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Abstract. *Motivation to learn a school subject is crucial for achieving knowledge and skills and, consequently, for good academic performance in the subject. There are several approved questionnaires dedicated to assessing motivation for science and biology but none for upper secondary school Czech students. Therefore, existing Science Motivation Questionnaire was evaluated, validated and modified in order to create a Czech version of a Biology motivation questionnaire (BMQ). The original version of the questionnaire had 30 questions, arranged in the following subscales: Internal Motivation, External Motivation, Personal Relevance, Responsibility, Self-efficacy and Anxiety. Validation was based on a survey of 517 upper secondary school Czech students. Analysis of the questionnaires revealed that, although the questionnaire could be used as a whole with satisfactory Cronbach alpha values, the underlying constructs in the Czech version were different from the six ones originally suggested. Based on Exploratory Factor Analysis and Structural Equation Modelling, 14 questions retained in three constructs: a) Self-efficacy, b) Responsibility and c) Motivation as a combination of Internal Motivation, External Motivation and Personal Relevance. This shorter version of the BMQ showed satisfactory Goodness of Fit Indices in contrast to the original 30-item version.*

Keywords: *biology motivation questionnaire, questionnaire modification, EFA, secondary school students.*

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EVALUATION, VALIDATION AND MODIFICATION OF SCIENCE MOTIVATION QUESTIONNAIRE FOR UPPER SECONDARY SCHOOL

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Introduction

Biology teachers all around the globe are trying to find the best way how to get their students involved in science, motivate them and ensure they gain knowledge, skills, and positive attitudes toward biology at the same time. From the historical perspective someone can recognize continuous experimenting with many different methods, forms, strategies, technologies, etc. wishfully leading toward better Biology education (e.g. Michael, 2006). However, it seems that one of the keys to better Biology education is motivation towards both the content and the process of acquiring knowledge, skills and positive attitude. In order to gain knowledge about different types of motivation (see below), with the aim of making biology education better, tested instruments are needed to evaluate motivation before and after the intervention. Only then, and following the evidence provided by the test results, teachers and others involved in curriculum design, can introduce changes leading toward better knowledge and appreciation of Biology as an interesting discipline (Dohn, Fago, Overgaard, Madsen, & Malte, 2016), worth to be learned or chosen, when election is an option (Bathgate & Schunn, 2016). Hopefully, students motivated for Biology and related topics were more likely to show career aspirations in STEM (Science, Technology, Engineering and, Mathematics) as a plausible study choice and follow up career (Šorgo et al., 2018).

Motivation is perceived as an internal state and can be recognized as a psychological process determining the intensity, direction and persistence of learning-related behaviour. If someone is motivated, he/she is moved to do something (Beihler & Snowman, 1997; Ryan & Deci, 2000); therefore, motivation to learn is crucial for successful learning. Motivation to learn is linked to achievement in the subject, with self-efficacy (Bandura, 1977) being the motivational factor most related to achievement because it directly influences the academic goals that students set for themselves (Zimmerman, Bandura, & Martinez-Pons, 1992). There exists a number of studies connecting self-efficacy with different aspects of learning and teaching biology. Lawson, Banks, and Logvin (2007) connected SE with reasoning ability and find positive correlation; moderate correlations were established with academic performance (Honicke & Broadbent, 2016).

To paraphrase Glynn, Brickman, Armstrong, and Taasoobshirazi (2011), motivation to learn biology can be defined as an internal state that arouses, directs and sustains biology-learning behavior. The connection between motivation, and different aspects of teaching and learning Biology was approved in numerous studies (e.g. Dyrberg, Treusch, & Wiegand, 2017; Jenö, Grytnes, & Vandvik, 2017; Mahler, Großschedl, & Harms, 2017).

However, learning is not influenced only by the higher or lower levels of motivation but also by the type of motivation. Deci and Ryan (1985) formulated a self-determination theory distinguishing between different types of motivation: intrinsic and extrinsic motivation and amotivation. Additionally, extrinsic motivation consists of several subtypes as reviewed by Ryan and Deci (2000) who further discriminate external control and true self-regulation. According to theory, intrinsic motivation leads to performance of an activity for satisfaction, because of interest, curiosity and will to explore, and is recognized as the preferred incentive for success in schoolwork. However, many (if not most) school activities are extrinsically motivated, or more reliably, the motivational drive is a combination of internal and external motives. Gagné and Deci (2005) recognized that activities that are not intrinsically motivating require extrinsic motivation. Extrinsic motives can be internalized, meaning that they can be passively and even actively accepted and integrated. In the educational context 'it appears that intrinsic motivation (for active exploring and learning) becomes weaker with each advancing grade' (Ryan & Deci, 2000, p. 60), possibly because the extrinsic tangible rewards widely used in schools undermine internal motivation (Deci, Koestner, & Ryan, 2001). Ryan and Deci (2000) described the further structuring of external motivation, including external regulation, introjection, identification and integration. In education, motivation most of the time cannot be separated from the educational context and activities leading to a concept of situational motivation as motivation towards the specific activity in which students are engaged 'here and now' (Guay, Vallerand, & Blanchard, 2000; Vallerand, 1997). A Situation Motivational Scale consisting of four subscales - intrinsic motivation, identified regulation, external regulation and amotivation - was developed by Guay et al. (2000). Guay et al. (2000) also concluded that situational motivation connected to a specific academic activity was related to general motivational orientation within the school context.

Various survey instruments - questionnaires - have been constructed to measure motivation, sometimes including self-efficacy as well. Table 1 shows an overview of these questionnaires.

Table 1. A list of questionnaires used for assessment of motivation towards Biology and Science.

Authors	Constructs included	Subject	Target group	No. of Questions
Tuan, Chin, & Shieh, 2005	Self-efficacy, active learning strategies, performance goal, achievement goal, learning environment stimulation, science learning value	Science	Lower secondary school students	35
Glynn, Taasoobshirazi, & Brickman, 2007, 2009	Internal motivation, external motivation, personal relevance, responsibility, self – efficacy, anxiety	Science	University students	30
Britner, 2008	Self-efficacy, self-concept, achievement goal orientation, science anxiety	Science	Upper secondary school students	59
Shihusa & Keraro, 2009	Motivation to learn biology using the advanced organizer teaching strategy and the traditional methods	Biology	Secondary school students	20
Ekici, 2009, 2010	Like Glynn, Taasoobshirazi, & Brickman, 2007, 2009	Biology	Upper secondary school students	30
Zeyer, 2010	Like Glynn, Taasoobshirazi, & Brickman, 2007, 2009	Science	Upper secondary school students	30
Velayutham, Aldridge, & Fraser, 2011	Learning goal orientation, task value, self-efficacy, self-regulation	Science	Lower secondary school students	32
Glynn et al., 2011	Intrinsic motivation, self-determination, self-efficacy, career motivation, grade motivation	Science	University students	25
Ates & Saylan, 2015	Internal motivation, external motivation, grade motivation, responsibility, self-confidence, test anxiety	Biology	University students	30



Authors	Constructs included	Subject	Target group	No. of Questions
Mavrikaki, Andressa, & Dermitzaki, 2015	self-efficacy, biology learning value, active learning strategies, performance goal, achievement goal, learning environment stimulation	Biology	Upper secondary school students	34

The focus of this research was the motivation among Czech upper secondary school students for learning biology. The aim was to translate and adapt Science Motivation Questionnaire (SMQ) (Glynn, Taasobshirazi, & Brickman, 2007, 2009) to Czech environment. In this research, the questionnaire (although originally applied to university students) was applied to upper secondary school students and was adapted for biology by simply changing the word Science to Biology (Ekici, 2009; Glynn et al., 2011; Zeyer, 2010). The SMQ, where the word Science was changed and the words Pedagogy/Didactics were used to measure the difference between motivation toward the science courses and the pedagogically/didactically oriented courses of prospective teachers, was used in an international research by Šorgo et al. (2017). Despite the existence of revised version of SMQ (Science motivation questionnaire II; Glynn et al., 2011) the original SMQ was chosen in this research. In the revised version of SMQ, the major changes of the initial version were exclusion of the Anxiety dimension from the set of items and formation of three new constructs: Career motivation, Self-determination, and Grade motivation, replacing External Motivation, Personal Relevance, and Responsibility. In this way the questionnaire was shortened to 25 items. However, due to the orientation toward the students' college science we made informed decision to retain the original version of the questionnaire which can be seen as more related to the original theories of Deci and Ryan (1985).

From the practical point of view, any research instrument has to balance the accuracy and length. The length of a questionnaire has been shown to negatively influence the number of respondents who complete it. Also the time spent by answering the questions positioned later in the questionnaire is shorter and the answers are more uniform compared to the answers positioned closer to the beginning of the questionnaire (Galesic & Bosnjak, 2009). Although Rolstad, Adler, and Rydén (2011) also concluded the longer the questionnaire the lower the respondent rates, the content of a questionnaire can have an impact as well. The trend of shortening questionnaires can be seen in different areas, e.g. psychology (Rammstedt & John, 2007).

Aim and Purposes of the Research

The aim of the research was to provide a validated (Czech) tool suitable for exploring the motivation of upper secondary school students to learn biology (adapted from Glynn et al., 2007, 2009) not only by translating it but with a test of validity of underlying theoretical construct.

Differences between students, based on varied characteristics and traits such as gender and residence, were explored but were not considered as factors in the following models. The reason does not lie in the unimportance of recognizing such differences; however, the aim of this research was to find a universal instrument valid for exploring motivation at the secondary school level. As is the case in majority of such studies the aim was to find a robust instrument for assessment of general trends and not individual differences between different strata of the sample (e.g. gender, enrolment in a classroom, etc.).

In conducting the research, answers to the following research questions were sought:

- a) In what ways are the constructs transferred from SMQ (Internal Motivation, External Motivation, Personal Relevance, Responsibility, Self – efficacy and Anxiety) to BMQ valid in the Czech version?
- b) Is it possible to shorten the original questionnaire without losing too much information (if yes, how)?

Research Methodology

General Background

For this research, the quantitative approach was chosen to find the answers to the research questions. The constructs of the Czech version of Biology motivation questionnaire were explored using questionnaires completed



by Czech upper secondary school students. Exploratory factor analysis and confirmatory factor analysis were used to explore the construct of motivation. An alternative model was developed and described.

Sample and Sampling

The sampling was performed during the practical courses that were offered at the Department of Teaching and Didactics of Biology, Faculty of Science of Charles University, Prague (Czech Republic) to schools from all parts of the Czech Republic as a voluntary activity from 2012 to 2014. During the course, the students (groups of 10 – 25) were asked to take part in the research by completing the BMQ in paper and pencil format. Students were given basic information about the purpose of the questionnaire, as well as the information that responding to the questionnaire was voluntary and anonymous, and no benefits or disadvantages were foreseen for those who participated or those who did not. Completion of the questionnaire was supervised by the University staff. Typically, the task took 20 minutes. Most students (about 90%) agreed and provided a completed questionnaire.

The sample represents students accompanied with their teachers who chose practical courses offered by the Faculty of Science, Charles University, Prague. The sample consisted of 517 upper secondary school students from 20 different schools in the Czech Republic (seven from Prague, 13 from other towns from all Czech districts; 30 % of the students were from middle size towns, 29 % from Prague and big towns and 41 % from little towns and villages). Only questionnaires with no missing data were used in further analysis. This sample consisted of 332 (64%) girls and 185 (36%) boys, from year level ten ($N = 53$; 10%), 11 ($N = 82$; 16%), 12 ($N = 211$; 41%) and 13 ($N = 171$; 33%); the students were 15 – 19 years old, and in the last four years of upper secondary school (years 10 – 13 in the Czech Republic, after having finished nine years of compulsory education). A minority of the students were from Prague ($N = 133$; 26%) and most were from other towns ($N = 384$; 74%). Approximately one in five students attended an elective biology course ($N = 106$; 21%); the rest of the students ($N = 411$; 79%) had only compulsory biology lessons.

Instrument and Procedures

The construction of the new version of Biology Motivation Questionnaire (BMQ) started from 30 questions from the Science Motivation Questionnaire (SMQ) developed by Glynn et al. (2007, 2009). The questionnaire was based on a 5-point Likert scale, as follows: never (1), rarely (2), sometimes (3), usually (4), always (5). Five items (Table 2: 4, 6, 11, 12, and 16) are negatively coded, and were recoded to be included in statistical tests; however, for clarity, these are presented in Table 2 in the format as answered by respondents. In the tables, these items are marked with an asterisk. The initial difference between the original questionnaire and the new version was in the leading statement, where the word *Science* was replaced by the word *Biology*. The leading sentence is as follows: 'In order to better understand what you think and feel about your biology courses, please respond to each of the following statements from the perspective of: When I am in a (high) school biology course...'. Later in the questionnaire items, the word *Science* was replaced by the word *Biology*.

The questionnaire was translated to the Czech language by two translators proficient in both languages, and two university teachers of different Biological subjects in context of education. When in doubt conciliar approach was applied to find the best match between Czech translation and the original. Content validation was not questioned, because the intention was not to develop a questionnaire from the scratch, however sometimes small adjustments were necessary to accommodate differences between college and secondary school levels, and differences in school systems and content of the syllabi (e.g. Biology versus Science).

The initial questionnaire BMQ had six subscales following constructs as suggested by Glynn et al. (2009). The constructs were as follows: Internal Motivation (IM); External Motivation (EM); Personal Relevance (PR); Responsibility (RE); Self-efficacy (SE); and Anxiety (AN).

The constructs applied in the theoretical models of motivation and the factors involved in it and their theoretical base were described elsewhere (e.g. Glynn et al., 2007, 2009; Ryan & Deci, 2000; Vallerand, 1997; Vallerand et al., 1992), they are presented only briefly here, as follows. Internal Motivation (IM): (intrinsic motivation in Introduction section) refers to the circumstances when an activity is done for its own sake, for the pleasure and satisfaction of the participant (Vallerand et al., 1992, p. 1004). As mentioned by Vallerand et al. (1992), internal motivation can be further divided as IM to know, IM toward accomplishments and IM to experience stimulation. External Motivation (EM): (extrinsic motivation in Introduction section) refers to behavior as a mean to an end, an activity done in order



to attain some separable outcome' (Deci & Ryan, 1985; Ryan & Deci, 2000, p. 60). Further structuring is mentioned in Introduction. Personal Relevance (PR): was understood as described by Glynn et al. (2007, p. 1095) as 'relevance of learning science to personal goals' e.g. future life and career. Responsibility (RE): refers to self-determination for learning science, in a sense of students' belief that they have control over their learning (Glynn et al., 2007, p. 1090). Self-efficacy (SE): was understood as defined by Bandura (1977) as an expectation of personal efficacy to be able to finish an activity. Self-efficacy determines the amount of effort expended, the duration of the behavior and therefore the achievement in the subject. Anxiety (AN): refers to assessment anxiety (Glynn et al., 2007, p. 1090), as a debilitating tension associated with grading in science. In case the level of assessment anxiety is high, it hinders students' motivation and therefore achievement (Cassady & Johnson, 2002), what can be understood as amotivation in a sense of Ryan and Deci (2000).

Reliability of the scale and subscales was calculated as Cronbach's alpha. Reliability of the entire scale was .91, showing appropriate internal consistency. Alphas of the subscales and items are presented in Table 3 in the Results section.

Data Analysis

Evaluation of the BMQ and its Constructs

For evaluation of the BMQ and its underlying constructs, three plausible options were available (Figure 1). Models were adapted from Pekrun, Goetz, Frenzel, Barchfeld and Perry (2011). The first model is based on the prediction that motivation is univariate. The second model is based on the prediction that motivation follows discrete constructs predicted by a theory (Ryan & Deci, 2000) and applied by Glynn et al., (2007, 2009). The third model is based on the prediction that theoretical constructs (Glynn et al., 2007, 2009) are predictors of a single second order factor.

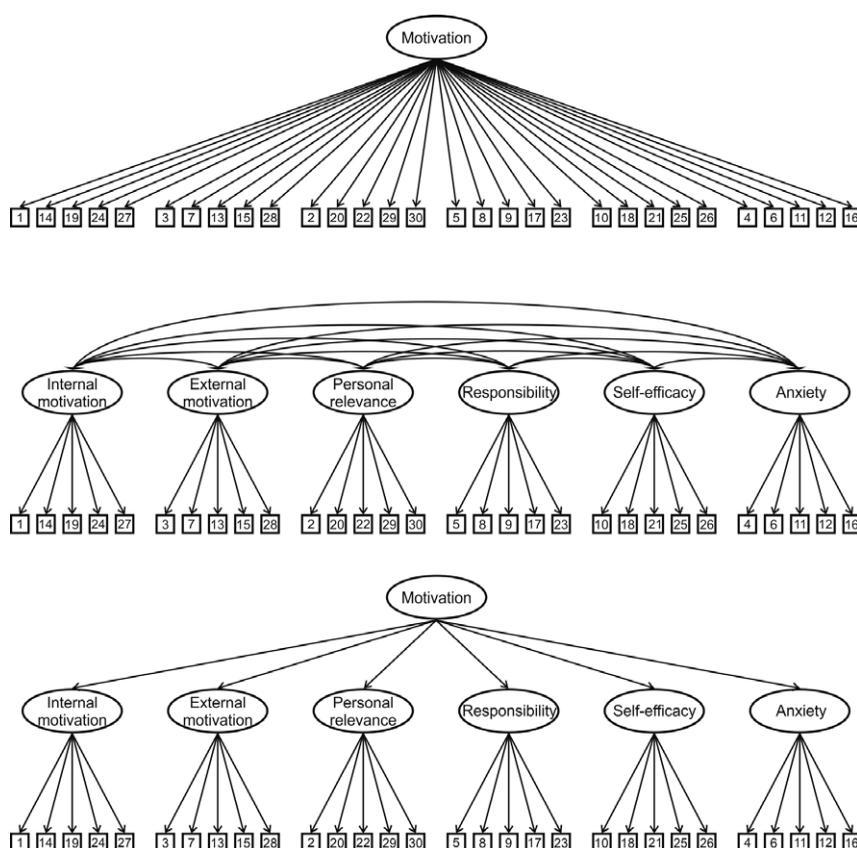


Figure 1. Theoretical models for evaluation of BMQ (adapted from Pekrun et al., 2011).

Statistical Procedures

To explore construct validity of the instrument two methods were chosen: Exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) (see Schmitt, 2011) for overview of factor analysis usage and recommendation on using EFA). CFA was used to determine whether the responses of the participants followed the pre-existing factor models for the BMQ. Principal Component Analysis (PCA) with Direct Oblimin rotation calculated with SPSS ver. 24 was chosen, because correlation between constructs was expected. SEM analyses by use of AMOS ver. 24 package were performed to explore model fits. Upon discovering poor-fit for initial models, exploratory factor analysis (EFA) was used to develop alternative models. SEM and CFA were interchangeably used to establish the fit of the newly trimmed questionnaire. Only some of the key steps (initial and final models) are presented in the article, and not all steps in every statistical method applied (e.g. Cronbach's alpha if item deleted, step by step improvement of the models by connecting error terms, and similar). The reason is to shorten the article to a reasonable length, however, if someone is interested in post-hoc analysis or in comparative study anonymized data are available on request.

Reliability and Validity of a Measurement Model

Models were built by use of raw data collected from 517 respondents to the BMQ. No missing data was in the data set. Reliability of each construct was assessed by the inspection of factor loadings on each construct and Cronbach's alpha. Factor loadings with values greater than .4, and alphas above the .7 level were considered appropriate for the models describing motivation and its factors.

The Construct Validity was checked by analysing Fitness Indices as follows: *RMSEA* (Root Mean Square of Error Approximation), *GFI* (Goodness of Fit Index), *AGFI* (Adjusted Goodness of Fit), *CFI* (Comparative Fit Index), *NFI* (Normed Fit Index) and *Chisq/df* (Chi Square/Degrees of Freedom). There is no agreement among researchers on which fitness indices to use. Threshold values for each index were compiled from several sources (Kline, 2015; Šumak et al., 2017; Šumak & Šorgo, 2016). A modification procedure with correlation of error terms was used to improve model fit (Hooper, Coughlan, & Mullen, 2008).

SPSS 24 and AMOS 24 software were applied for calculation. Figures were created using CorelDRAW X6.

Weakness of the Research

The major weakness of the research is one shared with a majority of similar studies: every Czech student does not have an equal chance to be included in a sample, which is the assumption behind random sampling. The sample consisted of students who might not themselves have been motivated for biology; however, they had motivated teachers with the resources to travel to the workshops at Charles University. However, the sample used was sufficiently large to allow robust conclusions based on applied statistical methods. Retesting of the shortened version of the questionnaire on a different sample and, hopefully, random sampling, should be the next steps.

Research Results

Descriptors from the Biology Motivation Questionnaire

Students were asked to provide answers to the initial statement, as follows.

In order to better understand what you think and feel about your biology courses, please respond to each of the following statements from the perspective of: 'When I am in a (high) school biology course...'

Frequencies of their answers and values of mean (*M*), standard deviation (*SD*), median (*Mdn*) and Mode (*Mod*) are provided in Table 2. Items J4, J6, J11, J12, and J16 (denoted by an asterisk) were reverse coded for follow up analyses; however, in Tables 2, 4 and 7, these are presented in the format as received from the respondents. Information about subscales as defined by Glynn et al. (2007, 2009), and Cronbach's alphas for each construct are given in Table 3.



Table 2. Frequencies of answers and descriptive statistics on the Biology Motivation Questionnaire (N = 517).

No. of Statement	Statement	F1%	F2%	F3%	F4%	F5%	M	SD
J1	I enjoy learning biology.	13.9	44.7	24.4	10.6	6.4	2.51	1.06
J2	Biology I learn relates to my personal goals.	21.7	25.0	23.0	20.3	10.1	2.72	1.28
J3	I like to do better than the other students in biology assessments.	58.8	19.5	12.4	5.4	3.9	1.76	1.11
J4	I am nervous about how I will do in biology assessments.*	14.5	18.0	28.6	21.7	17.2	3.9	1.29
J5	If I am having trouble learning biology, I try to figure out why.	26.1	29.8	28.0	10.8	5.2	2.39	1.14
J6	I become anxious when it is time to sit a biology assessment.*	17.8	33.5	25.9	12.0	10.8	2.65	1.22
J7	Achieving a good biology grade (Achieved / Merit / Excellence) is important to me.	39.1	34.0	18.0	6.6	2.3	1.99	1.02
J8	I put enough effort into learning biology.	29.2	40.8	17.0	9.1	3.9	2.18	1.07
J9	I use strategies that ensure I learn biology well.	8.7	20.3	31.5	24.2	15.3	3.17	1.17
J10	I expect to do as well as or better than other students in biology course.	30.6	40.6	19.9	7.2	9 1.7	2.09	.97
J11	I worry about failing biology assessments.*	11.4	27.3	31.3	15.1	14.9	2.95	1.22
J12	I am concerned that the other students are better in biology. *	20.9	27.5	22.6	15.9	13.2	2.73	1.31
J13	I think about how biology will affect my overall subject or certificate endorsement.	22.1	24.0	25.5	16.8	11.6	2.72	1.30
J14	Biology I learn is more important to me than the grades I receive.	30.6	29.0	25.3	8.9	6.2	2.31	1.17
J15	I think about how learning biology can help my career.	32.7	21.3	17.4	17.8	10.8	2.53	1.38
J16	I hate taking biology assessments.*	13.2	26.1	28.2	18.4	14.1	2.94	1.24
J17	It is my fault if I do not understand the biology ideas.	37.9	37.3	16.2	4.6	3.9	1.99	1.04
J18	I am confident I will do well on the written and practical biology assessments.	15.7	44.5	30.6	7.0	2.3	2.36	.91
J19	I find learning biology interesting.	34.0	31.9	21.9	6.8	5.4	2.18	1.14
J20	Biology I learn is relevant to my life.	20.9	33.5	26.3	14.1	5.2	2.49	1.13
J21	I believe I can master the knowledge and skills in the biology course.	22.1	45.6	25.5	5.8	5 1.0	2.18	.87
J22	Biology I learn has practical value for me.	20.7	29.4	30.6	14.1	5.2	2.54	1.12
J23	I prepare well for the biology assessments (both internal and external)	12.8	38.3	27.1	15.7	6.2	2.64	1.08
J24	I like biology that challenges me.	10.8	21.5	28.8	21.9	17.0	3.13	1.24
J25	I am confident I will do well in the biology assessments.	13.9	38.7	35.6	9.1	2.7	2.48	.94
J26	I believe I can earn 'excellence' grades in the biology course.	10.4	26.5	30.4	16.8	15.9	3.01	1.22
J27	Understanding biology gives me a sense of accomplishment.	27.9	33.3	21.1	12.8	5.0	2.34	1.16
J28	I think about how learning biology can help me get a good job.	21.9	24.0	23.4	19.5	11.2	2.74	1.30



J29	I think about how biology I learn will be helpful to me.	24.6	33.3	27.5	10.6	4.1	2.36	1.09
J30	I think about how I will use biology I learn.	21.3	33.1	29.4	10.4	5.8	2.46	1.11

Note: M mean, SD standard deviation, Mdn median

Table 3. Subscales of the BMQ and their Cronbach's alphas.

Subscales of BMQ	Items	Alphas
Internal motivation (IM):	1, 14, 19, 24, 27	.84
External motivation (EM)	3, 7, 13, 15, 28	.73 (.75 if 13 deleted)
Personal relevance (PR)	2, 20, 22, 29, 30	.89
Responsibility (RE)	5, 8, 9, 17, 23	.75 (.82 if 17 deleted)
Self-efficacy (SE)	10, 18, 21, 25, 26	.83
Anxiety (AN)	4, 6, 11, 12, 16	.66 (.72 if 16 deleted)
Whole questionnaire	1 to 30	.91

All subscales except the anxiety subscale (AN) passed the .7 threshold; however, it was possible to raise the alpha level of this subscale to acceptable levels by deleting one item.

From the initial calculations of Cronbach's alphas, it can be concluded that the questionnaire and its subscales (constructs) can be used for studies about high school students' motivation towards biology.

Principal Component Analysis of the BMQ

Initial checking for suitability of the matrix for factorial analyses reveals the values for the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy as .947 and Bartlett's Test of Sphericity as $Chi-square = 9323.24$; $df = 435$; $p < .0001$. Principal component analysis with Oblimin rotation based on Eigenvalue > 1 criteria revealed five components. Based on the results of the parallel analysis (Hayton, Allen, & Scarpello, 2004), only the first three components should be retained. However, when considering alphas, only the first, the third and the fourth component passed the .7 threshold. Even more, the second component had negative value of alpha. Three items (11, 18, and 6) load on two components, and the loading of item 9, did not exceed the .4 threshold (Table 4). When considering correlations between components, a mixture of negative and positive correlations between principal components can be discerned (Table 5).

Table 4. Principal component structure and item loadings of the BMQ.

No. of Statement	Motivation	PC1	PC2	PC3	PC4	PC5
J29	PR	.94				
J30	PR	.93				
J28	EM	.86				
J15	EM	.75				
J2	PR	.68				
J20	PR	.65				
J22	PR	.60				
J27	IM	.54				
J19	IM	.46				
J24	IM	.45				



No. of Statement	Motivation	PC1	PC2	PC3	PC4	PC5
J14	IM	.43				
J5	RE	.43				
J4	AN		.72			
J13	EM		-.66			
J11	AN		.66	-.42		
J12	AN		.64			
J3	EM		-.60			
J7	EM		-.48			
J25	SE			-.83		
J26	SE			-.77		
J10	SE			-.69		
J21	SE			-.67		
J18	SE			-.62	.48	
J6	AN		.49	-.51		
J23	RE				-.57	
J8	RE				-.51	
J16	AN				-.47	
J1	IM	.43			-.44	
J9	RE					
J17	RE					.92
Variance		37.64	11.56	6.15	3.87	3.46
Eigenvalue		11.29	3.47	1.85	1.16	1.04
Alpha		.94	-.53	.80	.79	NA

Note: Cumulative variance 62.68 %.

Table 5. Component correlation matrix.

Component	1	2	3	4	5
1					
2	-.31				
3	-.33	.01			
4	-.37	.11	.26		
5	.26	.04	-.21	-.17	

Based on the findings from the initial analyses of principal components, we concluded on the basis of the sufficiently high value of Cronbach's alpha (.91), that the initial SMQ applied as BMQ could be suitable for assessment of motivation towards Biology if applied as an entire instrument or a particular extracted construct. However, the resulting constructs from the described analysis do not follow the theoretical reasoning of the authors of the SMQ (Glynn et al., 2007, 2009), showing a mixture of motivational types, so we continued the SEM analysis, as follows.

CFA of initial BMQ using SEM

The procedure was repeated using all thirty items in six proposed subscales (Glynn et al., 2009), building three models based on SEM statistics (Figures 2, 3, 4) following Pekrum et al. (2011).



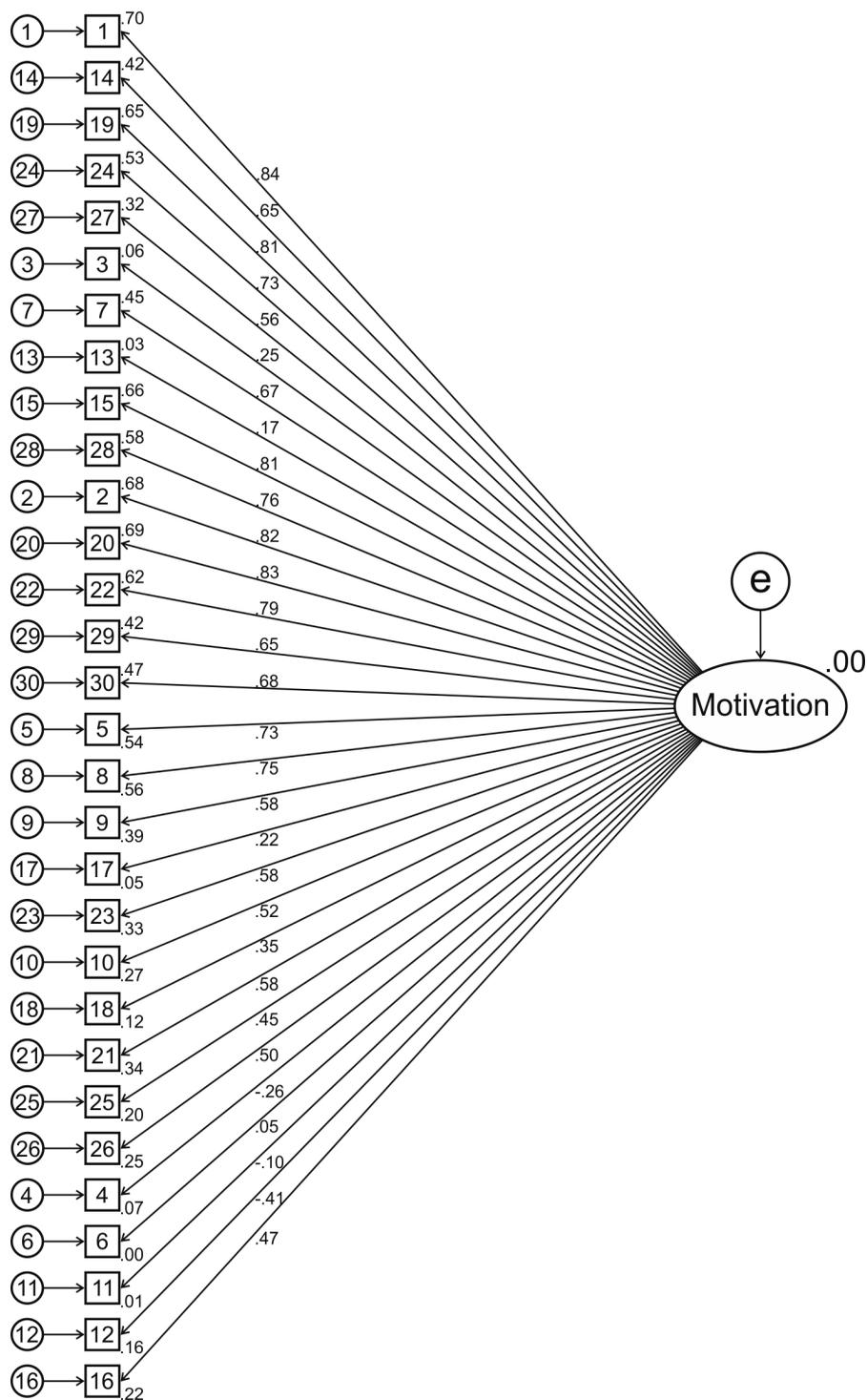


Figure 2. CFA diagram of Model 1.



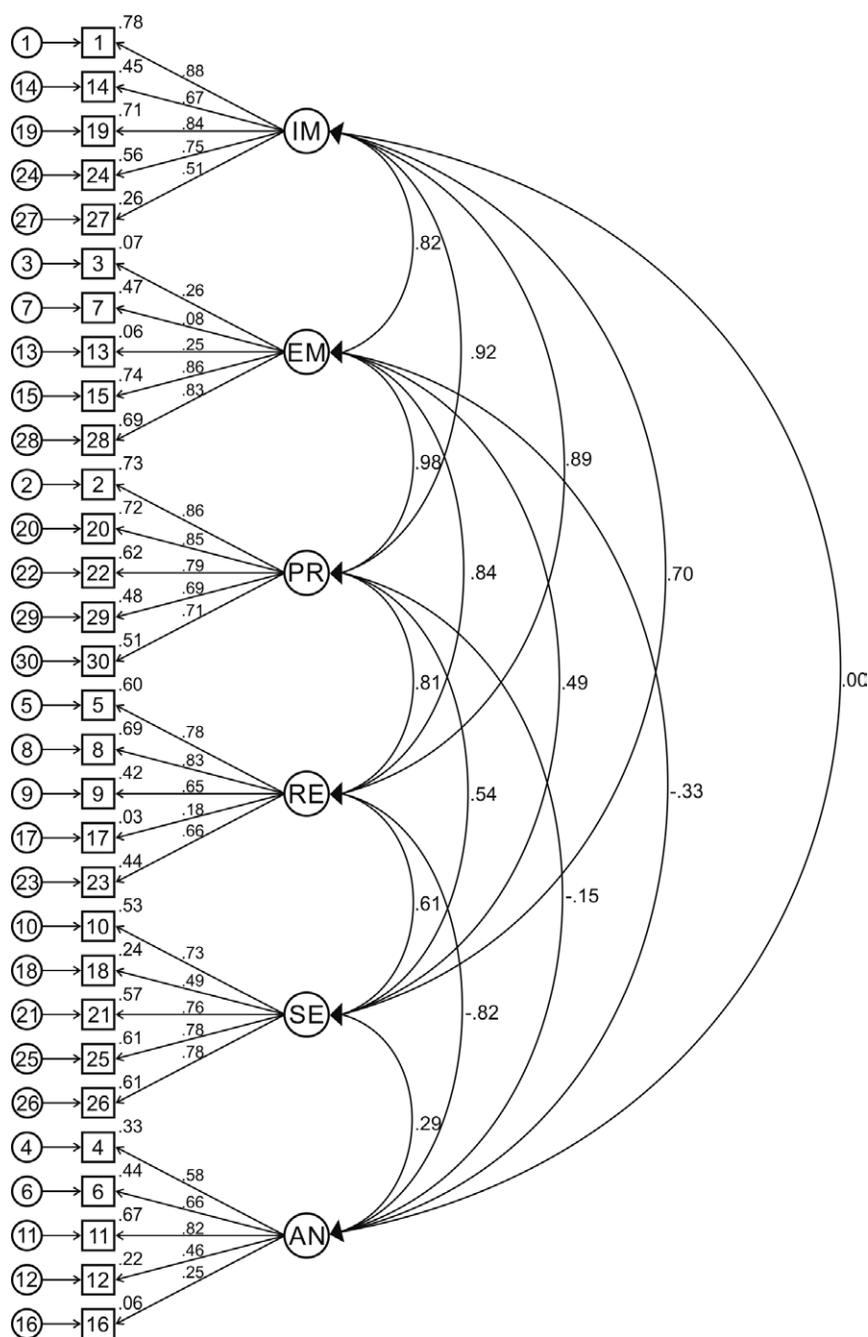


Figure 3. Initial model (M2) based on a modified SMQ (Glynn et al., 2009).

Note: (IM Internal Motivation, EM External Motivation, PR Personal Relevance, RE Responsibility, SE Self-efficacy and AN Anxiety)

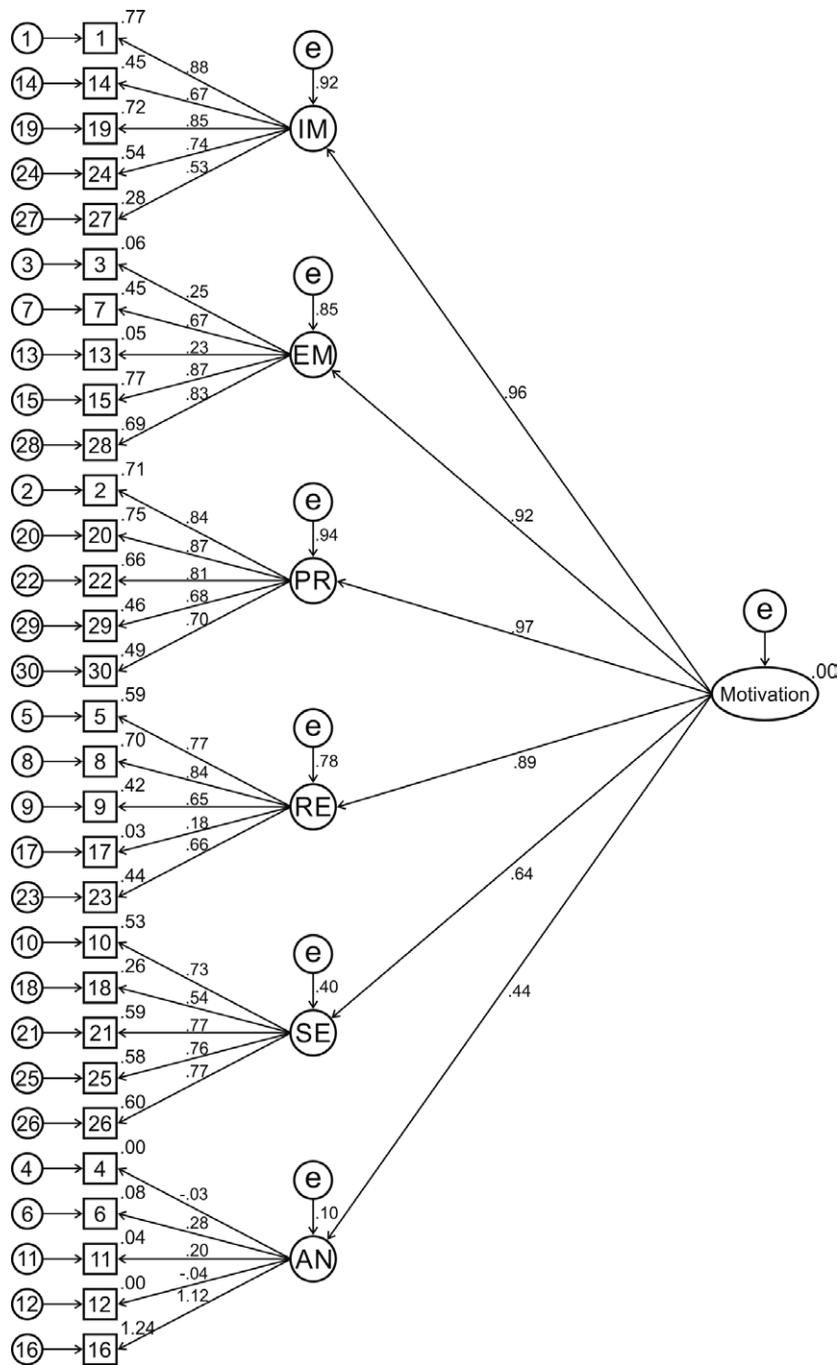


Figure 4. Model 3 assuming that theoretical constructs are predictors of a single second-order variable.

Note: (IM Internal Motivation, EM External Motivation, PR Personal Relevance, RE Responsibility, SE Self-efficacy and AN Anxiety)

The resulting models (M1-M3) do not fit well (Table 6) according to recommendations compiled from several sources (see Šumak & Šorgo, 2016).



Table 6. Model fit summary of the models (M1-M3) based on a modified SMQ (Glynn et al., 2009).

Fit index	Recommendation	M1	M2	M3
χ^2	Non-significant	3260.8	1995.7	2563.1
Degrees of freedom (<i>df</i>)	n/a	405	390	399
χ^2/df	< 3.00	8.05	5.02	6.4
Goodness-of-fit index (GFI)	> .90	.59	.78	.69
Adjusted Goodness-of-fit index (AGFI)	> .80	.53	.74	.65
Comparative fit index (CFI)	> .90	.69	.83	.76
Root mean square error of approximation (RMSEA)	< .08	.12	.09	.10
Normed fit index (NFI)	> .80	.66	.80	.73
Parsimony normed fit index (PNFI)	> .60	.61	.71	.67

Note: M1: One construct model; M2 = Initial model based on SMQ with six constructs (30 items); M3 = second order model

From inspection of the models (Figures 2 – 4), it was concluded that Model 2 (M2) showed the best Fit, so it was considered for the improvement. It can be recognized that correlations between the construct Anxiety (AN) and all other constructs, except Self-efficacy (SE) are negative or none in the case of internal motivation (IM). This finding can be attributed with considering Anxiety as Amotivation in a sense of Self Determination Theory. All other correlations in the model fall in the positive range. The highest value in the model (.98) is between External Motivation (EM) and Personal Relevance (PR), allowing us to conclude that both constructs form or are a part of a single factor. The same is probably true for other motivational constructs (IM, EM, PR, RE), other than SE, where all correlations are above the .8 level. Additionally, standardized factor loadings of some items on the proposed constructs are below suggested levels (Kline, 2015).

Building a Model

With the procedure 'Alpha if item deleted', eight variables were excluded from the initial pool, leaving us with 22 variables considered for further analysis (Table 7). The Cronbach's alpha for the reduced questionnaire was excellent at .95. KMO at .96 and Bartlett's Chi-square test = 7791.83; 231 *df*; $p < .001$ allowed further principal component analysis. Based on Eigenvalue >1, three components, explaining 63.7% of variance were extracted; however, by parallel analysis, only the first two components should be retained, explaining 58.5% of variance.

Table 7. Three-component Model 1.

Motivation	PC1	PC2	PC3
PR	.83		
PR	.82		
EM	.81		
PR	.76		
IM	.75		
PR	.70		
EM	.69		



Motivation	PC1	PC2	PC3
IM	.65		
PR	.64		
IM	.62		
IM	.57		
RE	.45		
SE		.80	
SE		.75	
SE		.67	
SE		.63	
AN		.50	
RE			.72
EM			.71
IM			.65
RE			.64
RE			.63
Variance	48.80	9.66	5.26
Eigenvalue	10.74	2.11	1.16
Alpha	.94	.82	.83

From the item loadings to the components (Table 7), we can conclude that only Self-efficacy (SE) forms a stable construct (PC2), and even the single remaining AN (J16) item 'I hate taking biology assessments' can be, by the opinions of the authors, considered as Self-efficacy, not as Anxiety, because it is more probable that it indicates anger rather than fear. Personal Relevance (PR) is the main constituent of the first component (five items) and is combined with four items of Internal Motivation (IM), two items of External Motivation (EM), and one item of Responsibility (RE). Responsibility (three items) is the leading idea of the third component, accompanied with one item each from the IM and EM pools.

After analysis of the factor loadings on the components, we made the decision to exclude from the questionnaire the last remaining Anxiety item, therefore theoretical construct Amotivation was excluded from the model. With this intervention, the Cronbach's alpha of the scale stayed the same at the .95 value. However, the explained variance of the matrix rose to a value of 65.04% when three components were considered and to 59.64% when two components were considered. All items included in the second analysis, with the excluded AN item, stayed in the same components; however, small differences in loadings do appear. These differences are too minor to be considered as important.

From the component correlation matrix (Table 8), it can be seen that the components are correlated, with the highest correlation between the first and the third component. These correlations allow us to speculate that motivation is in reality a complex mixture of theoretically predicted constructs, thus allowing further shortening of the instrument.



Table 8. Component correlation matrix.

Component	1	2
2	.36	
3	.58	.22

A Three-construct model

A three-construct model, based on three components identified by EFA (PCA) analysis of the initial BMQ, excluding Anxiety (AN), was used as a basis for further shortening of the BMQ. By use of modification indices and deletion of some items in the AMOS program, we retained 14 items to be included in a new model (Table 9, Figure 5). PCA analysis revealed a matrix structure (KMO = .940; Chi Square = 4836; $df = 91$; $p < .001$) suitable for proceeding with calculations. Cronbach's alpha of the shortened instrument was .93. Based on eigenvalue > 1, three components were extracted (for the correlations, see Table 10); however, only the first two components passed the stricter thresholds calculated by parallel analysis (Hayton, Allen, & Scarpello, 2004). Cronbach's alphas for all three components passed the .7 threshold value, and it was not possible to raise this by deletion of any item.

Table 9. Principal components structure and item loading of the shortened 14-item BMQ.

NNo. of Statement	Motivation	Statement	PC 1	PC 2	PC 3
JJ15	EM	I think about how learning biology can help my career.	.91		
JJ20	PR	Biology I learn is relevant to my life.	.87		
JJ2	PR	Biology I learn relates to my personal goals.	.87		
JJ22	PR	Biology I learn has practical value for me.	.84		
JJ28	EM	I think about how learning biology can help me get a good job.	.78		
JJ19	IM	I find learning biology interesting.	.59		
JJ1	IM	I enjoy learning biology.	.55		
JJ26	SE	I believe I can earn 'excellence' grades in the biology course.		.84	
JJ10	SE	I expect to do as well as or better than other students in biology course.		.81	
JJ21	SE	I believe I can master the knowledge and skills in the biology course.		.76	
JJ23	RE	I prepare well for the biology assessments			.89
JJ9	RE	I use strategies that ensure I learn biology well.			.73
JJ8	RE	I put enough effort into learning biology.			.72
JJ7	EM	Achieving a good biology grade is important to me.			.62
	Variance		54.13	9.74	7.21
	Eigenvalue		7.58	1.36	1.01
	Alpha		.93	.78	.82

The model was confirmed by PCA analysis (Table 9) with appropriate reliability coefficients, explaining 71.08% of variance. However, correlations between components are still high (Table 10), revealing the possibility of reducing the model even further; however, we did not take this step, owing to achievement of the stricter threshold level of



the set of fit indices. Three constructs can be recognized from this model. The first is a mixture of Personal Relevance, External and Internal Motivation. The construct does not follow distinctions between Internal Motivation and the various kinds of External Motivation. The second construct is Self-efficacy, and the third one Responsibility, both with low factor loadings (Figure 5).

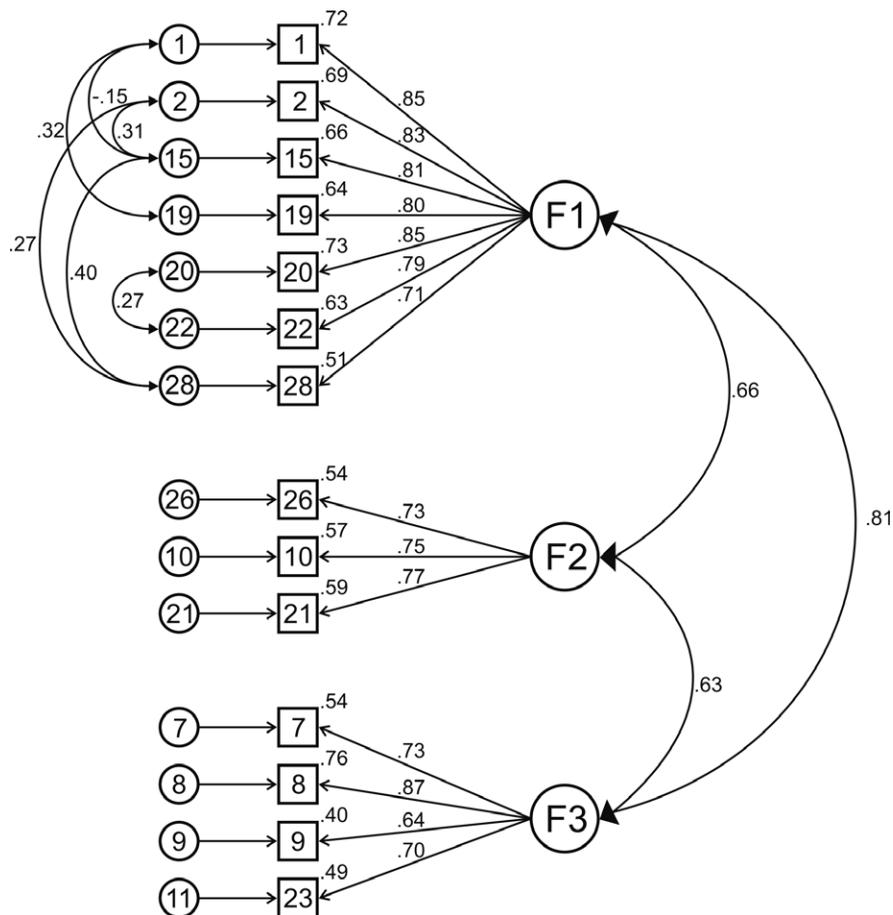


Figure 5. Three-component SEM model.

Table 10. Component Correlation Matrix.

Component	1	2
2	.45	
3	.61	.40

Discussion

The SMQ (Glynn et al., 2007, 2009) has been used for upper secondary school students (Zeyer, 2010) and adapted for measuring motivation to learn biology (Ekici, 2009, 2010). It was used to measure Czech upper secondary school students’ motivation for learning biology and also explored the construct itself, since Glynn et al. (2009) suggested that some items needed revision to improve the construct validity. The original SMQ (Glynn et al., 2007, 2009) was used, despite the existence of the revised SMQII (Glynn et al., 2011), which was used for university students.



Originally, the SMQ and the derived BMQ consisted of the following constructs: Internal Motivation, External Motivation, Personal Relevance, Responsibility, Self-efficacy and Anxiety (Glynn et al., 2007, 2009). The whole SMQ (BMQ) construct or individual constructs can be used as described (Ekici, 2009; Glynn et al., 2007, 2009; Zeyer, 2010); however, the connections between variables are far from the initial constructs. Our analysis showed that there should be fewer constructs included in the Czech version of the BMQ. Very high covariance between External Motivation and Personal Relevance, as well as among Internal Motivation, External Motivation, Personal Relevance and Responsibility revealed that these factors are in fact most probably parts of a single, underlying motivational construct. Therefore, it was concluded that only Self-efficacy could be considered a firmly based factor, as proposed by Bandura (1977), whose model combined personal accomplishment, vicarious experience, verbal persuasion and psychological states. Academic self-efficacy, student beliefs about their academic capability, have been shown to be an effective predictor of learning and also of motivation to learn, as it determines students' aspirations and therefore academic accomplishment. It was shown to be a predictor of science achievement (Britner & Pajares, 2001, 2006). Students with low self-efficacy approach difficulties almost as threats, whereas students with high self-efficacy approach difficulties as 'challenges to be mastered' (Bandura, 1993). Self-efficacious students also persist longer and work harder when they have to overcome difficulties, compared to students with lower self-efficacy (Bandura, 1997). Based on the results, Personal Relevance, Internal Motivation and External Motivation were combined into the second factor. Responsibility remained as the leading construct for the third and last proposed factor. Internal motivation emerged as only marginally important in our construct. Based on this research, it is suggested that anxiety should be excluded from the BMQ. Although it is an aspect of negative motivation (Bandura, 1986), which can be stronger for females than males in the case of science (Mallow, 1994), it correlated negatively with the remaining BMQ constructs. This is understandable when one considers that anxiety can be paralyzing. The negative correlation is predictable, since as one of the remaining constructs was Self-efficacy, which has been shown to correlate negatively with anxiety (Pajares & Kranzler, 1995a, 1995b). This research shows that anxiety should not be included, or not as it was in the original SMQ. It might be more appropriate to measure anxiety by itself, as suggested by (Cassady & Johnson, 2002) and not as a part of motivation.

A shortened instrument suitable for exploring upper secondary school students' motivation for studying biology based on the SMQ (Glynn et al., 2007, 2009) was introduced. Mavrikaki et al. (2015) also provided a valid questionnaire for measuring motivation to learn biology, although this is more than twice as long as the one described in this research. Since time can be one limitation on research conducted in schools, an adequate, but shorter version can be useful for both researchers and teachers.

Conclusions / and Implications

Based on analysis including the BMQ completed by 517 Czech upper secondary school students, a shorter version of the Czech BMQ was suggested: 14 questions instead of the original 30 in the SMQ. Such a questionnaire is suitable for measuring the motivation of upper secondary school students to learn biology. This reflects the constructs behind the BMQ, which showed that three factors should be retained: Self-efficacy itself, a factor combining Personal Relevance, Internal Motivation and External Motivation, and a third factor consisting mostly of Responsibility and containing one question included in the original External Motivation construct. Anxiety questions were excluded, based on the analysis. Hopefully, the construct described above will be useful when investigating motivation to learn biology.

Disclosure statement

No potential conflict of interest was reported by the authors. Neither the Agency nor its employees had any influence on the work in progress.

Primary anonymised data for secondary analyses is available on request from the authors in electronic form as an Excel file. In the case of data usage, it is expected that the publication source will be properly cited.



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