesis for students' career (Table 4).

Comparisons of correlations between the students' knowledge about photosynthesis and their attitudes toward biology and photosynthesis were also calculated. After the teaching units, 97% of calculated correlations in the control and the experimental groups were significantly different than before the teaching units (*ps* < .001). Also, after the teaching units, the correlations between the knowledge and the attitudes in the control group were significantly different from those in the experimental group (*ps* < .001).

Table 4. Correlations between the students' knowledge about photosynthesis and their attitudes toward biology and photosynthesis (pre-survey: *N* = 414; post-survey control group: *n* = 202; post-survey experiment group: *n* = 211).

		Biology interesting			Photosynthesis interesting			Photosynthesis important for life on Earth			Knowledge of photosynthesis important for general knowledge			Knowledge of photosynthesis important for my career		
Item	Correct answer	Pre	PoC	PoE	Pre	PoC	PoE	Pre	PoC	PoE	Pre	PoC	PoE	Pre	PoC	PoE
1	Sunlight energy does not add to the mass of the plant at all.	-.02	.07	.11	-.07	.15*	-.01	.13**	.09	.06	-.03	.16*	.08	-.12*	.10	.08
2	Molecules of carbon dioxide add to the mass of the plant a lot.	.10*	.07	-.09	.13**	.00	.03	.20**	-.04	-.06	.11*	.01	.02	.10*	.01	.04

https://doi.org/10.33225/jbse/19.18.569

		Biology interesting			Photosynthesis interesting			Photosynthesis important for life on Earth			Knowledge of photosynthesis important for general knowledge			Knowledge of photosynthesis important for my career		
Item	Correct answer	Pre	PoC	PoE	Pre	PoC	PoE	Pre	PoC	PoE	Pre	PoC	PoE	Pre	PoC	PoE
3	Molecules of minerals that plant receives through the roots add a medium amount of mass to the plant.	.09	.18**	-.03	.06	.10	-.13	.00	.03	.05	-.01	.04	-.11	-.08	.07	-.02
4	Molecules of water that plant receives through roots add to the mass of the plant a lot.	.09	.08	-.04	.14**	-.04	.02	.21**	.05	-.03	.19**	.04	-.13	.18**	-.18*	-.17*
5	Carbon dioxide and water are the reactants in photosynthesis.	.08	.11	.07	.12*	.30**	.05	.10*	.18*	.15*	.11*	.15*	.18*	.12*	.10	.01
6	Glucose and oxygen are the products of photosynthesis.	.19**	.12	.01	.26**	.11	.13	.19**	.02	.09	.20**	.16*	.18*	.22**	.03	.25**
7	Carbon dioxide and water are needed in photosynthesis and glucose, and oxygen are the products of photosynthesis.	.22**	.11	.02	.08	.17*	.08	.17**	.16*	.14*	.09	.25**	.13	.10*	.03	.13

** p < .05, ** p < .01*

Discussion

The first research question dealt with whether a teaching unit that includes the method of the conceptual change could bring about a better understanding of the concept of increasing the mass of plants than a traditional teaching unit could.

Students in agricultural education first completed a pre-test that consisted of seven items. With four items, the knowledge of the reasons for increasing the mass of the plants was tested. With the other three items, the insight into the basic knowledge of what are substances (reactants (carbon dioxide and water) and products (glucose and oxygen)) involved in photosynthesis was gained. The average knowledge of students on these seven items on the pre-test was 48.1%, which was well below the 60% that was set as the limit of adequate knowledge. This result was not surprising, as photosynthesis is a very difficult topic for students at all levels of education (Stavy, Eisen, & Yaakobi, 1987; Waheed & Lucas, 1992).

Results showed that students found it easier to recognise the products of photosynthesis (65.4% correct answers) in comparison to reactants (54.2%). This is in line with the research of Marmaroti and Galanopoulou (2006) which was done on a sample of pupils aged 13. At the same time, it contradicts the research of Gobec and Strgar (2019) in which the knowledge of students aged 15-18 about the reactants in photosynthesis (61.2%) was not very different from that about the products (66.1%).

Considering four items dealing with the possible reasons for increasing the mass of plants (contribution of water, solar energy, carbon dioxide, and minerals), the majority of students (76.5%) correctly answered that molecules of water add a lot to the mass of plants. The results concerning water are in line with those of Anderson, Sheldon, and Dubay (1990), and Simpson and Arnold (1982), who stated that students think that plants increase biomass from substances they receive from the soil, and that plants' feeding is similar to that of animals, except that they receive food through the roots instead of through the mouth. This also explains why most students (67.9%) thought that minerals that plants also receive from the soil add a lot to the mass of plants. Only 27.8% of students knew that minerals, in fact, add little mass.

Many students (45.3%) knew that carbon dioxide contributes a lot to the plant mass. This is surprising because many students find it difficult to connect it to the "solid" matter of plants, because of the gaseous nature of carbon dioxide. Research showed that students did not seem to be able to perceive gases as substances that have weight and can add to mass (Eisen & Stavy; 1988; Stavy, Eisen, & Yaakobi, 1987; Parker et

https://doi.org/10.33225/jbse/19.18.569

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

al.; 2012). Only 5.6% of students knew that sunlight energy does not add to the mass of the plants at all. Most frequently (74.9%) they answered that sunlight energy contributes a lot which suggests that they considered it to be a substance that is incorporated into the mass of plants (Köse, 2008; Hartley et al., 2011; Parker et al., 2012). This means that they do not understand the transformation of energy, which, as Liu, Ebenezer, and Fraser (2002) stated, may be a consequence of poor understanding of basic physical concepts. Results of the knowledge test, therefore, showed that understanding the reasons for increasing the mass of plants is not satisfactory among agricultural students.

After having completed the knowledge test, the students took part in teaching units that dealt with reasons for increasing the mass of plants. The control group participated in a theoretical explanation of this process combined with a discussion. The experimental group carried out the experiment "the impact of carbon dioxide on the increase in plant mass". The aim of this was to provoke cognitive conflict in students. This, in turn, should allow for a change in understanding once the students had realised that with their existing knowledge, they could not satisfactorily explain the results of the experiment. At this point, the teacher presented the correct answers which were then a subject of evaluation and discussion, as proposed by Strike & Posner (1992). Care was taken that answers were based on students' questions (Thompson & Zeuli, 1999), and that students played an active role in learning because understanding concepts cannot be transferred from teacher to student (Millar, 2004).

After the lessons, all students completed the knowledge test about photosynthesis again (post-test). Results of the post-test showed that average knowledge improved in both groups. In the control group, average knowledge was 57.0% which is still below the 60% limit of adequate knowledge, while in the experimental group it was satisfactory (68.7%). More detailed results showed that during the teaching units, students in both groups improved their knowledge on every item, except in the experimental group on Item 4 (molecules of water add a lot to the mass of plants). On the post-test, the experimental group had a significantly better understanding than the control group of the contribution of solar energy and carbon dioxide to the increase in the mass of plants (Items 1 and 2), as well as about the reactants and the products in photosynthesis (Items 5-7). About the contribution of the minerals (Item 3), there was no significant difference in improvement between the control and the experimental groups. Very interestingly, concerning the contribution of water to the mass of plants (Item 4) students in the experimental group in the post-test had a much lower score (43.9%) than in the control group (80.9%). Furthermore, the knowledge of the experimental group on this item was much lower than before the teaching unit, when it was 76.5%. This apparent deterioration of knowledge revealed that the correct response on the pre-test was, in fact, not a consequence of students' good understanding but rather of their misconception that the substances received through roots increase the mass of plants. Because of good results concerning the water in the pre-test, this substance was neglected during the teaching unit and more emphasis was placed on the contribution of solar energy, carbon dioxide and minerals to the increase in the mass of plants. These results showed that gaining an understanding of concepts is a gradual process (Millar, 2004) during which students are easily confused and can even develop new misconceptions.

In the present research, the method of conceptual change was chosen because the literature suggested it is especially effective for topics about which students hold misconceptions (Yenilmez & Tekkaya, 2006). The results of the present research on agricultural students support the conclusion that the method of conceptual change was more effective than the traditional method in improving the understanding of the concept of increasing the mass of plants.

Before and after the teaching units, students were also asked to rate five survey statements concerning their attitudes toward biology and photosynthesis. The results showed that before the teaching units, students were aware of the importance of photosynthesis for life on Earth (M = 4.33), but were slightly less convinced that the knowledge of photosynthesis was important for general knowledge (M = 3.44), and even less so that it was important for their careers (M = 2.98). Prokop, Tuncer, and Chuda (2007) also reported that most students were aware of the importance of biology but did not find it necessary for their daily life. The students were undecided about how interesting biology and photosynthesis were (M = 3.32; M = 3.04). After the teaching units, the control group found photosynthesis significantly less interesting and less important for life on Earth, while the other changes were not significant (and mostly negative). This showed that the traditional teaching unit not only failed to persuade students about the importance of photosynthesis but had even the opposite effect.

https://doi.org/10.33225/jbse/19.18.569

In contrast with that, after the teaching units, the experimental group found biology and photosynthesis significantly more interesting, and photosynthesis significantly more important for general knowledge and their career. Beside the teaching unit itself, some other factors may also have contributed to better attitudes. One is the fact that live plants were used during the experiment which had a positive impact on attitudes toward biology as Prokop, Tuncer, & Chuda (2007) reported. The other factor was laboratory work because students usually find it interesting (Šorgo & Špernjak, 2009).

The second research question attempted to determine whether the effectiveness of the method of conceptual change is related to the students' attitudes toward biology and photosynthesis. Identification of attitudes has become an essential topic in pedagogical research, as there is evidence of a relationship between attitudes and knowledge. Several authors reported that the attitudes toward biology (Gobec & Strgar. 2019; Prokop, Tuncer, & Chuda, 2007; Zeidan & Jayosi, 2015), as well as individual interest of students (Harackiewicz et al., 2002; Randler & Bogner, 2007), were positively related with the knowledge. In the present research, before the teaching units, students with better knowledge of photosynthesis predominantly (57.5% significant relations) expressed slightly more positive attitudes toward biology and photosynthesis. As a consequence of the traditional teaching unit, the percentage of significant relations plummeted to 27.5%, and after the teaching unit based on the practical laboratory work, it sank to 15.0%. Taking into account the results of the knowledge test and the survey it can, therefore, be concluded that the attitudes did not improve as much as the knowledge did.

Students in the experimental group expressed that the practical work they undertook helped improve their understanding of the impact of carbon dioxide on the mass of plants in photosynthesis, and that they liked doing it. The latter may have had some positive influence on their knowledge as according to Nasr & Soltani (2011) better knowledge is related to how fun students find biology.

Conclusions

This research showed that students in agricultural education in Slovenia did not have adequate initial understanding of photosynthesis. Two teaching units (traditional and experimental) that addressed the same curricular objectives were prepared and implemented in classes. The knowledge in the experimental group where the method of conceptual change was used improved significantly more than in the control group in all but two items. Results suggested that the method of conceptual change combined with experimental work in small groups of students can help students in understanding topics that are counter-intuitive, such as the mass of gases. This is especially important for students in agricultural education who need convincing examples with straightforward and gradual presentation of topics.

A surprising finding was that during the teaching unit students in the experimental group developed a new misconception about the contribution of water to the mass of plants. This was most likely the result of their previous misconception, which was not recognised and therefore not tackled adequately in the teaching unit. This suggested that even a very well prepared, and structured teaching unit is no guarantee that students will understand it the way it was intended. The experiment presented should be undertaken again with a new generation of students to verify this presumption. Further analysis should also be conducted to ascertain the depth of the knowledge regarding the contribution of the minerals to the mass of plants.

The limitation of this research is the sample, which is large enough but limited to one school in Slovenia, so the results cannot be generalised.

Conservation agriculture as a foundation of sustainable agriculture requires good basic knowledge of biology in agricultural students. The role of biology teachers is of great importance here. Therefore, teachers could use the design and findings of this research to plan their teaching units. The results provide insight into possible changes in several aspects of the tested teaching unit. The unit in its improved version will be prepared and spread among interested schools. One way to assist the teachers is also to address pre-service teachers. They should be made aware of the problematic topics that are reported by researchers. Furthermore, they must receive the necessary didactical knowledge about those topics as well as the skills to teach them more effectively. Based on the results of this research, other topics such as the cellular respiration of plants and the role of sunlight as a source of energy could be prepared with the method of the conceptual change and included in regular pre-service biology teacher's programmes.

https://doi.org/10.33225/jbse/19.18.569

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Acknowledgements

Sincere gratitude to the School Centre Šentjur for the logistic and supports. Special thanks to all students who participated in the research.

References

Albrechtová, J., Lhotáková, Z., Daněk, L., Tylová, E., Nátr, L., Semeráková, B., … Randolph, G. (2007, July-August). GLOBE carbon cycle plant-a-plant: Hands on photosynthesis experiments. In G. G. Geary (Ed.), *11th GLOBE annual conference symposium conducted at the meeting of The GLOBE programme*. San Antonio, Texas.

Ameyaw, Y. (2016). Evaluating students' misconceptions of photosynthesis and respiration in a Ghanaian senior high school. *International Journal of Advanced Biological Research*, *6*(2), 202–209.

Amir, R., & Tamir, P. (1994). In-depth analysis of misconceptions as a basis for developing research-based remedial instruction: The case of photosynthesis. *The American Biology Teacher*, *56*(2), 94–100.

Anderson, B. (1986). Pupils' explanations of some aspects of chemical reactions. *Science Education*, *70*(5), 549–563.

Anderson, C. W., Sheldon, T. H., & Dubay, J. (1990). The effects of instruction on college nonmajors' conceptions of respiration and photosynthesis. *Journal of Research in Science teaching*, *27*(8), 761–776.

Barker, M. A., & Carr, M. D. (1989). Photosynthesis – Can our pupils see the wood for the trees? *Journal of Biological Education*, *23*(1), 41–44.

Bell, B. (1985). Students' ideas about plant nutrition: What are they? *Journal of Biological Education*, *19*(3), 213–218.

Brown, M. H., & Schwartz, R. S. (2009). Connecting photosynthesis and cellular respiration: Preservice teachers' conceptions. *Journal of Research in Science Teaching*, *46*(7), 791–812.

Cañal, P. (1999). Photosynthesis and 'inverse respiration' in plants: An inevitable misconception? *International Journal of Science Education*, *21*(4), 363–371.

Carey, S. (1991). Knowledge acquisition: Enrichment or conceptual change? In S. Carey, & R. Gelman (Eds.), *The epigenesis of mind: Essay on biology and cognition* (pp. 257–291). Hillsdale: Lawrence Erlbaum Associates.

Carlsson, B. (2002). Ecological understanding 1: Ways of experiencing photosynthesis. *International Journal of Science Education*, *24*(7), 681–699.

Champagne, A. B., Gunstone, R. F., & Klopfer, L. E. (1983). Naive knowledge and science learning. *Research in Science and Technology Education*, *1*(2), 173–183.

Chinn, C. A., & Brewer, W. F. (1993). The role of anomalous data in knowledge acquisition: A theoretical framework and implications for science instruction. *Review of Educational Research*, *63*(1), 1–49.

Clark, R. W., Threeton, M. D., & Ewing, J. C. (2010). The potential of experiential learning models and practices in career and technical education and career and technical teacher education. *Journal of Career and Technical Education*, *25*(2), 46–62.

Davis, J. (2001). Conceptual Change. In M. Orey (Ed.), *Emerging perspectives on learning, teaching, and technology* (pp. 183–192). Zurich: The Global Text Project.

Duschl, R., Schweingruber, H., & Shouse, A. (2007). *Taking science to school: Learning and teaching science in grades K-8*. Washington: National Academies Press.

Eisen, Y., & Stavy, R. (1988). Students' understanding of photosynthesis. *The American Biology Teacher, 50*(4), 208–212.

Ebert-May, D., Batzli, J., & Lim, H. (2003). Disciplinary research strategies for assessment of learning. *BioScience*, *53*(12), 1221-1228.

Field, A. (2009). *Discovering statistics using SPSS*. London: Sage Publications.

George, R. (2006). A cross-domain analysis of change in students' attitudes toward science and attitudes about the utility of science. *International Journal of Science Education*, *28*(6), 571–589.

Gobec, K, & Strgar, J. (2019). Agricultural students' knowledge of photosynthesis and the contextual factors that influence it. *Journal of Baltic Science Education*, *18*(1), 6–18.

Hesse, J. J., III, & Anderson, C. W. (1992). Students' conceptions of chemical change. *Journal of Research in Science Teaching*, *29*(3), 277–299.

Harackiewicz, J. M., Barron, K. E., Tauer, J. M., & Elliot, A. J. (2002). Predicting success in college: A longitudinal study of achievement goals and ability measures as predictors of interest and performance from freshman year through graduation. *Journal of Educational Psychology*, *94*(3), 562–575.

Hartley, L. M., Wilke, B. J., Schramm, J. W., D'Avanzo, C., & Anderson, C. W. (2011). College students' understanding of the carbon cycle: Contrasting principle-based and informal reasoning. *BioScience*, *61*(1), 65–75.

Haslam, F., & Treagust, D. F. (1987). Diagnosing secondary students' misconceptions of photosynthesis and respiration in plants using a two-tier multiple-choice instrument. *Journal of Biological Education*, *21*(3), 203–211.

Helldén, G. (2005). Exploring understandings and responses to science: A program of longitudinal studies. *Research in Science Education*, *35*(1), 99–122.

Hogan, K., & Fisherkeller, J. (1996). Representing students' thinking about nutrient cycling in ecosystems: Bidimensional coding of a complex topic. *Journal of Research in Science Teaching*, *33*(9), 941–970.

Johnson, P. (2000). Children's understanding of substances, part 1: Recognizing chemical change. *International Journal of Science Education*, *22*(7), 719–737.

https://doi.org/10.33225/jbse/19.18.569

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Koba, S., & Tweed, A. (2009). *Hard-to-teach biology concepts: A framework to deepen student understanding*. Virginia: National Science Teacher Association.

Köse, S. (2008). Diagnosing student misconceptions: Using drawings as a research method. *World Applied Sciences Journal*, *3*(2), 283–293.

Liu, X., Ebenezer, J., & Fraser, D. (2002). Structural characteristics of university engineering students' conceptions of energy. *Journal of Research in Science Teaching*, *39*(5), 423–441.

Magntorn, O., & Helldén, G. (2007). Reading nature from a 'bottom-up' perspective. *Journal of Biological Education*, *41*(2), 68–75.

Marmaroti, P., & Galanopoulou, D. (2006). Pupils' understanding of photosynthesis: A questionnaire for the simultaneous assessment of all aspects. *International Journal of Science Education*, *28*(4), 383–403.

Millar, R. (2004). *The role of practical work in the teaching and learning of science*. Paper prepared for the meeting: High school science laboratories: Role and vision. Washington, DC, National Academy of Sciences. 3–4 June 2004. Retrieved from https://semanticscholar.org

Movahedzadeh, F. (2012). Improving student success through hybrid mode of delivery in nonscience major biology classes. *Education*, *2*(7), 333–339.

Näs, H. (2012). Understanding *p*hotosynthesis and *r*espiration: Is *i*t a *p*roblem? Eight *g*raders' *w*ritten and *o*ral *r*easoning about *p*hotosynthesis and *r*espiration. In K. C. D. Tan, & M. Kim (Eds.), *Issues and challenges in science education research* (pp. 73–91). Dordrecht: Springer.

Näs, H., & Ottander, C. (2008). Students reasoning while investigating plant material. *NorDiNa-Nordic Studies in Science Education*, *4*(2), 177–191.

Nasr, A. R., & Soltani, A. K. (2011). Attitude towards biology and its effects on student's achievement. *International Journal of Biology*, *3*(4), 100–104.

Nussbaum, J., & Novick, S. (1982). Alternative frameworks, conceptual conflict and accommodation: Towards a principled teaching strategy. *Instructional Science*, *11*(3), 183–200.

Parker, J. M., Anderson, C. W., Heidemann, M., Merrill, J., Merritt, B., Richmond, G., & Urban-Lurain, M. (2012). Exploring undergraduates' understanding of photosynthesis using diagnostic question clusters. *CBE–Life Sciences Education*, *11*(1), 47–57.

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education*, *66*(2), 211–227.

Prokop, P., Tuncer, G., & Chudá, J. (2007). Slovakian students' attitudes toward biology. *Eurasia Journal of Mathematics, Science & Technology Education*, *3*(4), 287–295.

Radanović, I., Garašoć, D., Lukša, Ž., Ristić-Dedić, Z., Jokić, B., & Sertić Perić, M. (2016). Understanding of photosynthesis concepts related to students' age. In J. Lavonen, K. Juuti, J. Lampiselkä, A. Uitto, & K. Hahl (Eds.), *Electronic proceedings of the ESERA 2015 conference. Science education research: Engaging learners for a sustainable future. Part 1: Learning science: Conceptual understanding* (pp. 271–277). Helsinki: University of Helsinki. Retrieved from http://www.esera.org

Randler, C., & Bogner, F. X. (2007). Pupils' interest before, during and after a curriculum dealing with ecological topics and its relationship with achievement. *Educational Research and Evaluation*, *13*(5), 463–478.

ROSE questionnaire. (n.d.) The relevance of science education. Retrieved from http://roseproject.no/key-documents/questionnaire.html.

Ross, P. M., Tronson D., & Ritchie, R. J. (2006). Modelling photosynthesis to increase conceptual understanding. *Journal of Biological Education*, *40*(2), 84–88.

Russel, A. W., Netherwood, G. M. A., & Robinson, S. A. (2004). Photosynthesis *i*n *s*ilico: Overcoming the challenges of photosynthesis education using a multimedia CDROM. *Bioscience Education*, *3*(1), 1–14.

Simpson, M., & Arnold, B. (1982). Availability of prerequisite concepts for learning biology at certificate level. *Journal of Biological Education*, *16*(1), 65–72.

Skribe-Dimec, D., & Strgar, J. (2017). Scientific conceptions of photosynthesis among primary school pupils and student teachers of biology. *CEPS Journal*, *7*(1), 49–68.

Stavy, R., Eisen, Y., & Yaakobi, D. (1987). How students aged 13-15 understand photosynthesis. *International Journal of Science Education*, *9*(1), 105–115.

Stepans, J. (1996). *Targeting students' science misconceptions: Physical science concepts using the conceptual change model.* Idea Factory Inc.

Strike, K. A., & Posner, G. J. (1992). A revisionist theory of conceptual change. In R. Duschl, & R. Hamilton (Eds.), *Philosophy of science, cognitive psychology, and educational theory and practice* (pp. 147–176). Albany: State University of New York Press.

Svandova, K. (2014). Secondary school students' misconceptions about photosynthesis and plant respiration: Preliminary results. *Eurasia Journal of Mathematics, Science and Technology Education*, *10*(1), 59–67.

Šorgo, A., & Špernjak, A. (2009). Secondary school students' perspectives on and attitudes towards laboratory work in biology. *Problems of Education in the 21st Century*, *14*, 123–134.

Taiz, L., & Zeiger, E. (2006). *Plant physiology*, 4rd ed. Sinauer Associates.

Thompson, C. L., & Zeuli, J. S. (1999). The frame and the tapestry. In L. Darling-Hammond, & G. Sykes, G. (Eds.), *Teaching as the learning profession: Handbook of policy and practice* (pp. 341–375). San Francisco, CA: Jossey-Bass.

Vosniadou, S. (2002). On the nature of naive physics. In M. Limon, & L. Mason (Eds.), *Reconsidering conceptual change: Issues in theory and practice* (pp. 61–67). Amsterdam: Kluwer.

Waheed, T., & Lucas, A. M. (1992). Understanding interrelated topics: Photosynthesis at age 14. *Journal of Biological Education*, *26*(3), 193–199.

https://doi.org/10.33225/jbse/19.18.569

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Warnick, B. K., Thompson, G. W., & Gummer, E. S. (2004). Perceptions of science teachers regarding the integration of science into the agricultural education curriculum. *Journal of Agricultural Education*, *45*(1), 62–73.
Yenilmez, A., & Tekkaya, C. (2006). Enhancing students' understanding of photosynthesis and respiration in plant through conceptual change approach. *Journal of Science Education and Technology*, *5*(1), 81–87.
Zeidan, A. H., & Jayosi, M. R. (2015). Science process skills and attitudes toward science among Palestinian secondary school students. *World Journal of Education*, *5*(1), 13–24.

Received: *May 14, 2019* Accepted: *July 27, 2019*

Katja Gobec	MSc, Lecturer, Vocational College, School Centre Šentjur, Cesta na kmetijsko šolo 9, 3230 Šentjur, Slovenia. E-mail: katja.gobec@guest.arnes.si Website: http://www.sc-s.si.
Jelka Strgar	PhD, Associate Professor, Biotechnical Faculty, Department of Biology, University of Ljubljana, Večna pot 111, 1000 Ljubljana, Slovenia. E-mail: jelka.strgar@bf.uni-lj.si Website: http://www.bf.uni-lj.si https://orcid.org/0000-0002-3869-5333.

https://doi.org/10.33225/jbse/19.18.569