

VOLUME 23 ISSUE 2

The International Journal of

Assessment and Evaluation

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THE INTERNATIONAL JOURNAL OF ASSESSMENT AND EVALUATION
www.thelearner.com

First published in 2015 in Champaign, Illinois, USA
by Common Ground Publishing LLC
www.commongroundpublishing.com

ISSN: 2327-7920

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The International Journal of Learning in Assessment and Evaluation is a peer-reviewed, scholarly journal.

Formative Assessment and other Assessment Methods in Biology Education and Pre-service Biology Teacher Training in the Czech Republic

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Abstract: This paper presents data obtained by surveying students at the Faculty of Education, University of South Bohemia in Ceske Budejovice. Data were evaluated by statistical methods. Results show respondents didn't encounter formative assessment during their school attendance in elementary and high school. Instead, their learning in biology education was assessed by written examination and conventional grading. We found that respondents had no experience with formative assessment during their pedagogical and didactical training and practice. The importance of formative assessment as a part of pre-service biology teacher training emerged from our investigation where the formative assessment proved to be a necessary component of biology teaching and learning at primary and high school.

Keywords: Formative Assessment, Biology Education, Pre-service Teacher Training

Introduction

The implementation of modern teaching approaches into science education has recently become more frequent in the Czech Republic. As an example we can mention inquiry-based scientific education (IBE) which has become the often used approach in science education. The problem of unsuitable assessment instruments for assessing students' work has arisen along with the implementation of the IBE. Teachers are mainly used to assessing students in summative ways, and they pointed out that this approach is insufficient for the inquiry-based lessons (Rokos and Petr, in prep.).

Osborne and Dillon (2008, 9–24) noticed in their report that most European countries did not invest enough finances during 2006 in developing new assessment methods but mainly focused on the curriculum as a whole. Authors mentioned that it would be suitable to enhance efforts of preparing such assessment methods which would be more focused on assessing students' progress in learning process rather than on assessing mass results (results of curriculum). More and more teachers, researchers and institutions have recently become involved in the issues of assessing learning and teaching process.

The need for updating assessment methods and introducing new ways of organizing learning is stated in the report of European Commission (2012, 7). Although a range of assessment methods can contribute to formative assessment, the summative assessment performed by teacher is still the most important because it provides detailed insight over time (European Commission 2012). The Czech Ministry of Education has developed a testing platform that provides evaluation tools to all schools, teachers, students and parents. At this stage it has been tested only in the following subjects: Czech language, mathematics and foreign languages. However, the Ministry intends to use this platform for system-wide assessments (European Union 2014). The most significant limit for implementation of the formative assessment in teaching and learning process in Czech educational environment is under-defined terminology and lack of professional and methodological publications in national language (Zlabkova and Rokos 2013). There hasn't been released any new publication focused on formative assessment yet. On the other hand some methodological guidelines are available for teachers but these are based on foreign literature sources (Novotna and Krabsova 2013). It is obvious that the term "formative assessment" is understood in very different ways. The unclear definition and terms do not represent problem

solely for the Czech Republic, for example Wiliam (2014, 3) has mentioned the conflict between usage of the two terms—“assessment for learning” and “formative assessment.” Bennett (2011) said that there are very important conceptual and practical differences between these terms. One of these definitions, which is commonly used in the Czech education system, was developed by the Organisation for Economic Co-operation and Development (OECD 2005): Formative assessment is a continuous assessment in which student is assessed during his/her performance, with teacher’s focus being not on finding mistakes, but instead on guiding the student to improve his/her activity to reach established learning goals. The most important publication about assessment in school written by Slavik (1999) describes formative assessment as the contrary of summative assessment, which is matching students’ achievement and their assignment to a concrete level on given scale designed by teacher and/or Czech Ministry of Education. Roberts and Gott (2003) accented that summative assessment provides only poor insight into the comprehensive students’ knowledge and skills and does not enable verification of students’ higher-level thinking and progress in the learning process.

Until now only one case study investigating the use of formative assessment in foreign language teaching has been published by Novotna and Krabsova (2013) and none in the science education in the Czech Republic.

Practical activities represent important component of biology lessons. They help teacher to reinforce students’ motivation to study in biology because students are interested in discovering, they also help to strengthen already gained theoretical knowledge, develop students’ manual skills and knowledge of methodological procedures. Students learn to work with data, develop ability to analyze them and apply them to practice (Cambridge Assessment 2013). Previous study revealed that methods of direct nature study connected to practical activities represent very attractive teaching method for Czech students (Rokos et al. 2013). The assessment of students’ work during practical activities (e.g. laboratory works or inquiry-based scientific teaching) is still the prevailing problem in science subjects; therefore it has come to the forefront of interest because the summative assessment is not an appropriate form of assessment as it is insufficiently focused on assessing skills, knowledge and competencies specific to science literacy.

The solution of this situation should be in the support of formative assessment implementation into science subjects’ teaching. A project, ASSIST-ME (*Assess Inquiry in Science, Technology and Mathematics Education*), is one of initiatives supporting new assessment methods. There are 10 educational or research institutions from 8 European countries involved in this project. The project is focused on ways of assessing students during inquiry-based lessons in science, technology and mathematics. The main aim of this project is to develop appropriate assessment methods which should add to already existing and used methods of summative assessment. Academic workers involved in this project in the Czech Republic are based at Department of Biology and Department of Pedagogy and Psychology at the Faculty of Education, University of South Bohemia in Ceske Budejovice.

The aim of our research focused on students of the Faculty of Education, University of South Bohemia in Ceske Budejovice, was to find whether our respondents have had personal experience with components of formative assessment during their school attendance at elementary and high schools. We also queried the frequency of their knowledge and skill examinations during practical works in biology lessons. This study presents a view on university students’ personal experience with assessment methods in integrated science¹ at elementary school and biology at high school, reveals which methods are used only sporadically and tries to propose changes to pedagogical and didactical preparation of pre-service teachers of integrated science and biology based on the discovered evidence.

The results could be used for modification of new teachers’ training at the Department of Biology to ensure better awareness of formative assessment. In the Czech Republic the future

¹*Integrated science* is called biology in Czech elementary schools.

biology, resp. integrated science teachers have to graduate from MSc program in Biology, resp. Integrated science Education at Faculty of Science, resp. Faculty of Education. The BSc study program contains courses of Biology disciplines as well as Philosophy, Computer science, one foreign language, Basics of child biology and Health prevention and Introduction to Pedagogy and Psychology. The MSc degree is more focused on teaching training and lessons of Pedagogy, Psychology and Didactics. Students have to take part in teaching practice at selected schools. There are three types of practice training: The Assistant practice, a student helps as a teacher assistant at school; the Long-term practice, a group of several students visit school and take turns in teaching (with the support of faculty teachers); the Continuous practice, a student teaches at school for one month under the supervision of senior teacher.

Methods and Data Collection

Data were acquired with the use of a questionnaire survey. The Likert type questionnaire (Ary et al. 2010) was combined with open-ended and multiple choice questions. There were questions focused on demographic data about respondents (e.g. sex, age, type of higher education completed, and study branch—teaching or non-teaching), on which assessment methods were common during biology education and which method is in respondents' point of view the most beneficial. The questionnaire also investigated students' experience with formative assessment, their personal opinion on it and whether they intend to use it during their pedagogical practice (if they studied teaching branch).

The final representative sample contained 254 students of the Faculty of Education, University of South Bohemia in Ceske Budejovice (107 men, 147 women) who studied at the Department of Biology. One hundred and thirty-two respondents were attendants of teaching study program, while 122 respondents attended non-teaching study program *Environmental Education*. Both groups of respondents have relation to education because the graduates will become either integrated science teachers or they will work with children and youth in the frame of leisure time and after-school organizations. The age of respondents was between 19 and 28 years.

The type of completed higher education (105 respondents from gymnasium/grammar school, 149 from other high schools or vocational schools) was selected as a variable in some analysis. The obtained data were analyzed by classical statistical methods. Pearson chi-square test was used for analysis of nominal data. All tests were done at the level of significance $p = 0.05$. Some questions were analyzed with the use of multivariate linear analysis by program CANOCO (terBraak and Smilauer 1998). This program helps to find links between variables, more precisely between independent and dependent variables, and their subsequent visualization via ordinal axis. PCA analysis (principal coordinate's analysis) was used.

The Questionnaire

The questionnaire was distributed to respondents—university students—in printed form. The first question was focused on methods used by integrated science and biology teachers to check students' knowledge. Respondents were asked to comment on four ways of school assessment—oral, written, practical examination (e.g. determination of non-living and living things, assembly of the apparatus etc.), and other ways of assessment—using three levels of frequency—“often,” “sometimes,” and “never.”

The next item of the questionnaire was focused on formative assessment and respondents' personal experience with it during their school attendance at elementary school and high school. To ensure proper understanding of the term “formative assessment” short definition was part of this question. The formative assessment was described as continuous assessment in which student is assessed during his/her performance, with teacher's focus being not on finding

mistakes, but instead on guiding the student to improve his/her activity to reach established learning goals (OECD 2005).

In the third question the respondents were asked about areas of their school work which the teacher was focused on during assessment. They had a choice of three frequency options—“often,” “sometimes,” and “never,” which were to be matched with these areas: A) knowledge of terms, facts and definitions; B) ability of logical thinking and individual work; C) fluency and formal quality of oral speech; D) ability to follow the working procedure during practical works; E) graphical layout of submitted works; F) monitoring of progress during school work and knowledge (improvement/deterioration); G) guiding additional student’s activity leading to achievement of learning goals, H) other area. Respondents were allowed to choose more options.

Then the respondents commented on concrete assessment forms used by their teachers during integrated science and biology lessons. Respondents chose one or more from the following options: A) point/percentage system converted to grades; B) classical grading; C) classical grading accompanied by oral comment; D) oral verbal assessment; E) written verbal assessment; F) continuous assessment emphasizing areas the student should improve in; G) portfolio assessment.

We were also interested in fact, whether students were assessed during their practical activities (e.g. observing, laboratory works or inquiry-based lessons), and subsequently in concrete forms of this assessment.

Next part of the questionnaire investigated respondents’ subjective opinion on formative assessment. Respondents should decide whether formative assessment is a useful method or not for their learning in science. There was an open-ended question where students could express their own subjective opinion. Their answers were divided into clusters with similar meaning and then coded. The last item was intended only for students of teaching branches. These students had an opportunity to state whether they would like to use the formative assessment in their own pedagogical practice.

Results

Respondents selected the written examination (199; 78.3% of all respondents) and oral examination (142; 55.9%) as the most often used methods that their integrated science, resp. biology teachers, used to check students’ knowledge “often.” On the other hand the practical examination was used only sometimes and 121 (47.6%) respondents mentioned that they were never assessed in this way. Other way of assessment was chosen only by minimum respondents (10; 3.9%) and in all cases it was a portfolio assessment.

The next item was focused on respondents’ personal experience with formative assessment during their school attendance at elementary school and high school. Eighty-nine respondents met with components of formative assessment at elementary school, 165 respondents mentioned that they had no experience with it. The situation was similar at high school—57 had experience, 134 had no experience with this approach. Sixty-three respondents answered “don’t know”—which could be caused by misunderstanding of the definition or by inability to imagine concrete assessment methods. After comparing respondents’ answers based on whether the formative assessment was used during teaching at elementary or high school, it was found that the type of school had no significant effect on answers’ frequency ($\chi^2 = 0.31$, $df = 1$, $p = 0.58$). The same result was obtained when we monitored the link between frequencies of respondents’ answers and type of visited school. In this case the difference between gymnasium and other type of high school had also no significant effect on answer’s type ($\chi^2 = 0.28$, $df = 1$, $p = 0.06$).

From the descriptive statistics point of view the respondents stated that during assessment their teachers mainly focused on knowledge of terms, facts and definitions (189; 74.4%). This option was followed with ability of logical thinking and individual work (95; 37.4%), ability to follow the working procedure during practical works (69; 27.2%), graphical layout of submitted

works (65; 25.6%). Fluency and formal quality of oral speech were chosen by 50 respondents (19.7%). Forty-four respondents (17.3%) stated that the use of formative assessment, which focuses on monitoring of progress during school work and knowledge or rather on guiding student's additional activity leading to achievement of learning goals.

Areas which the teacher was focused on during the assessment were visualized by PCA method, because any of explanatory variables (gender, teaching vs. non-teaching branch of study, finished type of high school) had no significantly important influence on respondents' answers. Results of analysis are summed up in Figure 1.

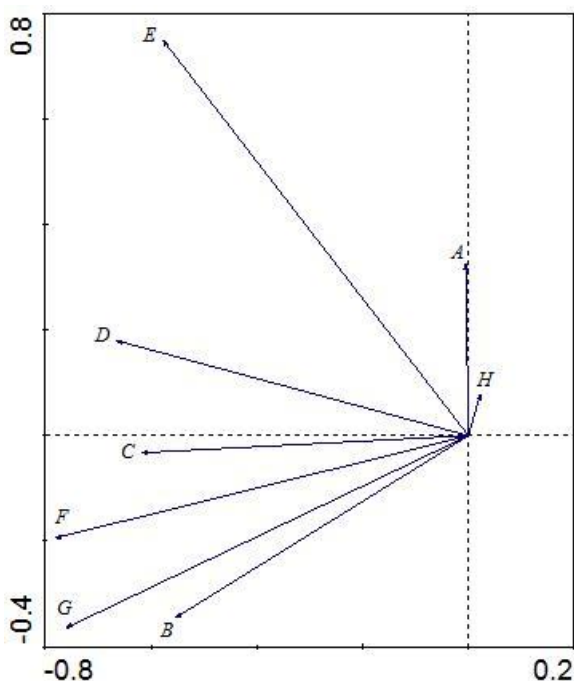


Figure 1: Teacher's Areas of Interest during the Assessment from Students' Points of View

Legend: A) knowledge of terms, facts and definitions; B) ability of logical thinking and individual work; C) fluency and formal quality of oral speech; D) ability to follow working procedure during practical works; E) graphical layout of submitted works; F) monitoring of progress during school work and knowledge (improvement/deterioration); G) guiding additional student's activity leading to achievement of learning goals, H) other area.

The first axis (horizontal) explaining 41.9 % of variability indicates distribution of A and H options against other options (E, D, C, F, G and B). Option H ("other area") was found in minimum cases. The second axis (vertical) indicates distribution of options F, B and G strongly against E, partially against A and D.

The selected answers revealed that integrated science teachers used the classical grading (136; 53.5% of respondents selected this option) as the most frequent form of concrete assessment. The classical grading was followed by classical grading accompanied with oral comment (30; 11.8%) and point/percentage system (27; 10.6%). The amount of other answers was lower than 15. The respondents mentioned that their high school teachers used mainly classical grading (92; 48.7% of all respondents), followed by point/percentage system (78; 41.3%) and classical grading with oral comment (46; 24.3%) as the most common forms of assessment in biology lessons. Other answers were not more frequent than twelve-times. Sixty-five respondents did not answer this question because they did not have biology as a study subject at high school.

The answers were compared to find any differences in assessment styles at gymnasium and other type of high schools (vocational schools, e.g. agricultural, economy, technical school etc.), but no significant difference was discovered ($p > 0.37$).

The analysis in program CANOCO was used to compare answers of respondents who had integrated science at elementary school and biology at high school (Fig. 2). Respondents who did not have biology at high school were rejected from this analysis. In the PCA multivariate analysis the first two axes explained 49% (1. horizontal axis 25.7% and 2. vertical axis 23.3%) of variability. Classical grading was incompatible with point system at first axis. The figure shows classical grading and point system plotted against classical grading with added oral comment. Based on the figure it is possible to say, that results of options ES-C and SS-C correspond. If respondents did not choose option A or B, then they most often chose option C.

From the point of view of the first axis there is larger difference between answers related to high school attendance compared to answers related to elementary school attendance, however, this conclusion cannot be verified from the vertical axis point of view.

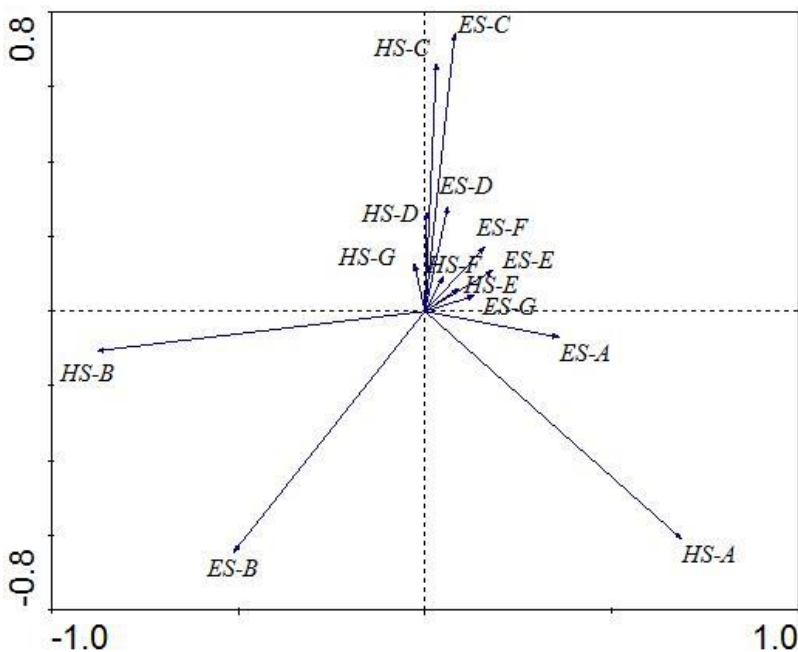


Figure 2: Concrete Assessment Forms Used in Integrated Science and Biology Lessons from Students' Points Of View

Legend: ES—elementary school; HS—high school; A) point/percentage system converted to grades; B) classical grading; C) classical grading accompanied by oral comment; D) oral verbal assessment; E) written verbal assessment; F) continuous assessment emphasizing areas the student should improve in; G) portfolio assessment.

Teaching methods focused on direct study of nature (laboratory works and/or inquiry-based lessons) are often used in integrated science and biology. One hundred and forty respondents were assessed during laboratory works in integrated science at elementary school. On the other hand, 115 respondents stated that their performance was never assessed during laboratory works. The same situation was revealed from answers in relation to laboratory works at high school, where 104 respondents said that they were assessed and 88 respondents were not assessed. Sixty-three respondents did not answer this question because they did not have biology as a subject during their high school attendance. Pearson-chi square test unveiled that students' practical skills at gymnasiums are assessed more often than at other high schools ($\chi^2 = 3.98$, $df = 1$, $p =$

0.046). No difference between the frequency of assessing practical skills and knowledge at elementary and high school was proved ($\chi^2 = 0.67$, $df = 1$, $p = 0.41$).

More than half of respondents (167; 65.7%) considered the formative assessment to be a beneficial method for their learning in integrated science and biology. Seventy-seven respondents (30.3%) disagreed with this statement and 6 respondents (2.3%) were not sure in their answer. Effect of the teaching and non-teaching study program had no significance on the type of answer ($\chi^2 = 0.004$, $df = 1$, $p = 0.95$).

Respondents had an opportunity to express own subjective opinion on formative assessment in an open-ended question. Answers were summarized, divided into 6 clusters (1: useful method; 2: method that I like, interesting method; 3: motivating method; 4: method that is difficult to use (due to lack of time or sources); 5: method that I don't like; 6: common assessment is better, formative assessment could be only additional method) and the frequencies of relevant clusters were visualized in Figure 3. The formative assessment was described the most frequently as a new and useful approach to school assessment (86 answers). Sixty-four respondents considered the formative assessment to be an interesting opportunity to assess students, 26 respondents highlighted motivational function of this assessment, 9 respondents said that it is difficult to handle the formative assessment due to time consumption and/or lack of resources, 8 respondents would not apply formative assessment into practice because they disagreed with main ideas of this approach. Seven respondents would rather use summative assessment and the formative one only as a complementary method of assessment. Thereafter insignificant amount of respondents stated that the formative assessment is not motivational and fair. Some respondents confessed they could not imagine the assessment methods thus they would not answer this question.

Large number (82) of respondents did not answer this question; this could be caused by miscomprehension of the definition or lack of experience with this assessment approach.

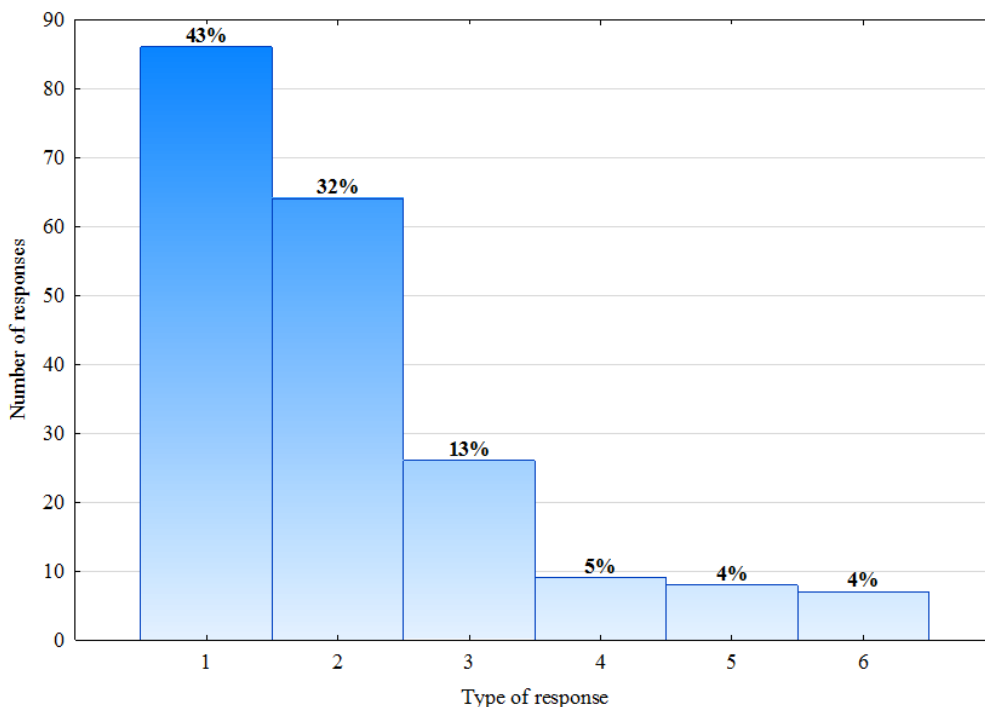


Figure 3: Respondents' Opinions on Formative Assessment

Legend: 1: useful; 2: I like it, interesting; 3: could motivate students; 4: difficult to use (time or sources); 5: I don't like it; 6: common assessment is better, it could be only addition

University students of teaching study programs had an opportunity to comment on whether they would like to use the formative assessment in their future pedagogical practice. Majority stated they would use it (106 answers) and only 26 respondents are not going to use this assessment approach. We found a dependence between the answers of respondents who stated that the formative assessment provides them better background as students so they would like to use the formative assessment as teachers in their own practice ($\chi^2 = 19.59$, $df = 1$, $p < 10^{-5}$).

Discussion

Results of this study revealed that written or oral exam are classical forms of assessing students' performance in science education at elementary and high schools in the Czech Republic. In consideration of higher potential of written tests with respect to verification of students' knowledge, all statewide assessments in teaching practice (including evaluation of students' knowledge at elementary schools and state part of graduation exam at high schools) are supported by the Czech curricular documents. Osborne and Dillon (2008) mentioned in their report that statewide testing and its orienting only on students' knowledge can cause focusing solely on topics of science subjects which could be tested by these exams and the use of summative assessment continuously leads to this situation in our education system. This was confirmed by research of Rokos and Petr (in prep.) who found that Czech teachers focus mainly on knowledge of facts and definitions as this can be verified easily by tests. The consequence of this situation might be fragmented students' knowledge, because they learn isolated units of subject matter out of context and teachers becoming the only active elements in the teaching process. This fact could also reduce the students' interest in science subjects.

Students' ability to think logically and individually is assessed by teachers during oral examination, which provides more space for it than the written examination. In contrast to this assumption it was found that integrated science and biology teachers use written examination more often. Aspects of formative assessment, i.e. continuous assessment with accent on what the student should improve in, or portfolio assessment, were selected by smaller percentage of respondents (less than 6.5 % for both options). This underlined, that formative assessment is not a commonly used type of assessment and 32.3 % respondents were not able to describe this assessment method. Moreover the majority (53.0 % at elementary school and 65.0 % at high school) of respondents had no experience with formative assessment during their learning at elementary and high school.

The classical grading remains the most commonly used form of classification in integrated science at elementary school (70.8% of respondents selected this option), but this grading is balanced with point or percentage system in biology at high school (classical grading was mentioned by 41.2% of respondents and point or percentage system by 48.7%). In several cases respondents said they had received verbal comment alongside given grade from written or oral examinations, but the question, whether the teacher provides the feedback on students' performance and gives students opportunity to apply the knowledge which they receive from the feedback in their further work, still remains open. The grading itself often does not encourage students to increase effort in their learning process (Black and Wiliam 1998; Hattie 1999). These authors accomplished analysis of researches related to assessment and found out that there is no better way to improve students' acquired knowledge with such a high efficiency as just to provide a feedback which is not associated with classification. They also mentioned that feedback should relate to specific characteristics of student's work, be supplemented by advice about what the student can still improve, and should avoid any comparison with other students.

Our results show that half of respondents had experience with assessing their performance during laboratory works at elementary school. The same conclusion was found in answers connected to respondents' high school attendance. Taking into account the types of Czech high schools we expected the students visiting vocational schools with many practical subjects should

have been assessed during laboratory works more often than gymnasium students where the curriculum is focused on general knowledge. However, we discovered that gymnasium teachers assessed practical skills of their students more frequently than teachers from other type of high schools (61.0% of gymnasium students, 26.8% of other high school students). Nevertheless the practical examination (e.g. determination of non-living and living things, assembly of the apparatus etc.) was represented with only 7.5% answers on question which types of assessment are commonly used by integrated science and biology teachers. The assessment of students' laboratory skills, as well as practical examination, has several limits in our educational system. One of them might be a tendency to carry out standardization, i.e. to compare student's performance in relation to classmates. The standardized summative assessment like grading and/or awarding plus points, which are added to assessment results of tests and oral examinations, provides no information in relation to development of student's competencies. It only informs the student about the level of teacher's selected goal that was reached. The teachers themselves described classical grading in this case as inappropriate form of assessment (Rokos and Petr, in prep.). For example during laboratory works and/or inquiry-based activities students should be engaged in problems that require higher-level thinking and complexity of activities (e.g., identification of hidden relations, data evaluation and interpretation, hypotheses formulation, or identification of control and dominant variables in the process of planning experiments) (Osborne and Dillon 2008; Cambridge Assessment 2013). Cambridge Assessment (2013, 6) added, that if the task is more complex (e.g. open-ended inquiry), it is necessary to realize that the assessment methods have to be more complex too. If that activity is assessed only in summative way, then it leads to suppression of thinking about science phenomenon and issues.

The research showed that almost fifty percent of respondents identified formative assessment as a useful new approach to school evaluation and one third of them emphasized the motivational function of this approach. Some of them (2.7%) stated that they would still prefer classical summative assessment or they would use formative assessment only as a supplement to the classical summative approach. In this case it might have been insufficiently explained that the formative assessment would not be the only assessing approach.

Our respondents also named several limiting factors for implementation of the formative assessment, which show that students of faculty of education were able to think about strengths and weaknesses of this assessment approach. They stressed high demands on teacher's time for planning and appropriate use in teaching. Some respondents (less than 2 %) believed that formative assessment is not motivational and fair to all students. By contrast, Furtak (2009, 6) described formative assessment as an approach which leads to better equality in education because it helps students with worse results to achieve desired goals. Moreover, the formative assessment may increase chances of all students to access high-quality science education (White and Frederiksen 1998).

The positive result of this study is the fact that more than three quarters of our respondents who attend teaching program and have personal experience with formative assessment from their elementary and high school education would definitely like to use it in their future teaching practice. However, it is necessary to familiarize all students—future teachers—with elements of formative assessment already during their training at faculties of education. At the same time it is necessary to create both sufficient and high-quality methodological manuals and professional publications dedicated to the use of formative assessment in science education because there is a lack of publications focused on this topic in the Czech Republic.

Conclusions and Implications

Our study has shown that respondents—students at the Department of Biology of the Faculty of Education, University of South Bohemia in Ceske Budejovice—met with elements of the formative assessment rather sporadically during their school attendance at elementary and high

school. However, majority of respondents rated this assessment approach very positively. Respondents from teaching study program claimed they would like to implement formative assessment to their future teaching practice, but they noted that they became conscious of their insufficient knowledge of this methodological approach.

This finding represents a challenge for the Department of Biology that prepares integrated science and biology teachers, because the topic of formative assessment is not sufficiently incorporated into the thematic plans of General Didactics and moreover the students are not trained to use this approach in Didactics of Biology/Integrated science as well as in the teaching practice at schools. This time the topic of formative assessment was implemented into pedagogical and didactical preparation of pre-service both biology teachers and integrated science teachers. This change in the study program will lead to better understanding of how to perform formative assessment properly, how to select appropriate methods and what type of feedback should be given to students in order to enhance their school performance.

Currently, two other studies performed by the Department of Biology, and Faculty of Education, University of South Bohemia, are under way. The first one is focused on integrated science and biology teachers' knowledge about formative assessment and assessment methods used in their teaching practice. The second one deals with students' personal experience with formative assessment in science education.

Acknowledgment

The study was funded by grants of the Grant Agency of the University of South Bohemia GA JU 075/2014/S and GA JU 078/2013/S.

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ISSN: 2327-7920

