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AGRICULTURAL STUDENTS' KNOWLEDGE OF PHOTOSYNTHESIS AND THE CONTEXTUAL FACTORS THAT INFLUENCE IT

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Abstract. *This research aimed to assess the knowledge of photosynthesis among students in agricultural education and understand the influence of the contextual factors on it. In photosynthesis, biomass is produced, so understanding these processes is essential for successful agriculture. The research sample consisted of 330 students in agricultural education in Slovenia. Data were collected with a knowledge test and a contextual questionnaire. Better knowledge of photosynthesis was positively related with higher awareness of the importance of biology as a science and of photosynthesis. There was no significant relation between the knowledge of photosynthesis and positive attitudes toward biology lessons. The average achievement on the knowledge test of photosynthesis was 56%: the highest on the item about energy and the lowest on the item about the primary purpose of photosynthesis. Between these two achievements was the knowledge of reactants and products in photosynthesis, and the knowledge concerning chlorophyll. Considering these results, improvements should be made in teaching. For this population, more experimental and less theory-based lessons were suggested. The findings could benefit biology and science teachers in agricultural education and help improve national curriculum for biology in agricultural programmes.*

Keywords: *agricultural education, biology education, contextual factors in education, knowledge of photosynthesis*

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Introduction

The process of photosynthesis is a topic about which students struggle to comprehend adequately. According to previous research, students have various misconceptions, misunderstandings, and naive and alternative conceptions about it (Waheed & Lucas, 1992). The same or similar problems in knowledge of photosynthesis were reported at all educational levels: elementary school (Skribe-Dimec & Strgar, 2017; Tekkaya & Balci, 2003), secondary school (Barak, Sheva, & Gorodetsky, 1999; Jin & Anderson, 2012; Lin & Hu, 2003; Svandova, 2013), pre-service teachers (Brown & Schwartz, 2009; Harman, 2012; Tekkaya, Capa, & Yilmaz, 2000), and practising teachers (Domingos-Grillo, Reis-Grilo, Ruiz, & Mellado, 2012; Lenton & McNeil, 1993). Biology topics concerning cells, organelles, physiological and biochemical processes, and transformation of energy present difficulties to many students (Lazarowietz & Penso, 1992; Marmaroti & Galanopoulou, 2006). The chemistry of photosynthesis was perceived as one of the most difficult topics in school biology (Johnstone & Mahmoud, 1980).

Marmaroti and Galanopoulou (2006) have stated that photosynthesis is one of the most essential of the processes that are indicators of life in plants, and that it has numerous different features in comparison to other biochemical processes. This makes photosynthesis a central subject of biology courses at all levels, especially at the secondary level of education.

On completion of compulsory primary education, typically at the age of 15, Slovenian students continue education in secondary school and choose from among programmes of either general, vocational, or technical education. Over 60% of students enrol in vocational or technical programmes.

In Slovenia, students in secondary agricultural education are enrolled either in a three-year vocational programmes of Country Farmer and Gardener or four-year technical programmes of Agricultural-Entrepreneurial Technician and Horticultural Technician. In vocational programmes, all biology content is integrated into the subject of Science. Most of the learning objectives in the Science syllabus include biology content, and students have to acquire basic knowledge of ecosystems, physiology, genetics, and plant nutrition and be aware of the significance of plants (Poberžnik, Skvarč, Verovnik, & Vičar, 2007). In these two educational programmes, many biology topics are also integrated into various agricultural subjects. In technical programmes, there is a separate subject of Biology; according to its syllabus, students should acquire general and fundamental knowledge to be able to understand the laws of nature and perform their work in plant, animal, horticultural, and floricultural production and supplementary activities. Photosynthesis is a compulsory part of their syllabus in topics about understanding the basic concepts of life and ecological processes (Vičar, 2007).

Different teaching methods, models, and approaches impact students' attitudes toward biology; and attitudes influence students' knowledge (George, 2000). Ajzen (2001) has explained how the conceptualisation of attitude and its formation and activation are correlated with peoples' accessible beliefs, and what the influence of affective versus cognitive processes in the formation of attitudes is. The development of attitudes starts in primary school. If students do not have positive experiences there, they tend to avoid science in their later education, resulting in a lack of knowledge and commitment to science (Simpson & Oliver, 1990).

Attitudes toward science, and biology specifically, are well studied from different perspectives. A positive correlation between students' attitudes toward biology and their achievements and process skills performance has been reported (Kubiatko, 2012; Nasr & Soltani, 2011; Owino, Yougungu, Ahmed, & Ogolla, 2015; Shaheen & Kayani, 2017). In Slovenia, however, 15-year-olds have shown good knowledge of biology but a poor attitude toward it (Štraus, Šterman Ivančič, & Štirn, 2016). Hansen and Birol (2014) have found that high-performing biology programme students have more expert-like attitudes than low-performing students do.

A large amount of attitudinal research has focused on gender, age or year of study, either deliberately or as a side finding. Some research has shown that girls have a significantly greater interest in biology than boys do as well as more positive attitudes toward biology (Prokop, Prokop, & Tunnicliffe, 2007). The majority of studies found no difference between boys and girls in attitudes toward biology (Nasr & Soltani, 2011; Šorgo & Špernjak, 2009; Zeidan & Jayosi, 2015) or their attitudes toward plants (Fančovičová & Prokop, 2010). According to Šorgo and Špernjak (2009), different age classes do not differ in the general directions of their expressed attitudes; they like or dislike the same things, but they differ in the strength of their attitudes (p.131).

Students' attitudes toward biology can be affected by different variables; in the case of plants, some students lack positive attitudes toward them, but if the family has a garden, more positive attitudes toward plants emerge (Fančovičová & Prokop, 2010). In Slovenia, it has been discovered that students in vocational and technical secondary education value biology more than students in general secondary education do (Šorgo & Špernjak, 2009).

Agriculture is a science that includes biology along with other sciences (Baird, Lazarowitz, & Allman, 1984; Terry & Torres, 2006).) Agricultural and natural resources should be used to teach biology and incorporate agricultural concepts into plant science (Connors & Elliot, 1995). Teachers have agreed that integrating more biology in agricultural education would assist in students' better understanding of science concepts and their application (Mayer, 1987).

Problem of Research

National aims are to raise the level of food self-sufficiency and the number of farms whose agricultural production is sustainable (Hrustel Majcen & Paulin, 2001; Strategija razvoja Slovenije, 2005). This requires good basic knowledge of biology in farmers, especially of the process of photosynthesis which is at the basis of agricultural production because it connects the living and non-living worlds (Waheed & Lucas, 1992). It also requires the awareness of farmers about the importance of photosynthesis. According to Mayer (1987), a significant amount of agriculture is conducted without any knowledge of the biological principles involved. In Slovenia, most future farmers finish some level of agricultural education, which includes biology either as a separate subject or as biology topics that are part of other agronomical subjects. Previous research indicated that students of different ages find photosynthesis difficult to understand and have inadequate knowledge of it (Domingos-Grillo, Reis-Grilo, Ruiz, & Mellado, 2012, Marmaroti & Galanopoulou, 2006; Özay & Öztaş, 2003; Svandova, 2014).

Research Focus

The main aim of this research was to explore the level of knowledge of photosynthesis among Slovenian students in agricultural education. Research also focused on contextual factors affecting the knowledge of students': their attitudes toward photosynthesis, the importance of biology, and biology lessons and learning habits of students. The following research questions were formulated:

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- How well do students in agronomical education understand the process of photosynthesis?
- Is there any relation between the students' knowledge of photosynthesis and the selected contextual factors?

Methodology of Research

General Background

The research design was quantitative. Descriptive and correlational methods were used. Knowledge of photosynthesis of Slovenian students in secondary agricultural education and contextual factors affecting their knowledge were explored by administering a knowledge test and a contextual questionnaire. The research was conducted in spring 2017 in three secondary agricultural schools in Slovenia.

Sample

The total number of participants is 330, which is 35% of all students enrolled in four secondary agricultural programmes in Slovenia (Table 1). Included are all students who attended classes when this research was conducted. They are students of all three grades in the vocational programmes of Country Farmer (10.6% of total participants) and Gardener (19.8%) and students in all four grades in the technical programmes of Agricultural-Entrepreneurial Technician (49.9%) and Horticultural Technician (19.7%). The Country Farmer and Agricultural-Entrepreneurial Technician programmes are focused on farming while the Gardener and Horticultural Technician programmes are focused on horticultural production. The proportion of female adolescents among participants is 51.5%; 66.1% of participants come from a home with a farm.

The research was anonymous; all the parents of the students signed an agreement to allow their children to participate in it.

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

Educational programme	Participants			
	Year	Age	*N*	*f* (%)
Country Farmer	1	15	10	3.1
	2	16	13	3.9
	3	17	12	3.6
Gardener	1	15	25	7.6
	2	16	22	6.8
	3	17	18	5.4
Agricultural-Entrepreneurial Technician	1	15	41	12.4
	2	16	51	15.4
	3	17	39	11.8
	4	18	34	10.3
Horticultural Technician	1	15	18	5.4
	2	16	17	5.2
	3	17	16	4.9
	4	18	14	4.2
Total			330	100.0

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Instrument and Procedures

Data were collected using a set of demographic questions (educational programme, year of study, gender, and farm at home), knowledge test about photosynthesis, and a contextual questionnaire about students' attitudes toward photosynthesis, the importance of biology, and biology lessons and their learning habits.

The knowledge test contained nine multiple choice items. Participants had to choose one answer out of three to five. The same items were used in research by Domingos-Grilo, Reis-Grilo, Ruiz, and Mellado (2012; 'What is the main purpose of photosynthesis?'), Marmaroti and Galanopoulou (2006; 'Which pair of substances are the reactants in photosynthesis?', 'Which substances are products of photosynthesis?', 'Which parts of the plant contain chlorophyll?', and 'In which parts of the plant does photosynthesis take place?'), Çepni, Taş, and Köse (2006; 'Into what type of energy do plants transform sunlight energy?'). An item used in a survey by Skribe-Dimec and Strgar (2017; 'What type of energy do plants receive from the sun?') was added. Two pairs of items were compiled into two new items, which acted as control items: 'In which parts of the plant does photosynthesis take place, and which parts of the plant contain chlorophyll?', and 'Which pair of substances is needed in photosynthesis, and which pair of substances are the products of photosynthesis?').

With multiple choice items, the following four conceptions in connection with photosynthesis were evaluated:

1) The function of photosynthesis (item F - 'What is the main purpose of photosynthesis?').
2) Photosynthesis and energy (item E1 - 'What type of energy do plants receive from the sun?', and item E2 - 'Into what type of energy do plants transform sunlight energy?').
3) The process of photosynthesis, (item P1 - 'Which pair of substances are the reactants in photosynthesis?', item P2 - 'Which substances are the products of photosynthesis?', and item P3 - 'Which pair of substances is needed in photosynthesis, and which pair of substances are the products of photosynthesis?').
4) Chlorophyll (item C1 - 'In which parts of the plant does photosynthesis take place?', item C2 - 'Which parts of the plant contain chlorophyll?', and item C3 - 'In which parts of the plant does photosynthesis take place, and which parts of the plant contain chlorophyll?').

The choice of items was based on the fact that biomass is produced in photosynthesis, so understanding these processes is essential for successful agriculture.

The contextual questionnaire contained 22 statements assessing students' attitudes toward photosynthesis, the importance of biology, and biology lessons and learning habits of the students. Most of these statements were adapted from the questionnaire used in The Relevance of Science Education study (The ROSE questionnaire, n.d.). The contextual questionnaire used a 5-point Likert scale, ranging from strongly disagree (1) to strongly agree (5).

After each of the three agricultural schools confirmed their participation in the research, copies of tests and questionnaires were delivered to them. Instructions for biology teachers were given in person and in writing. Students completed the set of demographic questions, the knowledge test, and the contextual questionnaire during their regular lessons of biology or science in approximately 20 to 25 minutes.

Data Analysis

For the knowledge test of photosynthesis, frequencies were calculated. Data were tested for normal distribution with the Kolmogorov-Smirnov test; considering that the distribution of data was not normal, non-parametric testing was used. A chi-square test was used to identify statistically significant differences in the knowledge of photosynthesis between students of different genders, years of study, educational programmes, and whether they come from a farm or not. Post hoc pairwise comparisons were made using z-test and Bonferroni correction.

Data from the contextual questionnaire were subjected to Principal Component Analysis (PCA). The oblique rotation (direct oblimin) method with Kaiser normalisation was conducted on 22 items. The value of the Kaiser-Meyer-Olkin measure of sampling adequacy was .920, which means that the sample size was adequate for PCA. Bartlett's test of sphericity was highly significant ($\chi^2 = 3021.279$, $df = 231$, $p < .001$), indicating that correlations between items were sufficiently large for PCA.

According to PCA, four components can be extracted. Seven items were loaded onto component 1 (positive attitudes toward biology lessons); seven items were loaded onto component 2 (importance of biology); three items loaded onto component 3 (positive attitudes toward photosynthesis), and five items loaded onto compo-

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nent 4 (good learning habits). Cronbach's alphas for three components were between .77 and .87 while for one component it was .65 (Table 2). These four components explained 55.93% of the variance. Cronbach's alpha for all 22 items was .92. Correlations between components were calculated using Spearman's correlation coefficient (r_s).

Table 2. Summary of principal component analysis results for the attitude toward biology questionnaire.

Statement	Rotated Factor Loading			
	Component			
	1	2	3	4
I like the content taught in biology lessons.	.857			
I am looking forward to biology lessons.	.800			
I am very interested in the content of biology.	.784			
I understand everything in biology lessons.	.668			
I like the content I learn in biology.	.550			
I think it is important to learn the contents discussed in biology.	.549			
I finish my homework on time.	.445			
Progress in biology improves the quality of our lives.		.731		
Biology is useful in everyday life.		.722		
What I learn in biology lessons will benefit my everyday life.		.718		
I find it important to understand the contents of biology lessons.		.655		
Biology is important for society.		.586		
Everyone needs the basic biological knowledge.		.564		
Due to my biology lessons, I understand the world around me better.		.458		
Understanding photosynthesis will benefit my life.			.778	
Photosynthesis is interesting.			.756	
Understanding the essence of photosynthesis is important for general education.			.666	
I usually make a work plan for each day for what I have to do for school.				.818
I make myself learn even when I could do some more interesting things.				.751
I make myself work for school.				.546
In the lessons, I always concentrate on school subjects.				.528
I arrange my space, so I can learn without disturbances.				.513
Eigenvalue	8.09	1.89	1.25	1.08
% of variance	36.77	8.59	5.68	4.89
α	.87	.84	.65	.77
Number of items	7	7	3	5

Note. 1=Positive attitudes toward biology lessons, 2=Importance of biology, 3=Positive attitudes toward photosynthesis, 4=Good learning habits.

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Results of Research

Students' general Achievements on the Knowledge Test about Photosynthesis

According to the results of the knowledge test about photosynthesis (Table 3), which contained nine multiple choice items, all participating students achieved an average of 55.9% of correct answers. In the part about energy, which was checked by two items (E1, E2), students reached an average of 67.6% of the correct answers for those two items. In the part about photosynthesis as a process, which was checked by three items (P1, P2, P3), students achieved an average of 63.9% of correct answers for those three items. With the part about chlorophyll, which was checked by three items (C1, C2, C3), students achieved an average of 51.0% of correct answers for those three items. The content part of the function of photosynthesis was checked by one item (F), and the achievement of the students here was 23.3%.

The students had the lowest achievements on item F ('What is the main purpose of photosynthesis?'; 23.3%) and item C3 ('In which parts of the plant does photosynthesis take place, and which parts of the plant contain chlorophyll?'; 33.6%). On two items (E2 – 'Into what type of energy do plants transform sunlight energy?' and C2 – 'Which parts of the plant contain chlorophyll?'), the achievements were 56.4% and 57.3%, respectively, which is slightly below 60.0%, which was a limit for adequate knowledge. For five items, the achievements ranged between 61.2% and 78.8% (P1 – 'Which pair of substances are the reactants in photosynthesis?'; C1 – 'In which parts of the plant does photosynthesis take place?'; P2 – 'Which substances are the products of photosynthesis?'; P3 – 'Which pair of substances are needed in photosynthesis, and which pair of substances are the products of photosynthesis?', and E1 – "What type of energy do plants receive from the sun?) (Table 3).

Table 3. Percentage of students' correct answers to the items on the knowledge test, and statistical significance of differences between their answers according to gender, year of education, educational programme.

	Total	Gender			Year of education					Educational programme					Farm at home		
		Female	Male	χ^2	1.	2.	3.	4.	χ^2	CF	G	AET	HT	χ^2	No	Yes	χ^2
Statements	*f(%)*	*f(%)*	*f(%)*	*p*	*f(%)*	*f(%)*	*f(%)*	*f(%)*	*p*	*f(%)*	*f(%)*	*f(%)*	*f(%)*	*p*	*f(%)*	*f(%)*	*p*
F - The main purpose of photosynthesis is the production of glucose.	23.3	23.4	23.3	.972	25.5	17.5	25.9	27.1	.405	17.1	18.5	23.0	32.3	.208	26.8	21.6	.288
E1 - Plants receive sunlight energy from the sun.	78.8	78.5	79.1	.896	77.7	80.6	78.8	77.1	.950	51.4	70.8	85.5	84.6	< .001	78.6	78.9	.945
E2 - Plants transform sunlight energy into chemical energy.	56.4	50.6	61.6	.044	50.0	65.0	45.9	68.8	.009	48.6	38.5	60.6	67.7	.003	50.0	59.6	.095
P1 – Carbon dioxide and water are the reactants in photosynthesis.	61.2	66.5	56.4	.061	58.5	74.8	54.1	50.0	.006	22.9	60.0	63.6	76.9	< .001	67.0	58.3	.124
P2 – Glucose and oxygen are the products of photosynthesis.	64.5	64.6	64.5	.997	73.4	67.0	50.6	66.7	.013	42.9	55.4	64.2	86.2	< .001	69.6	61.9	.165
P3 - Carbon dioxide and water are needed in photosynthesis and glucose, and oxygen is the products of photosynthesis.	66.1	67.7	64.5	.541	68.1	74.8	57.6	58.3	.055	45.7	49.2	70.3	83.1	< .001	68.8	64.7	.460

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	Total	Gender			Year of education					Educational programme					Farm at home		
		Female	Male	χ^2	1.	2.	3.	4.	χ^2	CF	G	AET	HT	χ^2	No	Yes	χ^2
Statements	*f(%)*	*f(%)*	*f(%)*	*p*	*f(%)*	*f(%)*	*f(%)*	*f(%)*	*p*	*f(%)*	*f(%)*	*f(%)*	*f(%)*	*p*	*f(%)*	*f(%)*	*p*
C1 - Photosynthesis takes place in the green parts of the plant.	62.1	69.6	55.2	.007	74.5	60.2	63.5	39.6	.001	54.3	67.7	52.7	84.6	< .001	72.3	56.9	.006
C2 - Chlorophyll is in the green parts of the plant.	57.3	58.2	56.4	.737	57.4	62.1	55.3	50.0	.538	51.4	56.9	55.2	66.2	.409	50.0	61.0	.056
C3 - Photosynthesis takes place in the green parts of the plant and chlorophyll is in the green parts of the plant.	33.6	34.2	33.1	.842	34.0	36.9	37.6	18.8	.118	28.6	35.4	23.0	61.5	< .001	34.8	33.0	.744
Average performance	55.9	57.0	54.9		57.7	59.9	52.1	50.7		40.3	50.3	55.3	71.5		57.5	55.1	

Note. CF=Country Farmer, G=Gardner, AET=Agricultural Entrepreneurial Technician, HT=Horticultural Technician; Statistically significant values are shown in bold type.

Differences among Students' Achievements by Gender, Year of Study, and Programme

The average achievement of female adolescents was slightly higher (57.0%) than that of male adolescents (54.9%) (Table 3). We found two statistically significant differences in answers between genders. Item E2 on energy was answered more correctly by male adolescents, while item C1 on chlorophyll was more correctly answered by female adolescents.

The lowest average achievement of students on the knowledge test about photosynthesis was in the fourth year (50.7%), followed by students in the third year (52.1%), then the first year (57.7%), and the highest was the achievement of the second-year students (59.9%) (Table 3). Four statistically significant differences among the answers of students of these four years were found. According to the post hoc test, in most of these four items, the first-year and/or the second-year students significantly differed from the third-year and/or the fourth-year students.

Comparing students' knowledge in four different educational programmes the highest average achievements on the knowledge test of photosynthesis are held by the students in the educational programme of Horticultural Technician (71.5%), followed by Agricultural-Entrepreneurial Technician students (55.3%), then in Gardener students (50.3%); the lowest average exam performance was seen in the Country Farmer programme (40.3%) (Table 3). Students of these four educational programmes answered statistically significantly differently in seven out of nine items. According to the post hoc test, in almost all of these seven items, the students in the Horticultural Technician programme differed significantly from the students in the Country Farmer programme. Students in the Gardener programme and those in the Agricultural-Entrepreneurial Technician programme differed significantly from those in the Horticultural Technician programme in some items and from those in the Country Farmer programme in other items.

The average achievements of the students who have no farm at home were higher (57.5%) than that of the students coming from a farm (55.1%). There was only one statistically significant difference (Table 3). Students from a farm had lower achievement on item C1, about chlorophyll.

Correlations between the Students' Achievements on the Knowledge Test about Photosynthesis and Contextual Factors that Influence Knowledge

The correlations between the students' achievements on the knowledge test about photosynthesis and contextual factors that influence the knowledge were assessed (Table 4). The contextual factors were the components

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we obtained as a result of the PCA (attitudes toward photosynthesis, the importance of biology, and biology lessons and good learning habits) on a contextual questionnaire that students completed. Students who scored higher on the positive attitude toward photosynthesis (component 3 of PCA) also scored significantly higher on three items on the knowledge test: two out of three items concerning chlorophyll (C2, C3), and one out of three items concerning the process of photosynthesis (P1). All three significant correlations were positive and small ($.12 < r_s < .23$). Students who scored higher on the importance of biology (component 2 of PCA) also scored significantly higher on five items on the knowledge test: all three items concerning chlorophyll (C1, C2, C3), and two out of three items concerning the process of photosynthesis (P1, P3). All five significant correlations were positive and small ($.13 < r_s < .20$). There was no significant correlation between students' positive attitudes toward biology lessons (component 1 of PCA) and their achievement on the knowledge test about photosynthesis. Good learning habits (component 4 of PCA) correlated significantly to one item concerning energy (E1), and two items concerning the process of photosynthesis (P2, P3). These correlations were negative and small ($-.15 < r_s < -.23$).

Table 4. Correlations between the students' achievements on the knowledge test about photosynthesis and the contextual factors that influence the knowledge.

Statements	F1-Positive attitudes toward biology lessons	F2-Importance of biology	F3-Positive attitudes toward photosynthesis	F4-Good learning habits
F - The main purpose of photosynthesis is the production of glucose.	-.03	-.01	-.01	-.06
E1 - Plants receive sunlight energy from the sun.	-.08	-.03	-.02	-.15**
E2 - Plants transform sunlight energy into chemical energy.	.02	.08	.09	-.08
P1 – Carbon dioxide and water are the reactants in photosynthesis.	.02	.18**	.12*	-.51
P2 – Glucose and oxygen are the products of photosynthesis.	-.07	.07	.04	-,21**
P3 - Carbon dioxide and water are needed in photosynthesis and glucose, and oxygen is the products of photosynthesis.	-.08	.13*	.10	-,23**
C1 - Photosynthesis takes place in the green parts of the plant.	.08	.16**	.07	-.03
C2 - Chlorophyll is in the green parts of the plant.	.07	.15**	.23**	-.03
C3 - Photosynthesis takes place in the green parts of the plant and chlorophyll is in the green parts of the plant.	.03	.20**	.18**	-.04

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

Correlations between the Students' Achievements on the Knowledge Test about Photosynthesis

There were 22 significant correlations between the students' knowledge of photosynthesis, which was tested with nine items (Table 5). All of them were positive: fifteen were small ($.11 < r_s < .29$), and seven were medium ($.32 < r_s < .55$).

Items F ('What is the main purpose of photosynthesis?') and E1 ('What type of energy do plants receive from the sun?') each correlated to just one item. Six items concerning energy, the process of photosynthesis, and chlorophyll (E2, P1, P3, C1, C2, C3) each correlated to five or six other items. Item P2 ('Which substances are products of photosynthesis?') correlated to all other items. All three items concerning the process of photosynthesis (P1, P2, P3) inter-correlated. Among items concerning chlorophyll (C1, C2, C3), only item C3 correlated to both of the other items (C1 and C2) while there was no correlation between C1 and C2. The two items concerning energy (E1 and E2) did not correlate with each other.

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Table 5. Correlations between the students' achievements on the knowledge test about photosynthesis.

Statements	F	E1	E2	P1	P2	P3	C1	C2
F - The main purpose of photosynthesis is the production of glucose.	1.00							
E1 - Plants receive sunlight energy from the sun.	.04	1.00						
E2 - Plants transform sunlight energy into chemical energy.	-.04	.04	1.00					
P1 – Carbon dioxide and water are the reactants in photosynthesis.	.03	.09	.14*	1.00				
P2 – Glucose and oxygen are the products of photosynthesis.	.11*	.16**	.18**	.41**	1.00			
P3 - Carbon dioxide and water are needed in photosynthesis and glucose and oxygen are the products of photosynthesis.	.03	.10	.22**	.55**	.49**	1.00		
C1 - Photosynthesis takes place in the green parts of the plant.	.00	.02	.16**	.25**	.28**	.35**	1.00	
C2 - Chlorophyll is in the green parts of the plant.	.07	-.01	.17**	.29**	.24**	.26**	.08	1.00
C3 - Photosynthesis takes place in the green parts of the plant and chlorophyll is in the green parts of the plant.	.08	.09	.23**	.32**	.27**	.28**	.45**	.46**

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

Discussion

The first research question addressed in this paper has been how well the students in agricultural education understand the process of photosynthesis. The average achievement of all participants on the knowledge test about photosynthesis has been slightly under 60%, which was set as the limit of adequate knowledge. This is in line with the previous research that showed many difficulties in learning this process at all educational levels.

The first item in the knowledge test was focused on the primary purpose of photosynthesis (item F). Less than one quarter (23.3%) of students in agricultural education answered that the primary purpose of photosynthesis is the formation of glucose. The majority of students held the idea that the main function of photosynthesis is the formation of oxygen. As Skribe-Dimec and Strgar (2017) have pointed out, defining photosynthesis' main function is difficult. In evolution, the primary function of photosynthesis was the formation of glucose, and oxygen was a by-product. However, for aerobic organisms, both products are equally important. In their research conducted on the sample of elementary school students in Slovenia, more than one third (37.7%) answered that the main purpose of photosynthesis is the production of glucose. This suggests that elementary school students (aged 11-14) have a better understanding of the production of glucose in photosynthesis than agricultural students (aged 15-18) do. Others have also reported that students more often relate photosynthesis with oxygen and much more rarely with glucose (Anderson, Sheldon, & Dubay, 1990; Svandova, 2014). This could be due to the predominant presentation of photosynthesis, which stresses only both gasses (oxygen and carbon dioxide) but not also glucose (Cañal, 1999). Carlsson (2002) has stated that between the ideas of energy flow and transformation of the matter in the ecosystems, the latter is crucial for the more complex understanding of photosynthesis, and understanding photosynthesis is necessary for understanding ecosystems. For sustainable agriculture, farmers should be well aware of the circulation of matter in ecosystems.

The results related to the energy in photosynthesis (items E1 and E2) have shown that students in agricultural education know very well that plants receive light energy from the sun (78.8%). The second most frequent answer was heat. Anderson, Sheldon, and Dubay (1990) have come to similar conclusions. In other research (Marmaroti & Galanopoulou, 2006; Waheed & Lucas, 1992), the frequency of students who answered light energy has been similar to those who answered heat.

Over half of the participants in this research (56.4%) have answered correctly that in photosynthesis light energy is transformed into chemical energy. Less frequent answers have been that light energy is transformed into light or heat. According to these results and other reports (Carlsson, 2002; Eisen & Stavy, 1988; Marmaroti & Galanopoulou, 2006; Waheed & Lucas, 1992), energy transformation in photosynthesis presents a greater problem.

The results related to chlorophyll (items C1, C2, and C3) have shown that 62.1% of students in agricultural

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education know that photosynthesis takes place in the green parts of the plant and 57.3% know that the green parts of the plants contain chlorophyll. However, only a third (33.6%) has answered correctly on the combined item, i.e. that photosynthesis takes place in the green parts of the plant where chlorophyll is. This leads to the conclusion that participants poorly comprehend the role of chlorophyll in photosynthesis even though they know that chlorophyll is a necessary constituent of photosynthesis. In the present and other research (Marmaroti & Galanopoulou, 2006; Özay & Öztas; 2003), students frequently answered that photosynthesis takes place in the leaves and that chlorophyll is in the leaves. According to Skribe-Dimec & Strgar (2017), the reason for these answers might be textbooks that typically present photosynthesis with a picture of a plant leaf. The knowledge of students in this research (aged 15-18) has been considerably higher in comparison to that reported by Marmaroti and Galanopoulou (2006). At the same time, it was comparable with the knowledge of Slovenian students (aged 11-14) in research by Skribe-Dimec & Strgar (2017).

As a result of items about reactants and products of photosynthesis (items P1, P2, and P3), very similar proportions of students in agricultural education have correctly recognised reactants and products (61.2%-66.1%). According to Marmaroti and Galanopoulou (2006), students find it easier to understand what is produced in a chemical reaction than what enters it, but the results of the present research are not in line with that conclusion. Many authors have reported that students have difficulties in understanding the inputs and outputs of photosynthesis as well as the process itself (Anderson, Sheldon, & Dubay, 1990; Eisen & Stavy, 1988; Griffard & Wandersee 2001; Harman, 2012; Haslam & Treagust, 1987).

In this research, only two statistically significant differences in the knowledge test about photosynthesis considering gender have been observed. The first has been on the item 'In which parts of the plant does photosynthesis take place?', for which female adolescents' achievement was higher, and on the item 'Into what type of energy do plants transform sunlight energy?', for which male adolescents' achievement was higher. Our results have been in accordance with the findings of Baram-Tsabari and Yarden (2011) and Jones, Howe, and Rua (2000), which have shown that male students have greater affinity for physics while female students have greater affinity for biology. Svandova (2014) has also discovered better knowledge in male students in her research of photosynthesis. In contrast, in research by Haslam and Treagust (1987), the knowledge of photosynthesis of female and male students has been comparable.

Four statistically significant differences in the knowledge test about photosynthesis among answers of students of four different years of study have been found. Knowledge of the first- and the second-year students has been better than that of the third- and the fourth-year students. Significant differences in knowledge of photosynthesis regarding the year of study have also been reported by Haslam and Treagust (1987) while Svandova (2014) has not found any.

Students in the four educational programmes participating in this research have answered significantly differently to seven out of nine items on the knowledge test about photosynthesis. Students in four-year agricultural programmes have performed better in comparison to students in three-year programmes. This may be due to the fact that students who enrol in three-year education have lower academic scores in elementary level of education.

There has been only one significant difference in knowledge of photosynthesis between agricultural students coming from a farm and those who have no farm at home, which has been in favour of the latter. The expectation had been that students coming from a farm would possess better knowledge. To better understand the reasons that this was not the case, other contextual factors should be taken into consideration, such as socio-economic status and the region in which they live.

The second research question was to determine whether there has been any relationship between the students' knowledge of photosynthesis and the selected contextual factors (recognising the importance of biology, attitudes toward photosynthesis, attitudes toward biology lessons, good learning habits). Recognising the importance of biology and positive attitude toward photosynthesis have significantly positively correlated with higher performance on the knowledge test about photosynthesis, especially on the items concerning chlorophyll and the process of photosynthesis. In contrast, students' positive attitudes toward biology lessons have not correlated with knowledge. The same is true for general Slovenian 15-year olds, in PISA 2015, where Slovenian participants had the second-to-last average motivation for and interest in learning (Štraus, Šterman Ivančič, & Štirn, 2016). In research by Svandova (2014) no significant influences between attitudes toward biology and knowledge of photosynthesis have been found. Usak et al. (2009) and Atik and Erkoç (2015) have reported that positive attitude toward biology lessons and biology as a subject has been positively related with better knowledge of this subject. The present research, however, has shown that good learning habits are even negatively correlated with agricultural students'

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performance on the knowledge test. This result is difficult to explain. The plan is to explore the mentioned negative correlation further on an additional sample of agricultural students. The finding has contradicted the research of Duckworth and Seligman (2005) conducted at the middle school level, which had found self-discipline, including some good learning habits, to be positively correlated with the year of study and standardised test scores. Adodo and Oyeniyi (2013) and Udeani (2012) have also found significant positive correlations between learning habits and knowledge among secondary school students.

Conclusions

This research has shown that students in secondary agricultural education in Slovenia do not have adequate knowledge of photosynthesis. The knowledge has been related with the year of study and very strongly related to the educational programme. One important finding is that students in the last two years of education possessed less knowledge than students in the first two years do. This suggests that when they leave school and start their professional career, their knowledge is not sufficient. Knowledge of photosynthesis has been only weakly related to gender and the fact that a student comes from a home with a farm. Students with better knowledge of some aspects of photosynthesis have also had a higher awareness of the importance of biology and more positive attitudes toward photosynthesis. In this research, the knowledge of photosynthesis has not been related to positive attitudes toward biology lessons. There had been a negative relationship between knowledge and good learning habits; this is difficult to explain and should be investigated further.

In order to improve the agricultural students' knowledge of photosynthesis, more practical work in biology classes should be considered. Teaching activities should relate this process to daily life, so students will comprehend the relationship between what they learn in class and their experience in practical fieldwork. This could be also beneficial in strengthening students' positive attitudes toward biology lessons. Aspects of photosynthesis that students understand worse could help teachers in an orientation where to start making improvements.

The sample in this research was sufficiently large but limited to two regions in Slovenia where the three schools that agreed to participate are located, so the results should be treated with some caution.

Because in Slovenia there is not much interest in attending agricultural programmes, knowledge of photosynthesis and the attitude of every student in agricultural education matters. These students will professionally work in plant production and their attitudes toward photosynthesis, and their perception of the importance of biology could affect their decisions in fieldwork.

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References

Adodo, S. O., & Oyeniyi, J. D. (2013). Student variables as correlates of secondary school students' academic performance in biology. *International Journal of Science and Research*, *2*(7), 386–390.

Ajzen, I. (2001). Nature and operation of attitudes. *Annual Review of Psychology*, *52*, 27-58.

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.

Atik, A. D., & Erkoç, F. (2015). The investigation of 9th grade students' attitudes towards the science and the course of biology in terms of various variables. *Adiyaman University Journal of Educational Sciences*, *5*(2), 211–244.

Baird, J. H., Lazarowitz, R., & Allman, V. (1984). Science choices and preferences of middle and secondary school students in Utah. *Journal of Research in Science Teaching*, *21*(1), 47–54.

Barak, J., Sheva, B., & Gorodetsky, M. (1999). As 'process' as it can get: Students' understanding of biological processes. *International Journal of Science Education*, *21*(12), 1281–1292.

Baram-Tsabari, A., & Yarden, A. (2011). Quantifying the gender gap in science interest. *International Journal of Science and Mathematics Education*, *9*(3), 523–550.

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), 363–372.

https://doi.org/10.33225/jbse/19.18.06

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

Çepni, S., Taş, E., & Köse, S. (2006). The effects of computer-assisted material on students' cognitive levels, misconceptions and attitudes towards science. *Computers & Education*, *46* (2), 192–205.

Connors, J. J., & Elliot, J. F. (1995). The influence of agriscience and natural resources curriculum on students' science achievement scores. *Journal of Agricultural Education*, *36* (3), 57–63.

Domingos-Grilo, P., Reis-Grilo, C., Ruiz, C., & Mellado, V. (2012). An action-research programme with secondary education teachers on teaching and learning photosynthesis. *Journal of Biological Education*, *46*(2), 72–80.

Duckworth, A. L., & Seligman, M. E. P. (2005). Self-discipline outdoes IQ in predicting academic performance of adolescents. *Psychological Science*, *16* (12), 939–944.

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

Fančovičová, J., & Prokop, P. (2010). Development and initial psychometric assessment of the plant attitude questionnaire. *Journal of Science Education and Technology*, *19* (5), 415–421.

George, R. (2000). Measuring change in students' attitudes towards science over time: An application of latent variable growth modelling. *Journal of Science Education and Technology*, *9* (3), 213–225.

Griffard, P. B., & Wandersee, J. H. (2001). The two-tier instrument on photosynthesis: What does it diagnose? *International Journal of Science Education*, *23* (10), 1039–1052.

Hansen, M. J., & Birol, G. (2014). Longitudinal study of student attitudes in a biology program. *CBE Life Sciences Education*, *13* (2), 331–337.

Harman, G. (2012). Knowledge and misconceptions of science student teachers about physical and chemical change. *Journal of Education and Instruction Research*, *1*(3), 130–146.

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.

Hrustel Majcen, M., & Paulin, J. (Ed.). (2001). *Slovenski kmetijsko okoljski program* [Slovenian agricultural environmental programme]. Ljubljana: Ministrstvo za kmetijstvo, gozdarstvo in prehrano.

Jin, H., & Anderson, C. W. (2012). A learning progression for energy in socio-ecological systems. *Journal of Research in Science Teaching*, *49* (9), 1149–1180.

Johnstone, A. H., & Mahmoud N. A. (1980). Isolating topics of high perceived difficulty in school biology. *Journal of Biological Education*, *14* (2), 163–166.

Jones, M. G., Howe, A., & Rua, M. (2000). Gender differences and students' experiences, interests, and attitudes toward science and scientists. *Science Education*, *84* (2), 180–192.

Kubiatko, M. (2012). The investigation of Czech lower secondary school pupils toward science subjects. *Journal of Educational and Social Research*, *2* (8), 11–17.

Lazarowitz, R., & Penso, S. (1992). High school students' difficulties in learning biology concepts. *Journal of Biological Education*, *26* (3), 215–224.

Lenton, G., & McNeil, J. (1993). Primary school teachers' understanding of biological concepts: selected research findings. *Journal of In-Service Education*, *19* (2), 27–34.

Lin, C., & Hu, R. (2003). Students' understanding of energy flow and matter cycling in the context of the food chain, photosynthesis, and respiration. *International Journal of Science Education*, *25*(12), 1529–1544.

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.

Mayer, V. V. (1987). Agriculture and biology education. In A. N. Rao (Ed.), *Food, Agriculture and Education* (pp. 31–39). Oxford: Pergamon Press.

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.

Owino, O. A., Yungungu, A. M., Ahmed, O., & Ogolla, B. O. (2015). The relationship between students' attitude towards biology and performance in Kenya certificate of secondary education biology in selected secondary schools in Nyakach, Kenya. *Research Journal of Educational Studies and Review*, *1*(5), 111–117.

Özay, E., & Öztaş, H. (2003). Secondary students' interpretations of photosynthesis and plant nutrition. *Journal of Biological Education*, *37*(2), 68–70.

Poberžnik, A., Skvarč, M., Verovnik, I., & Vičar, M. (2007). *Katalog znanja: naravoslovje: za nove programe srednjega poklicnega izobraževanja (SPI).* [Catalogue of knowledge: Science for vocational secondary education]. Ljubljana: MŠZŠ, CPI, SSPSI, 2001. Ljubljana: ZRSS: Evropski socialni sklad: Evropska unija.

Prokop, P., Prokop, M., & Tunnicliffe, S. D. (2007). Is biology boring? Student attitudes toward biology. *Journal of Biological Education*, *42*(1), 36–39.

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

Shaheen, N. K., & Kayani, M. M. (2017). Improving students' attitude towards biology as a school subject: Do the instructional models really work? *Journal of Applied Environmental and Biological Sciences*, *7* (1), 170–179.

Simpson, R. D., & Oliver, J.S. (1990). A summary of major influences on attitude toward and achievement in science among adolescent students. *Science Education*, *74* (1), 1–18.

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.

https://doi.org/10.33225/jbse/19.18.06

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

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.

Strategija razvoja Slovenije. [Strategy for Development of Slovenia]. (2005). Ljubljana, Republika Slovenija, Urad Republike Slovenije za makroekonomske analize in razvoj, Retrieved from http://www.gov.si/umar/

Štraus, M., Šterman Ivančič, K., & Štirn, S. (Ed.). (2016). *Nacionalno poročilo: PISA 2015.* [National report. PISA 2015]. Ljubljana: Pedagoški inštitut. Retrieved from http://novice.pei.si/wp-content/uploads/sites/2/2017/10/PISA2015NacionalnoPorocilo.pdf.

Tekkaya, C., & Balci, S. (2003). Determined students' misconceptions of photosynthesis and respiration. *Journal of Hacettepe University Education Faculty*, *24*, 101-107.

Tekkaya, C., Çapa, Y., & Yılmaz, Ö. (2000). Pre-service biology teachers' misconceptions about biology. *Journal of Hacettepe University Education Faculty*, *18*, 140-147.

Terry, R., & Torres, R. M. (2006). Are teachers ready to integrate science concepts into secondary agriculture programs? *Journal of Agricultural Education*, *47*(4), 102–113.

Udeani, U. (2012). The relationship between study habits, test anxiety and science achievement. *Journal of Education and Practice*, *3*(8), 151–158.

Usak, M., Prokop, P., Ozden, M., Ozel, M., Bilen, K., & Erdogan, M. (2009). Turkish university students' attitudes toward biology: The effects of gender and enrolment in biology classes. *Journal of Baltic Science Education*, *8*(2), 88–96.

Vičar, M. (2007). *Katalog znanja: biologija: za nove programe srednjega strokovnega izobraževanja (SSI) in srednjega poklicnotehniškega izobraževanja (PTI).* [Catalogue of knowledge: Biology for technical and vocational-technical secondary education]. Ljubljana: MŠZŠ, CPI, SSPSI, 2001. Ljubljana, ZRSS: Evropski socialni sklad: Evropska unija.

Waheed, T., & Lucas, A. M. (1992). Understanding interrelated topics: Photosynthesis at age 14. *Journal of Biological Education*, *26*(3), 193–200.

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.

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