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The Benefit of the GLOBE program for the Development of Inquiry Competence in the Czech and Slovak Contexts

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ABSTRACT

This study compares the inquiry competence of the 8th-grade students participating in the science and environmental education program GLOBE in the Czech Republic with a sample of students of the same age not participating in the program from the Slovak and Czech Republics. Inquiry competence is analyzed as a set of variables representing students' investigation skills, understanding of the procedure of the scientific work, their understanding of the principles of scientific work, and their interest in science. While no differences between the Czech and Slovak students not involved in the GLOBE program were found, the Czech participants achieved a higher level of inquiry competence in most of the investigated variables. Gender was an important factor for both the groups not participating in the program, while no significant difference between boys and girls was found in the group of participants.

KEYWORDS
science education, environmental education, inquiry-based learning, GLOBE, evaluation

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Introduction

Although environmental education has been well spread in the Czech and Slovak Republics since 1989, it still does not fulfill its educational potential. According to Švajda (2002), environmental education suffers from a lack of practical exercises, insufficient cooperation with scientific partners, and missing linkage with international research in the Slovak Republic. Although environmental education is growing due to the large expansion of environmental education centers offering innovative programs in the Czech Republic, the lack of their linkage with the relevant research often undermines their effectiveness (Činčera, 2013).

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Environmental education is a broad term encompassing a large set of educational goals linked to the fields of both science and social science (Hungerford, Peyton, & Wilke, 1980). Inquiry competence, e.g. the competence allowing students to analyze environmental problems independently, is considered one of its "strands". According to Simmons et al. (2010):

Environmental literacy depends on learners' ability to ask questions, speculate, and hypothesize about the world around them, seek information, and develop answers to their questions. Learners must be familiar with inquiry, master fundamental skills for gathering and organizing information, and interpret and synthesize information to develop and communicate explanations (p. 5).

One of the international programs focusing on developing students' inquiry competence is the GLOBE program. The aim of the paper is to analyze whether students participating in the GLOBE program in the Czech Republic have a higher level of inquiry competence than uninvolved students of the same age in the Czech and the Slovak Republics.

In the first part, two instructional strategies applied in the GLOBE program, e.g. inquiry-based learning and citizen science, are discussed. The paper further introduces the methodology and findings of the international, Slovak-Czech study of inquiry competence of the 8th grade students participating and not participating in the GLOBE program. In the last part, the practical implications are discussed.

Literature Review

Development of inquiry competence has come to prominence recently in both republics (Papáček, 2010; Pastorová, 2011; Sýkorová, 2012; Kvasničák & Kvasničáková, 2013). The level of inquiry competence of Czech and Slovak students was systematically evaluated in the international studies PISA 2006 and PISA 2012. According to these studies, the performance of students in the Slovak Republic in scientific and environmental literacy over an extended period is below the average of the Organization for Economic Cooperation and Development (OECD) countries involved, and in the latest evaluation (Ferencová et al., 2015), students achieved significantly lower scores compared with evaluations in 2006 and 2009 (Koršňáková & Kováčová, 2007). Czech students, in contrast, demonstrated an adequate level of knowledge, but failed in applied skills, requiring knowledge as well as other competencies (Palečková, 2007).

Although inquiry competence can be developed through various instructional approaches, inquiry-based learning (Magnussen et al., 2000; Chiappetta & Adams, 2004) and citizen science (Dickinson & Bonney, 2015) have recently become more common.

Inquiry-based learning (IBL) and citizen science are close but distinctive approaches. In IBL, students follow the same procedure as real researchers, e.g. they formulate a hypothesis, plan their research, implement and evaluate it, and then present the results (Papáček, 2010). The main aim of inquiry-based learning is not a scientific, but an educational one, not to test new scientific hypotheses, but to develop students' scientific literacy.

In comparison, citizen science is based on the idea of creating effective partnerships between the public and the scientific community, by involving the general public in the process of collecting and sending various data from the environment (Dickinson & Bonney, 2015; Silvertown, 2009; Bonney et al. 2009). The main aim of citizen science is a scientific one, although the educational objectives of citizen science programs have been highlighted recently (Bonney et al., 2009; Toomey & Domroese, 2013). Citizen science, unlike inquiry-based learning, is usually associated with informal education, but can also become a part of a school curriculum (Trautman et al., 2015; Radhakrishna et al., 2014).

The benefits of both approaches have been evaluated and discussed several times (Sumerlee & Murray, 2010; Wolf & Laferrière, 2009; Magnussen et al., 2000; Gautreau & Binns, 2012). Especially the effectiveness of the educational impacts of citizen science projects has become a matter of debate, while the evaluation is often compromised by methodological issues and the existing results do not provide strong evidence for developing participants' competence beyond the level of particular knowledge and technical skills (e.g. species identification or entering data in a protocol) (Brossard et al., 2005; Phillips et al., 2015). However, the effectiveness of inquiry-based learning programs is also questioned by some authors (Kirchner et al., 2006).

In the Czech Republic, the effectiveness of IBL was analyzed in the Badatele.cz program (Explorers.cz). The Badatele.cz program was found to have a positive impact on students' investigation skills and their understanding of the research cycle (Činčera, 2014). There is a lack of evaluation of citizen science or inquiry-based learning programs in the Slovak Republic and existing literature is focused on promotion of some of these approaches rather than on analyzing their impact on students (Lapitková et al., 2016).

Despite their differences, both approaches could be effectively combined. Aristeidou, Scanlon & Sharpes (2013) suggest this type of mixed approach, which they call "citizen inquiry". GLOBE provides another example of combining aspects of both IBL and citizen science in one program.

The GLOBE (Global Learning and Observation to Benefit the Environment) is an international science and environmental education program originally launched by the U.S. Government on Earth Day in its 1994 program. Its vision is to build a worldwide community of students, teachers, scientists, and citizens working together to better understand, sustain, and improve the Earth's environment at the local, regional, and global scales (The GLOBE Program – About GLOBE, 2016).

To achieve this, the program aims to promote the teaching and learning of science, enhance environmental literacy and stewardship, and promote scientific discovery (The GLOBE Program – About GLOBE, 2016).

In GLOBE, small teams of students collaborate with scientists on various environmental investigations. Usually, they regularly collect data from the natural environment (e.g. temperature) and send it to the researchers via the Internet. Part of the program is also The GLOBE Games – regular meetings of students' teams who share and present their findings.

Although GLOBE provides a framework for conducting its activities, involved schools may adjust it to their needs. There is a big variety in the age of

participating students (it is not restricted by the program) or in the level of their involvement. Students are encouraged to work independently but the level of teachers' facilitation may differ among participating schools.

Nowadays, the program is spread across 110 participating countries. In the Czech Republic it was launched in 1995. It has been coordinated by the non-profit educational center TEREZA, an independent organization providing environmental educational projects and consultations to schools. In 2016, 148 elementary and secondary schools participated in the program (The GLOBE Program 2009; GLOBE - International eco-program 2009; The GLOBE Program – Czech Republic – Overview, 2016).

GLOBE, to a certain extent, shares features of both of IBL and citizen science. It is a part of school curricula but is optional and limited to a "GLOBE team" – a group of participating students. Students regularly collect data and record them in the protocols designed based on the needs of real scientific research. However, students are also encouraged to analyze the data independently and use them for their own research projects.

The GLOBE program has been evaluated many times (Means et al., 2002; Penuel et al., 2006). The results can be characterized as mixed and influenced by the focus of the evaluation and the applied methodology. The results of the evaluation in the Czech Republic did not show the expected relationship between the degree of involvement of students and their investigation skills (Činčera & Mašková, 2011).

The results motivated the Czech coordinator of the program, the TEREZA center, to strengthen the inquiry-based learning aspect of the program so as to more effectively develop student inquiry competence. However, the effectiveness of its approach has not been evaluated yet.

In light of the intended involvement of the Slovak Republic in the GLOBE program, it may be important to know the level of inquiry competence of Slovak students in comparison to the Czech students and, specifically, if they differ from the Czech students participating in the GLOBE program. These questions are to be analyzed in this paper.

Methods

The aim of the research was to determine whether the Czech students involved in the GLOBE program have a higher level of inquiry competence than comparable groups of uninvolved students from the Czech and Slovak Republics. Additionally, the study also compares the inquiry competence of uninvolved students of both countries.

For this research, "inquiry competence" was interpreted as a set of variables, specifically:

• 'Investigation skills', i.e. student skills associated with the specific stages of the research cycle;

• "Understanding the research cycle", i.e. understanding the procedure of scientific inquiry;

• "Understanding scientific principles," i.e. the ability to interpret in their own words the principles of scientific inquiry; and

• "Interest in science", i.e. an interest in natural science and activities.

Students from 8th-grade classes were included in the study. The sample consisted of randomly chosen schools that were divided into three categories (Czech participants of the GLOBE program, Czech non-participating students, and Slovak students).

Data collection was conducted from March to April 2016. Teachers in 10 randomly selected primary and secondary schools in the Slovak Republic and 25 schools in the Czech Republic were contacted and asked to collaborate in the research. Teachers who agreed to participate were sent questionnaires with instructions for their administration or were collected personally to ensure that all are administered similarly. Students had to respond to all the items in 40 minutes.

Seven schools from the Slovak Republic and eleven schools from the Czech Republic agreed to participate. Some of the schools who chose not to participate indicated that they had not implemented the GLOBE program in the 8th grade or that they did not have the time to participate. Data were obtained from a total of 348 8th-grade students from 18 schools. For the analysis, only respondents who answered all the items were included. Data from N = 298 respondents, the average age of 13.79 years, SD = 0.63 were collected. For further analysis, the group was then divided into participants in the GLOBE program (only from the Czech Republic, N = 91), other Czech students not participating in the GLOBE program (N = 72) and students from the Slovak Republic not in the GLOBE program (N = 135), eventually uniting these students from both republics as non-participants in the GLOBE program (N = 207).

The applied instrument consisted of five main parts corresponding to different areas students learn in the GLOBE program. Besides demographic information about respondents (age, gender, location, participation in the GLOBE program), it focused on students' awareness of local environmental issues, climate knowledge, inquiry competence (e.g., investigation skills, understanding the research cycle, understanding scientific principles), and interest in science. In this study, only the last two parts are presented.

In order to analyze students' investigation skills, a test originally used by Penuel et al. (2005) and then by Činčera & Mašková (2011) was used. The test consisted of seven items with internal reliability Cronbach alpha=0.69. The understanding of scientific principles was analyzed with the help of 1-item Science and Engineering Indicator (SEI), published by Cronje et al. (2011) in their analysis of citizen science programs. For evaluation of students' understanding of the research cycle, a test published in the evaluation of a study on the inquiry-based learning program Explorers.cz was used (Činčera, 2014). A new, 4-item Likert-type scale for measuring the level of students' interest in science was developed, with the Cronbach alpha=0.69.

In most of the tests, the correct answers for the items were awarded 1 point. Incorrect answers or ones with no response did not get any points. Altogether, students could gain 0-7 points in the test of investigation skills.

In the test analyzing the level of their understanding of the research cycle, students were asked to rearrange given sequences of fictional scientific research into the correct order. They could gain 0-40 points (the best understanding).

In the SEI, students were asked to interpret in their own words what it means to study something scientifically. Their answers were coded based on a coding table described by Cronje et al. (2011) so that the students could achieve 0 (poor understanding) points or 1 (appropriate understanding) point.

Finally, students' answers on the Likert-type scale for Interest in Science were coded on a scale from 1 for completely disagree to 5 for completely agree.

The focus of the study on inquiry competence corresponds with the effort of the national coordinator to promote inquiry-based aspects of the program. The national coordinator also validated the applied instruments.

It is recommended to interpret the results in the light of its methodological limits. Relying on a quantitative design only may ignore other important areas of interpretation of the program. The relatively small sample size means that the results are not representative for the whole population (Fryková, 2012).

Results

Comparing all of the three groups revealed significant differences in the investigation skills, while for understanding of the research cycle and interest in science remained insignificant (see Table 1).

Tab. 1 Comparison of the three groups for the investigation skills, understanding of the research cycle and attitudes (interest in science)

	Group	Respondents	Mean gain	Standard deviation	F	P
Investigation skills	GLOBE participants	91	5.42	1.63	3.26	0.039
	Other students from CZ	72	4.75	1.92		
	Students from SK	135	4.96	1.78		
Understanding			28.88	8.35	2.87	0.058
			26.43	9.35		
			26.03	9.31		
Interest in			3.51	0.92	1.34	0.26
			3.33	0.79		
			3.34	0.78		

The results seemed to be affected by participation in the GLOBE program and by respondents' gender, while their nationality did not play a role. Age did not positively correlate with any of the monitored variables. For the group of all of the respondents, investigation skills and interest in science significantly correlated ($r = 0.20$); other correlations were found between understanding of the research cycle and interest in science ($r = 0.21$) and investigation skills and understanding of the research cycle ($r = 0.54$). A similar pattern was found in the further analysis of

the subgroups of the GLOBE participants and other Czech and Slovak students not involved in the GLOBE program.

Students involved in the GLOBE program achieved better results for investigation skills than students not involved in the GLOBE program in the Czech and Slovak republics (see Table 2). Differences between students not involved in the GLOBE program in both republics were not statistically significant (see Table 3).

Tab. 2 Comparison of the level of investigation skills between GLOBE program participants and other students from the Czech and Slovak republics

Groups	Respondents	Mean gain	Standard deviation	t	P
GLOBE participants	91	5.42	1.63	2.42	0.016
Other students from CZ and SK	207	4.88	1.83		

Tab. 3 Comparison of the level of investigation skills among the Czech and Slovak students not participating in the GLOBE program

Groups	Respondents	Mean gain	Standard deviation	t	P
Students from SK	135	4.96	1.78	0.79	0.42
Other students from CZ	72	4.75	1.92		

Analyzing the whole group of respondents, no statistical difference was found between boys and girls ($m_{girls} = 5.14$, $SD = 1.66$, $m_{boys} = 4.94$, $SD = 1.92$, $t = 0.97$, $p = 0.32$) in the level of their investigation skills. However, the results for the subgroup of students from Slovakia revealed a statistical difference in favor of girls ($m_{girls} = 5.24$, $SD = 1.53$, $m_{boys} = 4.54$, $SD = 2.05$, $t = 2.32$, $p = 0.02$). For the group of students participating in the GLOBE program, no statistical difference between girls and boys was found.

Students involved in the GLOBE program achieved better results in their understanding of the research cycle, in comparison with the other students not involved in the GLOBE program (see Table 4). However, the differences between both Slovak and Czech groups of students not involved in the GLOBE program were not significant (see Table 5).

Tab. 4 Comparison of understanding of the research cycle between GLOBE program participants and other students from the Czech and Slovak republics

Groups	Respondents	Mean gain	Standard deviation	t	P
GLOBE participants	91	28.88	8.35	2.38	0.017
Other students from CZ and SK	207	26.17	9.30		

Tab. 5 Comparison of understanding of the research cycle between Czech and Slovak students not participating in the GLOBE program

Groups	Respondents	Mean gain	Standard deviation	t	P
Students from SK	135	26.03	9.31	0.28	0.77
Other students from CZ	72	26.43	9.35		

The gender difference in the understanding of the research cycle for all the respondents was statistically significant (mgirls = 28.08, SD = 8.9, mboys = 25.75, SD = 9.19, t = 2.21, p = 0.027) and also for the group of Slovak students (mgirls = 2.36, SD = 9.32, mboys = 22.32, SD 8.08), t = 3.84, p = 0.0001). Gender differences were not statistically significant for students participating in the GLOBE program.

The proportion of respondents with an appropriate level of understanding of scientific principles was significantly higher for the group of Czech students participating in the GLOBE program in comparison with the Slovak students ($\chi 2$ = 4.60, p = 0.03). The difference between Czech students involved in GLOBE and the other Czech students not involved in GLOBE was not significant ($\chi 2$ = 2.95, p = 0.08) and no significance was found in the comparison between both the groups of non-participating students from both republics either ($\chi 2$ <0.001, p = 0.96) (see Table 6). Gender differences were not evaluated due to the small number of correct responses.

Tab. 6 Comparing the frequency of correct answers for understanding the principles of scientific work

Groups	Respondents	Absolute frequency of correct answers	Absolute frequency of incorrect answers	Relative frequency of correct answers (%)	Relative frequency of incorrect answers (%)
GLOBE participants	91	16	75	17.6	82.4
Other students from CZ	72	6	66	8.3	91.7
Students from SK	135	11	124	8.1	91.9

Neither participation in the GLOBE program nor nationality affected the students' interest in science. Girls from the whole group of respondents were more interested in science than boys (mgirls = 3.54, SD = 0.76, mboys = 3.22, SD = 0.88, t = 3.38, p = 0, 0008), and the same pattern was found in the group of Czech (mgirls = 3.65, SD = 0.70, Mboys= 3.08, SD = 0.78; t = 3.24, p = 0.001) and Slovak students (mgirls= 3 46, SD = 0.70, Mboys = 3.15, SD = 0.87, t = 3.84, p = 0.02). Gender differences were not statistically significant in the group of students participating in the GLOBE program.

Discussion

On the basis of our findings, we could see that students participating in the GLOBE program have a higher level of inquiry competence than comparable groups of uninvolved students from the Slovak and Czech Republics. Although the results might be interpreted as a success of the program, other possible explanations of the findings should be considered. As participation in the program is optional for students, it is likely to attract students interested in science and the environment. Although such interest may not necessary correlate with inquiry competence, we must consider the hypothesis that the GLOBE participants are not average students and may have stronger motivation to learn how to investigate nature. Still, a benefit of the program may be seen in providing them with such an opportunity.

Overall, no significant difference was found between the variables monitored in the groups of Czech and Slovak students not involved in the GLOBE program, i.e. the students achieved a comparable level of investigation skills, understanding of the research cycle and of the principles of scientific inquiry, and they reported comparable levels of interest in science. Girls tended to be more interested in science, more aware of the research cycle, and, in the Slovak Republic, girls also achieved higher levels of investigation skills.

There were no gender differences in the group of students participating in the GLOBE program. This group of participants achieved a higher level of understanding of the investigation cycle, of the principles of scientific inquiry, and a higher level of investigation skills.

In the light of these findings, it may be assumed that that the level of inquiry competence of Slovak and Czech 8th graders is comparable. Although further implication of these findings is not supported by other research, it may be interpreted that in some of these competencies, especially the understanding of principles of scientific inquiry or understanding the research cycle, students achieved relatively poor results. It is possible that understanding the "logic of scientific work" (Lederman, 1992) is, therefore, an area that is not sufficiently developed in the schools in this region.

In comparison with previous evaluations of the program, it now seems that GLOBE can positively develop the investigation skills of students (Penuel et al., 2006; Činčera & Mašková, 2011). This finding may support the Czech program coordinator's effort to strengthen the principles of inquiry-based learning in the program, i.e., to shift the emphasis of the program activities from collecting and sending data to formulating students' own questions and analysing collected data. Such a shift corresponds with an on-going discussion in the field of citizen science (Trautman et al., 2015).

Gender differences represent another interesting part of the findings. According to Osborne et al, 2003), girls usually report a lower level of interest and attitudes towards science than boys. However, according to the PISA survey, the situation in the Czech Republic differs as girls reported a higher level of interest in science and scientific literacy than boys (Palečková, 2007). A similar pattern has emerged also in the evaluation of the Explorers.cz program (Činčera, 2014). It may be surmised that a similar pattern found in the Slovak Republic indicated a broader contextual link between both countries, based on their common history and long-time shared educational traditions.

Although the findings did not support any assumed differences between the GLOBE-participants and the other students in the level of interest in science, it is possible that the program has other benefits, not analyzed by this research. Longitudinal cooperation of students in the GLOBE teams may positively impact a school climate, support some positive social norms, or increase students' proficiency in specific technical skills. However, such a claim still needs to be approved.

Further factors should influence the students' inquiry competence. Ferencová et al. (2015) demonstrated a strong relationship between reading and environmental literacy. According to their research, the lack of interest in science may not be caused only by a lack of knowledge, but by a low level of reading competence, which could interfere with students' ability to read and interpret charts and spreadsheets, regardless of their content. In light of this, it could be interesting to investigate this area in more detail.

If one of the reasons for initiating the research was the intended launching of the GLOBE program in the Slovak Republic, this study may provide some support for this idea. However, it is the way in which the program will be implemented, and the way in which the IBL principles will be accentuated that seems to be

crucial. Keeping the essential feature of the citizen science approach, collaborating with the scientific community on real projects, while providing students with some level of independence and ownership of their own inquiry-based projects, may pose a challenging balance but may also offer a strong path toward developing competence essential for both science and environmental education.

Conclusions

The aim of the work was to demonstrate the difference in the levels of inquiry competence between Czech students participating in the GLOBE program and the non-participating students from the Czech and Slovak Republics. As the findings support an estimated benefit of the program, the study provides a support for launching the program in the Slovak Republic. In addition, the study supports the effort in promoting IBL principles in school curricula (Výbohová, 2013) as a means for promoting students' inquiry competence.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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