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IBSE and Gifted Students

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ABSTRACT: Inquiry-based science education (IBSE) seems to be the appropriate method to encourage interest in science and technology education. The core principles of IBSE are involvement of students in discovering natural laws, linking information into a meaningful context, developing critical thinking and promoting positive attitudes towards science. IBSE is suitable in the education of all students, including gifted ones. For gifted students some components of IBSE must be selected and modified. The use of IBSE also allows teachers to discover hidden giftedness, because it enables an individual approach to students. IBSE matches the special educational needs of gifted students, because it corresponds with their behaviour. Gifted students have many questions, are curious, have unusual ideas etc. The objective of our research is to find which components of IBSE are suitable for gifted students. The main research method used in this study is design-based research. IBSE components for gifted students are a very important part of teachers' continuous professional development (CPD). Teachers and parents also need teaching/learning materials for gifted students. Our research outcomes have been created within the European project PROFILES, which supports science teachers in their use of IBSE.

KEY WORDS: IBSE, inquiry-based, gifted students

INTRODUCTION

Systematic support of gifted students in science is an important part of the educational strategies of developed countries. This support has also played an important role in students' personal development, establishment in society and on the labour market. Educational experts argue that about 2-3 % (Mönks & Ypenburg, 2002) of students are exceptionally gifted - the talented. However, in suitable conditions for the development of giftedness, the rate of students excelling in some areas might increase up to 20-25 % (Freeman, 2010). Multilateral support of students gifted in science is currently a social necessity.

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RATIONALE

The creation of suitable conditions for the development of science giftedness is an important task for science teachers. It involves not only the identification of giftedness, but also the development of students´ giftedness to the highest possible level. Important factors affecting the development of gifted students in science include intrinsic motivation. We found a set of special behaviours of gifted students, which are:

- They are not satisfied with passive memorizing
- They ask more questions
- They are curious and have unusual ideas
- They are independent and often prefer working on their own
- They use information to support their ideas
- They draw conclusions and bring new solutions
- They are able to link seemingly unrelated things into a meaningful unit
- They are creative
- They want to know how things work

The interests of gifted students differ from the interests of their peers.

Motivation and development of gifted students

According (Renzulli, 1986; Mönks & Ypenburg, 2002) motivation plays a decisive role in the development of students' giftedness. J. S. Renzulli (1986) created a three-ring model of determining aspects for the development of giftedness: creativity + ability + motivation (called task commitment). J. F. Mönks & F. J. Ypenburg (2002) modified Renzulli´s model and replaced the expression "task commitment" with the general term "motivation". They stated that the development of giftedness depends largely on a supportive environment.

We discovered (Trnova, & Trna, 2012) crucial areas for the support of gifted students:

a) Education of teachers for identifying and developing giftedness
b) Creation of a supporting system to help teachers and parents in the upbringing and education of gifted students
c) Setting up of high-quality school facilities for gifted students

Inquiry based science education (IBSE)

We can identify a set of motivational teaching/learning methods which are based on the intrinsic motivation of students (Trna & Trnova, 2006). One of these methods is inquiry-based science education (IBSE). IBSE is an

innovative educational method which has a strong motivational impact on students and also on teachers.

IBSE was born through a deep understanding of the process of science learning (Narode, 1987). The core principles of IBSE are student involvement in discovering natural laws, linking information into a meaningful context, developing critical thinking, and promoting positive attitudes towards science (Kyle, 1985; Rakow, 1986). In terms of teachers' and students' involvement, there are four levels of IBSE [1]:

1. Confirmation
2. Structured
3. Guided
4. Open

H. Banchi & R. Bell (2008) defined four IBSE levels (see Table 1). These levels are different according to the rate of the teacher's assistance (helping in the process, asking questions and formulation of expected results).

Table 1. Four levels of IBSE

IBSE levels	Questions (defined by the teacher)	Procedure (defined by the teacher)	Solution (defined by the teacher)
1. Confirmation	Yes	Yes	Yes
2. Structured	Yes	Yes	No
3. Guided	Yes	No	No
4. Open	No	No	No

IBSE as a motivational factor of the development of students gifted in science

Our experience supports the hypothesis that IBSE is a suitable motivational and developmental factor for gifted students in science. This hypothesis must be verified and if confirmed it is necessary to create appropriate curricular materials for the education of gifted students in science through the use of IBSE. This is what we aimed at in our research and we are now presenting the first results.

RESEARCH METHODS

To inquire into the motivational and developmental effect of IBSE on giftedness in science education, we used the method of design-based

research. This developmental research differs from other types of research. The main advantage of design-based research is its close connection with educational practice and its focus on the creation of a new product. We also used other sufficient research methods within the framework of design-based research: questionnaires, interviews, portfolios and collaborative action research based on ICT (Trna & Trnova, 2010; Trnova, 2010).

Design-based research can be described as a cycle (see Fig. 1): analysis of a practical problem, development of solutions, iterative testing of solutions, reflection and implementation (Reeves, 2006).

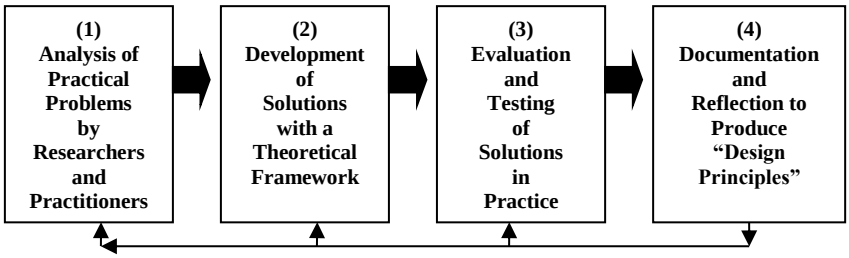


Figure 1. Design-based research (according: Reeves, 2006)

(1) Analysis of practical problems: We identified the existing educational problems in the motivation and development of students gifted in science while using methods of observation, students´ questionnaires, interviews, etc. Our research question was formulated as follows: *Which IBSE components are effective for the motivation and development of students gifted in science?*

(2) Development of solutions with a theoretical framework: We made the comparison of the specific educational needs of students gifted in science and the core IBSE components. On the basis of this comparison, we have created teaching materials in the form of IBSE modules within the project PROFILES. These teaching modules include IBSE components suitable for students gifted in science.

(3) Evaluation and testing of solutions in practice: Science teachers (participants of PROFILES project) were the authorised implementers and evaluators of the IBSE components. They used action research as their core method. In the last few years, action research has been implemented into daily practice more often. Thus, a significant development of PCK of each teacher who uses action research occurs on the basis of research-based teacher self-training.

(4) Documentation and reflection to produce "Design principles": The final stage of our research was the documentation and the establishment of a set of design principles in the form of suitable IBSE components for students gifted in science.

RESULTS AND DISCUSSION

Our research resulted in the verification of the hypothesis about the positive motivational and developmental effects of IBSE components on students gifted in science. Our research results are divided into four stages of design-based research. (See Research Methods):

(1) The first step of our design-based research was investigating the specific educational needs of gifted students. In the year 2011, we distributed a questionnaire with a representative sample of 15 students aged 15-18 from upper secondary schools who are gifted in science (Trnova, & Trna, 2012). Their giftedness was verified by a specialist pedagogical-psychological board and by the declaration of their teachers. We present (see Table 2) a part of the questionnaire results: a list of specific educational needs of gifted students indicated by more than 50 % of them.

Table 2. Specific educational needs of students gifted in science

Which activities would you like to do in classes; which activities interest and attract you?	Gifted students N =15
Experimentation	100 %
Measurement	93 %
Identifying the fundamental processes in nature	93 %
Observation	93 %
Analyzing phenomena	87 %
Expressing an opinion and defending it	87 %
Solving projects	80 %
Substantiation of solutions	80 %
Formulating conclusions	73 %
Describing phenomena	73 %
Verification of hypotheses	67 %
Data processing	67 %
Creating hypotheses	60 %
Evaluation	53 %

The questionnaire research produces the findings that gifted students in science have specific educational needs in comparison with non-gifted students (Trnova, & Trna, 2012). We cannot strongly generalise these results because of the low number of gifted students. We used these results as a source for the first part of our design-based research.

(2) The second step of our design-based research was a comparison of the specific educational needs of gifted students and core IBSE components. This comparison is presented in Table 3.

Table 3. Comparison of educational needs and IBSE components

Educational needs	IBSE components
Observation; experimentation Measurement; data processing Analyzing phenomena; identifying the fundamental processes in nature; describing phenomena	Inquiry: observation, experimentation, building apparatus, measurement, collection and evaluation of data; finding and checking and the importance of information (with the help of inquiry); development of conception; evaluation of preconceptions; the use of ICT
Creating hypotheses; verification of hypotheses; evaluation Formulating conclusions; expressing opinions and defending them; substantiation of solutions	Logical thinking, interconnection of facts, drawing conclusions (not only to memorize facts); implementation of own innovative solutions (not only to follow instructions blindly), argumentation, communication.
Solving projects	Suitable contents from everyday life; interdisciplinary nature of problems; using evidence gained from a range of information sources; understanding of science concepts through the students' own activity and reasoning. Student = active researcher Teacher = adviser and guide. Working in groups, cooperation, and discussion.

The IBSE components for gifted students in science education must be selected and modified according to their educational needs. It is obvious that there are IBSE components which correspond to the educational needs of gifted students. We have created specially adapted teaching materials in the form of IBSE modules within the project

PROFILES. These teaching modules include IBSE components suitable for gifted students.

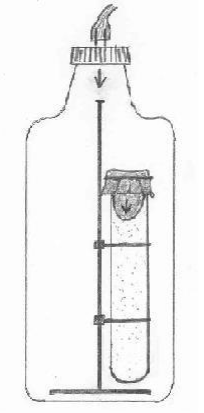
(3) The essence of the third stage of our design-based research was evaluation and testing our solution in practice in schools. The PROFILES modules contain all the IBSE components for gifted students. These modules were validated in the years 2012-2013 by fifty teachers in fifty classrooms in the Czech Republic. In these classes 45 students gifted in science were present. As an example, here is the most popular IBSE component – experimenting: IBSE is based on experimentation, which has a decisive role in science education (Trna & Trnova, 2012). The motivational and developmental role of experiments for students gifted in science is in line with the importance of experiments in science research (Trna, 2012) and the cognitive importance of experiments in science education (Haury & Rillero, 1994). We present as an example a learning task with an experiment (the fourth open level) from the module: "Safe swimming and diving" (See Figure 2.)

(4) The outcomes of our design-based research are IBSE components which broaden the IBSE theory in the field of the education of gifted students. An innovative IBSE approach in the teaching/learning of gifted students should meet the following important IBSE components appropriate for gifted students:

- Emphasis on the students' role, which should be very active
- Individual approach to students with great empathy on the part of the teacher
- Encouraging students to actively problem-solve
- Scientific way of working (analysing phenomena, verification of hypotheses, etc.)
- Wide use of experimentation and practical tasks (projects)
- Supporting connectivistic tasks (net-system gaining and collaboration)

These and other components of IBSE suitable for gifted students will gradually form a set of rules for the complex application of IBSE in the development of science and technology giftedness. This IBSE approach matches the special educational needs of gifted students, because it corresponds with their behaviour. The implementation of IBSE in teaching/learning allows teachers to satisfy the specific educational needs of gifted students and also to discover hidden giftedness in students, because it enables an individual approach with four IBSE levels.

An over pressurized bottle:
Experiments in a vacuum pump are often demonstrated. Create a mechanism that demonstrates an additional phenomenon in high pressure. How would this phenomenon be manifested in the human organ of hearing?



A solution by a gifted student (found in the course of research):
A test tube fixed in the over pressurized bottle is covered by a rubber membrane that bends due to overpressure (see Fig. 2). The overpressure is created with the help of a tyre valve in the neck of the bottle and an inflator. The rubber membrane simulates the behaviour of an eardrum while swimming or diving. The danger rests upon incidental failure of the eardrum due to a bump on the water surface or due to the pressure of the water column when diving.

Figure 2. Over pressurized bottle

CONCLUSION

Our research addresses a new topic: IBSE and giftedness. This pilot research suggested the importance of IBSE as a motivational and developmental method for gifted students in science. It is necessary to study this issue further. Teachers need special methods and tools, which have to be developed. These methods should be implemented into pre-service and in-service science teacher education (Trnova, 2012). One of the ways in which these ideas can be disseminated to teachers is through projects.

The PROFILES project (Professional Reflection-Oriented Focus on Inquiry-based Learning and Education through Science) is a European project which aims at the support of science teachers in using IBSE. The PROFILES project includes a set of teaching/learning modules adapted for IBSE (Profiles, 2013). We implemented our research outcomes into these modules of IBSE components for gifted students.

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REFERENCES

Banchi, H., & Bell, R. (2008). The Many Levels of Inquiry. *Science and Children*, *2*, 26-29.

Freeman, J. (2010). *Gifted Lives: What Happens when Gifted Children Grow Up*. New York: Routledge Chapman and Hall.

Haury, D. L., & Rillero, P. (1994). *Perspectives of Hands-On Science Teaching.* Columbus: ERIC-CSMEE.

Kyle, W. C. (1985). What research says: Science through discovery: Students love it. *Science and Children*, *2*, 39–41.

Monks, F. J., & Ypenburg, I. H. (2002). *Nadané dítě*. Praha: Grada Publishing.

Narode, R. (1987). *Teaching Thinking Skills: Science*, Washington: National Education Association.

Profiles (2013). *PROFILES project*, Retrieved May *20, 2013,* http://www.profiles-project.eu/.

Rakow, S. J. (1986). *Teaching Science as Inquiry***,** Fastback 246, Bloomington, USA: Phi Delta Kappa Educ. Found.

Reeves, T. C. (2006). Design research from the technology perspective. In J. V. Akker, K. Gravemeijer, S. McKenney, & N. Nieveen (Eds.), *Educational design research* (pp. 86-109). London, UK: Routledge.

Renzulli, J. S. (1986). The three-ring conception of giftedness: a developmental model for creative productivity. In Sternberg, R. J., Davison, J. E. (Eds.), *Conception of giftedness* (pp. 53-92). Cambridge, UK: Cambridge univ. press.

Trna, J. (2012). How to motivate science teachers to use science experiments. *Journal of Systemics, Cybernetics and Informatics*, *10*(5), 33-35.

Trna, J., & Trnova, E. (2006). Cognitive Motivation in Science Teacher Training. In *Science and Technology Education for a Diverse Word* (pp. 491- 498). Lublin, Poland: M. Curie-Sklodovska university press.

Trna, J., & Trnova, E. (2010). ICT-based collaborative action research in science education. In *IMSCI'10. The 4th International Multi-Conference on Society, Cybernetics and Informatics. Proceedings. Volume I* (pp. 68-70). Orlando, USA: International Institute of Informatics and Systematic.

Trna, J., & Trnova, E. (2012). Inquiry-based Science Education Experiments. In C. Bolte, J. Holbrook, & F. Rauch (Eds.). *Inquiry-*

based Science Education in Europe: Reflections from the PROFILES Project (pp. 212-215). Berlin, Germany: Freie Universitat Berlin.

Trnova, E. (2012). Teacher Development in IBSE. In *Badania w dydaktyce chemii* (pp. 181-184). Krakow, Poland: Pedagogical University of Krakow.

Trnova E. (2010). Realizace mezinárodních přírodovědných projektů v ICT prostředí (e-twinning). *Media4u Magazine*, *7*(X3), 167-170.

Trnova, E., & Trna, J. (2012). Development of Science and Technology Gifted Students through Inquiry-Based Science Education. In *Proceedings of the 8th International Conference on Education* (pp. 838-844). Samos, Greece: Research and Training Institute of East Aegean.