



DEVELOPING STUDENTS' SOFT SKILLS IN INQUIRY-BASED LOWER SECONDARY SCIENCE EDUCATION

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Abstract

Inquiry-based science education (IBSE) is a student learning management strategy focusing not only on the active construction of knowledge in the natural sciences. Through the used educational procedures, it also develops students' soft skills. The impact of IBSE on the development of soft skills was monitored in a group of 14- to 15-year-old students in Czech basic schools. The main aim of the study was to determine whether IBSE contributes to greater development of students' self-assessment of the achievement level of selected soft skills compared to the transmissive model of managing their learning activities. The study employed an educational experiment as its validation method. The experimental group (N = 232) received IBSE teaching over a five-month period, delivered by teachers who had received prior IBSE training and were regularly supervised by the research team. The control group (N = 207) was taught using the transmission model for the same duration. Soft skill self-assessment was conducted using an 80-questions questionnaire based on interval scales. For each skill, the level of self-assessment was calculated as the arithmetic average of respondents' ratings across 10 items. The collected data were analysed using descriptive and inferential statistical methods. The results show that students taught using IBSE reported significantly higher self-assessed levels in communication, teamwork, problem-solving, creativity, and the ability to learn new things compared to the control group. IBSE appears to be an effective educational model that not only supports science literacy but also fosters the development of key soft skills applicable in real-life and out-of-school contexts.

Keywords: soft skills, inquiry-based lower secondary science education (IBSE), science literacy, self-assessment, school environment

Introduction

Since the 1970s, the traditional approach to science education has been based on a scientific paradigm derived from the concept of developmental teaching. It focused primarily on the development of professional subject knowledge and so-called "hard skills."

This approach led to the training of experts with in-depth knowledge in specific disciplines. However, the current dynamics of society, the labor market, and the growing complexity of scientific knowledge require a fundamental paradigm shift. Soft skills, often neglected in the past, are now recognized as an integral part of the competencies of graduates at various levels of education – not only in science subjects – as they enable effective adaptation

to a rapidly changing environment. When studying natural sciences, students need both “hard” skills – cognitive and subject-specific skills – and “soft” skills – interpersonal and intrapersonal skills (Birzina et al., 2023). Lamanauskas (2022) pointed out the changing needs of society in relation to the outcomes of science education.

Soft skills represent a set of interpersonal, communication, and behavioral attributes that differ from specific scientific or technical competencies. They are often perceived as intangible, but their importance for success in various areas of life, including the professional sphere, is fundamental. Although there is no universally accepted definition, terms such as “transferable skills” (e.g., Chadha, 2006), “21st century skills” (Kennedy & Sundberg, 2020), or “personal skills” (Gammie et al., 2002) are often used interchangeably. Such terminological inconsistency can complicate the systematic integration and assessment of soft skills in education. This suggests a need for greater clarity in the definition and classification of soft skills within specific educational contexts.

In the context of science education, soft skills most often include critical thinking, teamwork, creativity and innovation, communication, problem-solving, curiosity, consistency, integrity, analytical skills, research skills, information literacy, and determination (Susilawati et al, 2020). Some researchers also mention time management and self-efficacy (Alfayez & Al-Omari, 2024). However, there is a high degree of variability in how soft skills are defined and categorised. Soft skills are best developed through experiential learning activities that provide real-world context and relevance. Active and experiential learning is not merely a supplement to traditional teaching methods; it is inherently more effective for developing soft skills because it allows students to develop science competencies more deeply and apply the knowledge they have acquired in practice (Santhalia & Yuliati, 2021). In science education, inquiry-based science education (IBSE) aligns most closely to this model.

Numerous research studies cited below indicate that IBSE has a positive impact on the development of a range of soft skills. These skills are intertwined in inquiry-based teaching and develop simultaneously. One of the key skills is critical thinking. Students learn to formulate questions, evaluate evidence, analyse information, and draw conclusions based on data. This strengthens their ability to objectively assess situations and make decisions based on logic and evidence. In their study, Arifin et al. (2025) pointed out the high impact of IBSE on the development of critical thinking skills (mean effect size of 1.27). At the same time, however, they state that the exact components that strengthen critical thinking skills are not sufficiently known. As a result, their findings show considerable heterogeneity. The researchers suggest investigating the impact of IBSE on the development of critical thinking with respect to the level of education, teaching strategies, the use of information and communication technologies, the duration of IBSE, and assessment methods. In a broader context, Hairida (2016) examined the impact of IBSE, where, in addition to critical thinking, she also mentions the positive impact of IBSE on the development of systematic and logical thinking. Sucilestari and Arizona (2020) pointed out that IBSE improves students' critical thinking in all aspects (interpretation, analysis, evaluation, deduction, and explanation) compared to non-inquiry learning models in the control class.

Another important aspect of soft skills is the development of communication skills, i.e., the ability to express ideas clearly and effectively, listen actively, and adapt verbal, written, and visual messages to different audiences. Xu et al. (2024) found how IBSE supports scientific creativity and emphasised the process of communication and reflection in research tasks. Students are encouraged to explain and evaluate concepts and discuss their findings, thereby significantly developing their communication skills. Ješková et al. (2022) discovered that the use of the IBSE method in schools for STEM (Science, Technology, Engineering, and Mathematics) subjects has led to a statistically significant improvement in students' ability to formulate questions, plan and conduct experiments, and communicate their results. The development of students'

argumentation skills, which are key to effective scientific communication, is also reported by Hakim et al. (2020). Students learn to formulate statements, justify them with evidence, and critically evaluate the arguments of others, which leads to an improvement in their ability to discuss scientific topics. In a broader context, the contribution of IBSE to the development of social skills – such as communication skills, interpersonal skills, decision-making skills, and verbal as well as nonverbal behaviors – is also mentioned by Kaur and Kaur (2024).

Since IBSE makes extensive use of group teaching, another soft skill that is developed is teamwork. Teamwork is implemented much more frequently than in traditional models of managing student learning activities, where frontal teaching is primarily used. Hairida et al. (2021) analysed the development of student collaboration in science subjects through inquiry-based and project-based learning in their study. The results show that students achieve a high level of collaboration skills, including contributing to discussions, working effectively in groups, and sharing responsibility. Gillies (2023) focused on the role of cooperative learning within IBSE and how it affects student engagement. He has emphasized that working in cooperative groups allows students to explore topics together, ask questions, and evaluate evidence, which strengthens their collaboration. Huang (2022) found that during inquiry-based laboratory work, students with less experience in teamwork are able to significantly improve their skills, narrowing the performance gap between less and more experienced students. Gillies (2023) confirmed in his meta-analytical study that well-structured group activities during IBSE significantly support the development of students' knowledge, communication skills, critical thinking, and emotional engagement. He emphasizes the role of the teacher in initiating and managing dialogue between students as well as meta-reflection during group discussions.

Creativity is also one of the most frequently discussed soft skills. The basic principles of IBSE – such as student activity, connecting information into meaningful contexts – developing critical thinking, promoting positive attitudes toward science, and fostering motivation – correspond to the basic components of creativity. Similarly, IBSE includes the basic processes that lead to creativity (Trnova, 2014). During IBSE, students are encouraged to ask their own questions about the world around them. These questions often do not have a single correct answer, which encourages students to think divergently or even in original ways. They learn to formulate hypotheses and propose their own ways of finding answers and seeking original solutions to problems. Kırıcı and Bakırcı (2021) demonstrated a statistically significant improvement in creativity – particularly originality, flexibility, and fluidity of thinking – in the IBSE-supported group compared to the control group in their quasi-experimental study. Thompson (2017) focused on teaching gifted students through IBSE and identified strategies such as brainstorming, divergent tasks, and an environment that supports free exploration, which naturally stimulates creativity in gifted students.

Among the soft skills that some researchers mention in connection with IBSE is self-efficacy. This is a significant predictor of students' academic performance and is therefore an important construct for measuring the achievement of educational goals. The results suggest a positive effect of IBSE on students' perception of self-efficacy (Sen & Sezen Vekli, 2016). A Spanish study shows that IBSE also enhances the self-efficacy of science teachers, especially in their ability to help students understand the nature of scientific inquiry and develop the procedural skills needed to carry it out (Toma et al., 2024). A strong positive correlation ($r = .903$, $p < .05$) between inquiry-based teaching and students' self-efficacy in chemistry has been reported by Nzomo et al. (2023). In their study, inquiry-based teaching took place only once a week. In addition to self-efficacy, IBSE also promotes students' self-confidence in their scientific skills, interaction with peers, science literacy competencies, and intrinsic motivation to learn science (Rau, 2022). Lamanaukas and Augienė (2018) emphasized the importance of applying scientific methods in primary science education, as this allows students to acquire and expand their scientific knowledge. According to the researchers, this activity is undoubtedly practical and requires creativity and appropriate motivation on the part of students.

Research Problem

Contemporary science and research, like many other areas of human activity, require not only deep technical knowledge (hard skills), but also a wide range of soft skills. IBSE is understood as a comprehensive strategy for managing students' learning activities, which provides an ideal environment for developing these skills because it simulates real scientific procedures.

Exploring the development of soft skills in inquiry-based science education enhances our understanding of how these skills form, how they can be purposefully developed, and how they contribute to students' overall success – both during their education and in their future lives. The study of soft skills development is a significant research issue in general, as these competencies are understood as key determinants of individual success in the current social and professional context. Research into their development is therefore necessary not only from a pedagogical and didactic point of view, but also from a psychological, sociological, and economic perspective. The importance of researching the formation of soft skills at various levels of education is highlighted, for example, by Chengere et al. (2025) and Orih et al. (2024). An important issue is how to effectively integrate soft skills into the existing school curriculum. Soft skills cannot be taught in isolation as a separate subject, but instead need to be developed across all subjects and everyday school activities. The problem is which strategies for student learning management are most effective for developing individual soft skills and how these strategies should be adapted to different age groups of students. Both inquiry-based and non-inquiry learning approaches based on the transmission instructional model (TIM) are currently used in science education (cf. Xie et al., 2018). It is therefore necessary to determine which of these educational models contributes more to the development of students' soft skills and whether this development is also perceived and reflected by them as actors in the educational process. The more effective model should then be systematically used in teaching. Solving the research problem will thus make it possible to identify effective educational strategies that lead to the development of soft skills, assess the degree to which they are acquired, and understand their impact on the development of students' personalities.

Research Aim and Research Questions

An analysis of theoretical principles raises the question of how soft skills are developed in science classes at ISCED2 level schools in the Czech Republic. The aim of the study was to clarify the suitability and usefulness of inquiry-based approaches in science education for the development of soft skills. The following research questions were formulated:

1. Which of the selected soft skills are developed during science lessons in terms of students' self-assessment of their achievement level?
2. What is the impact of IBSE on the development of self-assessment of selected soft skills achievement levels in students at the ISCED2 level of education?

Research Methodology

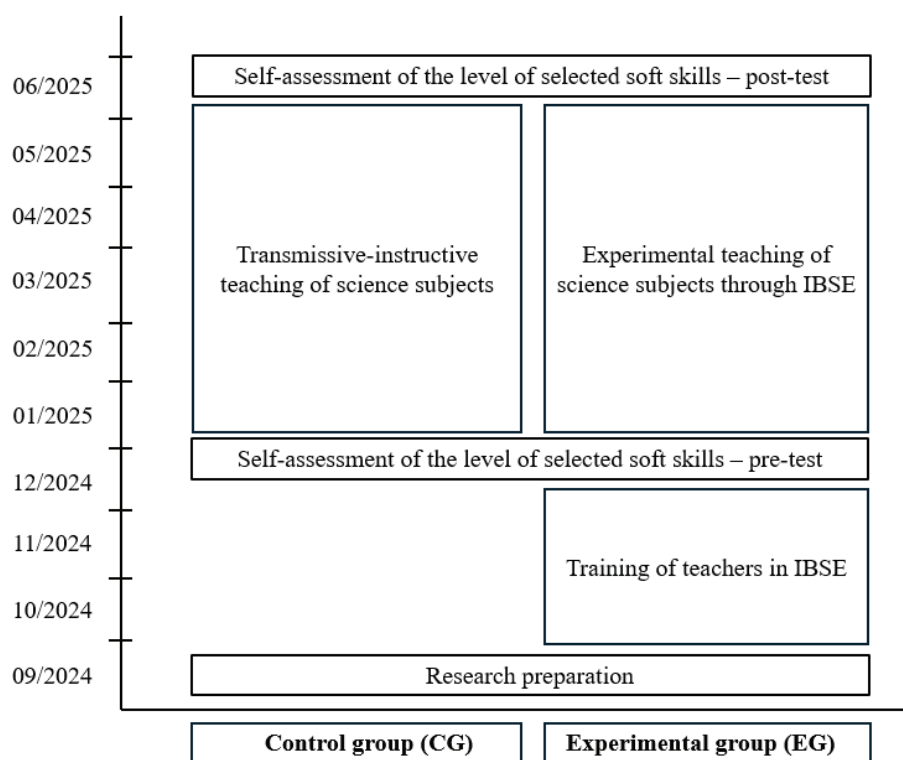
General Background

This research is based on a quantitative research design that uses a quasi-experiment and a subsequent questionnaire survey as its basic research instrument. Despite all its limitations, the use of quasi-experiments is common in analogous research studies (e.g., Chendere et al., 2025; Li, & Gu, 2023; Supriana et al., 2021). The research was conducted to obtain more information about the development of soft skills in 14- to 15-year-old students during science lessons.

Specifically, it focused on understanding how IBSE and the transmission instructional model contribute to the development of soft skills in science education and whether the inquiry or non-inquiry model of managing student learning activities is more effective in their development. As part of a quasi-experiment, an experimental group was formed in which science subjects were taught using IBSE, and a control group was formed in which teaching was carried out using the transmission instructional model. The research study included a preparatory phase lasting 3.5 months (September 2024 – December 2024) and an implementation phase lasting 5 months (January 2025 – June 2025).

The study focused on students' self-assessment of the level of selected soft skills achieved and on changes in this self-assessment due to strategies for managing students' learning activities, which were implemented during a quasi-experiment in science lessons in both groups under observation. For this purpose, a pre-test was conducted in both the control and experimental groups before the start of the five-month experimental period to assess students' self-assessment of their level of selected soft skills. After the five-month period, the same research tool was administered as a post-test. The timeline of the research study is shown in Figure 1.

Figure 1
The Course of the Research



This research is expected to serve as a basis for further research focused, for example, on the development of methods for the objective diagnosis of the achieved level of soft skills, or research reflecting the longitudinal and intercultural dimensions of soft skills development.

Hypotheses

Based on the research assumptions and analysis of information sources, the following factual hypotheses can be formulated:

1. The self-assessment of the level of selected soft skills achieved by students selected for teaching with the TIM application (control group) is consistent with the self-assessment of the level of selected soft skills achieved by students selected for teaching with the IBSE application (experimental group).
2. The self-assessment of the level of selected soft skills achieved by students taught using IBSE (experimental group) is more positive than the self-assessment of the level of selected soft skills achieved by students taught using TIM (control group).
3. The progress in self-assessment of the level of selected soft skills achieved by students taught using IBSE (experimental group) is greater than the progress in self-assessment of the level of selected soft skills achieved by students taught using TIM (control group).

Based on the factual hypotheses, general null hypotheses were formulated, which were then tested using inductive methods of statistical data analysis:

H01: The self-assessment of the achieved level of selected soft skills by students in the control group in the pre-test is statistically equivalent to the self-assessment of the achieved level of selected soft skills by students in the experimental group.

H02: The self-assessment of the achieved level of selected soft skills by students in the control group in the post-test is statistically equivalent to the self-assessment of the achieved level of selected soft skills by students in the experimental group.

H03: The progress in self-assessment of the achieved level of selected soft skills between the pre-test and post-test in students in the control group is equivalent to the progress in self-assessment of the achieved level of selected soft skills between the pre-test and post-test in students in the experimental group.

Sample

The research sample for this study was selected on the basis of purposive sampling, even though this method of selection reduces the generalizability of the results obtained.

A total of 12 school classes were included in the experimental group, whose science teachers had undergone training in the use of IBSE. The selection criterion was that all science subjects (physics, chemistry, natural history, and geography) in these classes were taught exclusively by trained teachers. A complementary sample of control classes, also numbering 12, was taken to complement the sample of experimental classes. These were classes from seven identical schools or schools of the same type (urban schools) attended by students from areas with a similar socioeconomic status. The aim of this selection was to eliminate as many intervening variables as possible that could undesirably influence the results of the research study. For this reason, the research sample was not randomized, as this would have seriously disrupted the organization of teaching at the schools concerned. Creating experimental and control classes by randomly selecting students would introduce a number of other intervening variables into the research (changes in the classroom climate, disruption of established communication patterns among students, disruption of teaching in other non-science subjects), which would reduce the validity of the results obtained. Only students who completed both the pre-test and post-test were included in the overall research sample. If students participated in the IBSE experimental teaching but did not complete either the pre-test or post-test, they were not included in the research sample, and their results were not included in the research data. The purified research sample thus consisted of $N = 232$ students from the experimental group

and $N = 207$ students from the control group. These were students in their final years of lower secondary education (ISCED2) aged 14–15. The difference in sample size between the control and experimental groups is due to a higher number of absences among the control group at the time of the pretest and posttest administration.

For practical reasons, it was not possible to carry out a purely random selection of the sample (it was determined by membership of selected school classes). It is therefore necessary to take into account the limited generalizability of the results obtained.

Instrument and Procedures

In the experimental group, science subjects were taught using IBSE for a period of five months. In the control group, science subjects were taught using TIM during the same period. In the experimental group, science subjects were taught by qualified teachers who had undergone special training in the use of IBSE for a period of three months. The training was conducted by subject-specific science educators from among the academic staff of teacher training faculties and by experienced teachers at the expert level (with at least five years of experience in teaching science subjects). The training consisted of 10 hours of theoretical preparation, 20 hours of practical seminars and workshops, and 20 hours of reflective classroom observations with teachers who use IBSE in their teaching. In the control group, teaching was carried out by qualified science teachers who had not undergone any specialised training in the use of IBSE.

An 80-item Self-Assessment Questionnaire of Own Abilities and Skills (available at <https://webshare.cz/#/file/Rmlf49M6VJ/dotaznik-sebehodnoceni-vlastnich-schopnosti-a-dovednosti-doc>) was used as a research tool. This research tool is used by school counsellors in elementary schools as part of professional and career counselling. The questionnaire is therefore primarily intended for the same age group of respondents who participated in this research study. The questionnaire contains 80 statements with which respondents express their level of agreement or disagreement on a 5-point Likert scale (yes – rather yes – I don't know – rather no – no). Ten items always cover one soft skill. The questionnaire thus assesses the self-evaluation of the level of achievement of a total of eight different soft skills. These are: communication, teamwork, problem-solving, independence, creativity, performance, responsibility, and the ability to learn new things. The calculation of the reliability of the entire research tool and the individual subscales representing the above-mentioned soft skills is shown in Tables 1 and 2 below.

Table 1
Research Tool Overall Reliability

Coefficient	Estimate	SE	95 % CI	
			Lower	Upper
Cronbach's α	.882	.006	.871	.893
Guttman's λ_2	.887	.006	.876	.898
McDonald's ω	.887	.008	.871	.903

The reliability coefficients found are generally considered good or acceptable for most research purposes. They are close to the threshold of an excellent level, which indicates a high internal consistency of the research tool (Adamson & Prion, 2013).

Table 2
Research Tool Subscale Reliability

Subscale	Item-rest correlation	Cronbach's α	Guttman's λ^2	McDonald's ω
Communication	.620	.872	.876	.876
Teamwork	.658	.867	.873	.874
Problem-solving	.624	.870	.876	.877
Independence	.561	.876	.881	.880
Creativity	.502	.892	.896	.896
Performance	.782	.853	.860	.858
Responsibility	.821	.850	.857	.852
Ability to learn new things	.743	.858	.863	.863

The reliability of the subscales representing individual soft skills also shows fully acceptable values. The item-rest correlation shows the lowest value for the creativity subscale. However, this is an integral part of soft skills. It is possible, however, that the respondents in the research study had some difficulty expressing their self-assessment of their abilities and skills in such abstract phenomena as creativity, imagination, and improvisation. It is precisely these phenomena that are discussed in the individual items of the research tool that make up the creativity subscale. A similar situation may arise in the independence subscale, where individual items assess, for example, the level of independence in decision-making, and students may not be able to adequately assess their skills.

One lesson (45 minutes) was allocated for completing the research tool (both in the pre-test and post-test). The authors of this paper administered the research tool. The students were given the following instructions: "The following questionnaire lists 80 different skills and abilities that help people not only at school but also later in their careers. We are not born with these skills and abilities; we do not come into the world with them automatically, but we learn them gradually in the course of our daily lives. Now, try to estimate which of your abilities and skills you can use in your future high school, but also in your future career. The skills and abilities are divided into eight different groups. Each group contains 10 often very diverse skills or abilities. Read each one and try to answer by circling one of the five numbers, the value of which expresses how well you have mastered a particular ability or skill." All students managed to complete the research tool before the time limit. It usually took students between 20 and 30 minutes to complete the questionnaire. During the study, efforts were made to eliminate the influence of various intervening variables as much as possible. Teaching in both the control and experimental groups took place in the same science subjects, on the same topics, with the same time allocation, and using the same textbooks and other supporting materials (atlases, aids, ICT, etc.). It always followed the school's educational program and the time and topic plan for the given subject. This was also a condition set by school administrators to allow the research to be conducted at their schools. The implementation of inquiry-based teaching was therefore not possible at the expense of reducing educational content. The use of experiments in science teaching was primarily guided by student safety. In the control group, experiments were mainly conducted by the teacher as demonstrations. In the experimental group, the aim was to involve students in conducting experiments as much as possible. However, the primary differences between the two groups lay in the strategies used to manage student learning activities. In the control group, teaching was primarily conducted in a frontal manner using teacher-led instruction. In the experimental group, teaching was conducted mainly in groups using inquiry-based approaches. The role of the teacher was also somewhat different. In the

control group, teachers acted more as mentors and used instructive strategies to manage student learning activities. In the experimental group, teachers acted as facilitators and made greater use of dialogic methods (e.g., discussion) in their teaching. In the control group classes, a traditional lesson structure was used: motivation, exposition, fixation, diagnosis, application. In the experimental group classes, the lesson structure was based on the 5E instructional model (engage, explore, explain, extend, evaluate). Table 3 provides a clear comparison of the teaching process in the control and experimental groups.

Table 3
Comparison of Basic Aspects of Teaching in the Control and Experimental Groups

Aspects of Teaching	Control Group	Experimental Group
Science subjects	Chemistry, physics, natural history, geography	Chemistry, physics, natural history, geography
Teaching topics	same in both groups, based on the school curriculum	
Time allocation	same in both groups, governed by the time-theme plan	
Textbooks	same in both groups	
Predominant paradigm	Behaviorism	Constructivism
Teachers	Without special training	Specially trained
Role of the teacher	Mentor	Facilitator
Teaching methods	Predominantly verbal monologue (explanation) and illustrative demonstration	Predominantly dialogical and practical
Organizational forms	mainly group (frontal) teaching	mainly group teaching
Experiments in teaching	mainly demonstration	mainly student-led
Assessment	mainly summative, by grade	mainly formative, verbal

Data Analysis

The data obtained were subjected both to descriptive and inductive methods of statistical analysis. Arithmetic means (*M*) and standard deviations (*SD*) were calculated for all 48 data sets. For the purpose of comparing the pre-test and post-test results between the experimental and control groups, the Fisher-Snedecor *F*-test was first performed to compare the variances of two independent data samples. Next, the appropriate type of Student's *t*-test was used depending on whether the variances were equal or unequal. Subsequently, effect sizes were calculated using Cohen's *d* in absolute value. Progress between the pre-test and post-test in both groups was calculated by pairing each student's self-assessment of their level of achievement of the soft skills being monitored and subtracting the pre-test results from the post-test results. The resulting difference represents progress. For some students, the self-assessment of the level of achievement of a particular soft skill was lower in the post-test than in the pre-test. In such cases, the progress was assigned a negative value. The calculated progress was then compared using the above-mentioned procedure. All comparative analyses were performed at a significance level of $\alpha = .05$ using Statgraphics Centurion XVI and JASP 0.19.3 statistical software.

The researchers are aware of the controversies that may arise from processing data obtained from Likert scales using parametric methods of statistical analysis. In many studies, there is disagreement about how these scales should be used and how the data obtained through them should be interpreted. Not only is the issue of scale range or item parity discussed, but also the characteristics and subsequent statistical evaluation of the data obtained. When

statistical analysis concerns variables created by combining at least four Likert-type scales into one variable (Likert scale data), many researchers recommend understanding this variable as interval rather than ordinal, as would follow from the nature of a single Likert-type scale (e.g., Allen & Seaman, 1997; Baggailey & Hull, 1983; Maurer & Pierce, 1998; Vickers, 1999). Boone and Boone (2012) stated that when processing data on an interval scale, it is necessary to use parametric methods of statistical data analysis. Since all the variables compared in this research study were created by aggregating ten Likert-type scales, the variables obtained in this way can be considered interval variables, and their subsequent comparison using parametric methods of statistical data analysis appears to be legitimate.

Research Results

First, a comparison was made between the self-assessment levels of achievement of individual soft skills monitored in the control and experimental groups during the pre-test. The results are shown in Table 4.

Table 4

Comparison of Pre-Test Score Differences Between the Experimental (EG) and Control (CG) Groups

Soft skills	CG		EG		<i>t</i>	<i>p</i>	Cohen's <i>d</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>			
Communication	3.86	0.43	3.80	0.35	1.583	.114	.154
Teamwork	4.08	0.57	4.01	0.44	1.531	.127	.138
Problem-solving	3.84	0.61	3.79	0.45	.824	.410	.094
Independence	3.96	0.55	3.98	0.53	-.448	.654	.037
Creativity	3.43	0.59	3.33	0.77	1.468	.143	.145
Performance	3.80	0.49	3.73	0.57	1.431	.153	.131
Responsibility	3.65	0.40	3.66	0.57	-.161	.872	.021
Ability to learn new things	3.78	0.44	3.70	0.50	1.753	.081	.169

The *p* shows that the self-assessments of the levels of achievement in all monitored soft skills do not show a statistically significant difference between the control and experimental groups. It is therefore possible to confirm the general null hypothesis (H01). Similarly, Cohen's *d* values show no effect (for a more detailed interpretation of Cohen's *d* values, see Cohen, 1988). It can be stated that the initial self-assessment of the levels of soft skills achieved is the same in both groups, which allows for a valid assessment of any changes in the eight variables representing individual soft skills due to the influence of IBSE in the experimental group.

After the systematic application of IBSE in the experimental group for a period of five months, a post-test was administered in both groups using the same research tool. The results of the post-test are shown in Table 5.

Table 5
Comparison of Post-Test Score Differences Between the Experimental (EG) and Control (CG) Groups

Soft skills	CG		EG		<i>t</i>	<i>p</i>	Cohen's <i>d</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>			
Communication	3.81	0.67	4.05	0.32	-4.789	< .001	.469
Teamwork	4.14	0.66	4.32	0.46	-3.349	< .001	.320
Problem-solving	3.88	0.65	4.18	0.51	-5.215	< .001	.512
Independence	4.21	0.62	4.29	0.53	-1.548	.122	.139
Creativity	3.52	0.74	3.83	0.73	-4.384	< .001	.422
Performance	3.94	0.59	3.99	0.45	-.961	.337	.096
Responsibility	4.05	0.55	4.12	0.51	-1.385	.167	.132
Ability to learn new things	3.73	0.68	4.04	0.55	-5.229	< .001	.504

The *p* shows that in the case of soft skills such as communication, teamwork, problem-solving, creativity, and the ability to learn new things, the self-assessment of their achievement reached higher values among students in the experimental group than among students in the control group. In the case of self-assessment of the level of achievement of these soft skills, the difference is statistically significant ($p < .001$). As for Cohen's *d* values for the above five soft skills, they range from a small effect to an intermediate effect. However, the interpretation of effect size values is not clear-cut; for example, Hattie (2009) referred to real educational contexts and therefore used a more lenient classification than Cohen. According to Hattie (2009), all effect size values in the case of a statistically significant difference in self-assessment of the level of achievement of the above-mentioned soft skills between students in the experimental and control groups fall within the zone of desired effects. In the case of communication, teamwork, problem-solving, creativity, and the ability to learn new things, the null hypothesis was not confirmed, and the alternative hypothesis was accepted. For these soft skills, the substantive hypothesis that IBSE contributes to an increase in the self-assessment of their achievement level applies. In an educational context, this effect is the desired outcome. In the case of independence, performance, and responsibility, the null hypothesis was confirmed. The difference in self-assessment of the level of their achievement between the experimental and control groups is not statistically significant. IBSE thus had no effect on the self-assessment of the level of achievement of these soft skills.

In order to eliminate statistically insignificant but non-zero differences in the pre-test results, progress was calculated for each respondent, i.e., the difference between the pre-test and post-test scores in the self-assessment of the level of achievement of all individual soft skills monitored. The results of the comparison in progress are shown in Table 6.

Table 6

Comparison of Pre-Test and Post-Test Score Differences (Progress) in the Control (CG) and Experimental (EG) Groups

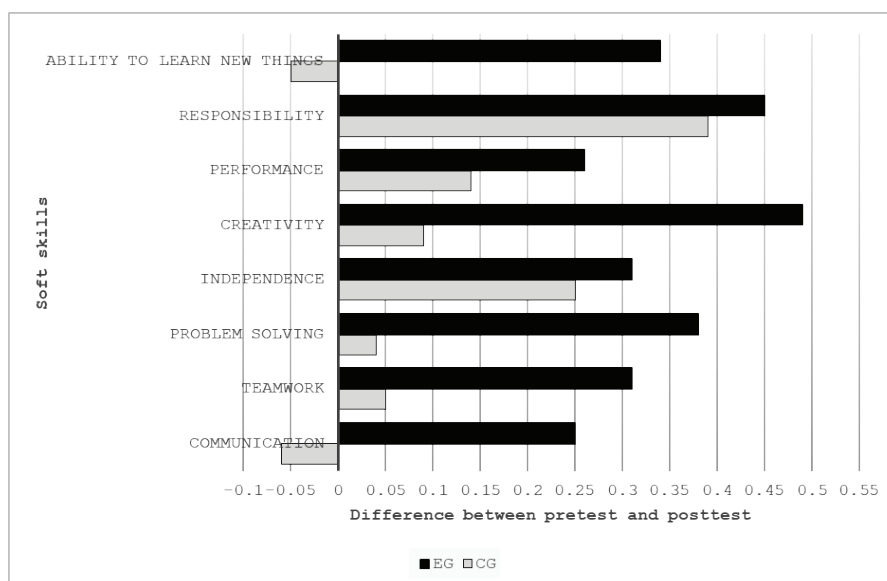
Soft skills	CG		EG		<i>t</i>	<i>p</i>	Cohen's <i>d</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>			
Communication	-.06	0.80	.25	0.47	-4.770	< .001	.479
Teamwork	.05	0.94	.31	0.63	-3.376	< .001	.329
Problem-solving	.04	0.91	.38	0.70	-4.349	< .001	.422
Independence	.25	0.87	.31	0.76	-.813	.417	.074
Creativity	.09	0.92	.49	1.06	-4.224	< .001	.401
Performance	.14	0.76	.26	0.72	-1.723	.084	.162
Responsibility	.39	0.66	.45	0.76	-.917	.359	.085
Ability to learn new things	-.05	0.81	.34	0.76	-5.221	< .001	.497

The analysis of individual students' progress provides more accurate and objective results than a simple comparison of post-test scores. However, the conclusions are the same in this case. The *p*-values show that in the case of soft skills such as communication, teamwork, problem-solving, creativity, and the ability to learn new things, the self-assessment of progress achieved higher values in the experimental group than in the control group. The null hypothesis is rejected, and the alternative hypothesis is accepted. In the case of independence, performance, and responsibility, the null hypothesis was confirmed. The difference in self-assessment progress in achieving these skills between students in the experimental and control groups is not statistically significant. The effect size values are also analogous to those in the comparison of post-test scores and lead to the same conclusions.

A clearer comparison of the progress values for students in the control and experimental groups is shown in Figure 2.

Figure 2

Pre-Test and Post-Test Score Differences in the Control (CG) and Experimental (EG) Groups



The graph clearly shows that the highest progress in self-assessment is achieved in creativity in the experimental group. This creativity is the soft skill most developed as a result of IBSE. In the experimental group, all soft skills show positive self-assessment progress. This is not the case for students in the control group. For communication and the ability to learn new things, self-assessment progress is even negative. Although these results are not statistically significant (communication: $t = 1.016$; $p = .311$; ability to learn new things: $t = .898$; $p = .369$), they suggest that the transmission instructional model of teaching does not primarily focus on developing these key soft skills. Very low and statistically insignificant progress is also observed in the control group for teamwork ($t = -.875$; $p = .382$) and problem-solving ($t = -.678$; $p = .499$). These are skills specifically developed during IBSE, as they are among the basic strategies for managing student learning activities, as evidenced by significant progress in the experimental group (teamwork: $t = -7.460$; $p < .001$; problem-solving: $t = -8.506$; $p < .001$).

Discussion

The statistically significant improvement in self-assessment of the level of communication, teamwork, problem-solving, creativity, and the ability to learn new things achieved by students in the experimental group was primarily the result of the learning activities that students performed during IBSE. The aim in managing the learning activities of students during IBSE in the experimental group was to follow a sequence of specific steps as consistently as possible. The exposition part of the lesson began with a presentation of a specific problem based, for example, on a particular natural phenomenon, chemical or physical experiment, specific behavior of animals or plants, meteorological or climatic phenomena, etc. This was followed by observation and individual analysis of the observations. Since inquiry-based teaching usually took place in groups, this was followed by comparisons between group members and mutual discussion. These activities led to the development of communication skills and teamwork. Elements of cooperative teaching were also intensively applied. Brecl et al. (2024) also highlighted the necessity of these competencies in science education. Discussions among group members should lead to a synthesis of knowledge in order to find ways to solve problems. These discussions are merely facilitated by the teacher, with the aim of guiding students towards independent problem-solving. At this stage, elements of problem-based teaching were applied, which improves students' problem-solving skills. Sukontawaree et al. (2022) analysed the impact of inquiry-based and cooperative learning on students' problem-solving skills. The results of their study also show that the integration of both strategies was beneficial for improving the problem-solving skills of most students. The study participants also expressed satisfaction with these educational practices. If the problems presented to students in class are well prepared and didactically processed by the teacher (e.g., with regard to the age of the students and their level of formal operations), they lead to the development of divergent thinking in students. Creativity is applied in the search for original solutions, thus leading to the development of this skill. However, some research evidence has shown that short-term intervention in the form of inquiry-based teaching is not sufficient to develop creativity. Conradty and Bogner (2019) conducted a four-hour inquiry-based lesson in their research, dealing with scientific phenomena related to bird flight. The intervention resulted in long-term knowledge and built a stable level of intrinsic motivation in students, but the aspects of creativity reported by the students themselves were not affected by this intervention. The researchers themselves point out that the development of creativity probably required systematic and continuous training in the use of inquiry-based approaches in STEM teaching. In our research study, five months of inquiry-based teaching led to the greatest progress in the self-assessment of the achievement level of this skill (creativity). The following step in managing the learning activities in the experimental group was generalization, i.e., creating a construct outlining the solution to the

presented problem. This phase involved discussions between individual groups of students and discussions with the teacher, further developing communication skills and the ability to learn new things. Baharin et al. (2018) emphasized the importance of this ability in STEM subjects, noting the crucial role of the teacher in fostering higher-order thinking skills. Mailool et al. (2020) also pointed out the importance of practicing soft skills in teacher training students. The construct was then applied in a sequence of steps during learning activities, ideally used in practical life, to explain other phenomena, in thought experiments, or to generate other problems. If the proposed construct proves effective, it is verified and becomes an integral part of the students' internal knowledge system.

The entire process of student learning activities described in IBSE creates a comprehensive platform for the development of the above-mentioned soft skills. Their formation is interlinked; it is not possible to talk about the isolated development of just one soft skill. This interconnection was also evidenced by the values of Pearson's correlation coefficients found in the experimental group of this research study, e.g., between communication and teamwork ($r = .572$; $p < .001$), creativity and problem-solving ($r = .642$; $p < .001$), creativity and ability to learn new things ($r = .584$; $p < .001$), ability to learn new things and teamwork ($r = .565$; $p < .001$). Communication in particular proved to be the most universal skill. It showed a statistically significant correlation at the $p < .001$ level with all other soft skills examined. As already mentioned, the development of communication skills is also related to the presentation of students' work and results and their ability to communicate their findings and argue in their favour. This was confirmed by the results of a study by Muspiroh et al. (2024), which demonstrated a significant improvement in students' scientific argumentation skills in STEM teaching based on problem-based learning.

However, this research study also identified soft skills for which there was no statistically significant difference in self-assessment of achievement levels between the control and experimental groups. These skills included responsibility, performance, and independence. For all three soft skills, there was a statistically significant increase in the self-assessment of their level of achievement between the pre-test and post-test in both the control and experimental groups. The results of this study, therefore, show that these skills were developed in both transmission instructional and inquiry-based teaching. An emphasis on performance and responsibility is one of the fundamental characteristics of TIEM. Schwerdt and Wuppermann (2011) provided evidence that monological teaching methods, which require a high level of responsibility and performance from students, also yield significantly better results. In the conclusions of their study, the researchers summarized that students taught by teachers who devote more teaching time to lecture-style presentations rather than letting students solve problems on their own or with the teacher's guidance, learned more (in terms of competencies tested in the TIMSS student achievement test). However, their research study focused primarily on "hard skills" and neglected the fact that very important soft skills (such as communication, teamwork, and the ability to learn new things) are rarely developed in the traditional teaching model. However, other researchers (e.g., Quereshi et al., 2023) confirmed the positive influence of cooperative learning and interaction with peers and teachers on students' academic performance. The result concerning independence may be surprising. Students are expected to have an independent attitude toward the task and to be responsible for completing it on time. Of course, this attitude is not only practiced in schools but also cultivated in everyday life. Independence is very important in learning contexts, as is the case with natural science learning. However, the expectation of a statistically significant higher progress in self-assessment of the level of independence achieved in the experimental group taught by IBSE was not confirmed. Similar results were obtained in a study of science education in Philippine schools (De Guzman, 2020). The results of this study showed fairly balanced findings, with 34.9% of students showing only a moderate level of independence and 25.5% showing a low level. In contrast, 25.5% of

students showed a high level of independence, and 9.4% showed a very high level. A possible explanation for the results of our research is that during IBSE, group teaching, cooperative learning, and dialogic teaching methods were used to a much greater extent. Students may have perceived these activities more as teamwork and, in their self-assessment of their level of independence, may have not realized that these activities could also lead to the development of independent and autonomous thinking. Another reason why IBSE does not contribute to significantly better development of responsibility and independence may be that even during inquiry-based teaching, the teacher continued to play a relatively strong role. Teachers still tended to control the teaching process so that the same educational content would have been delivered and the same teaching objectives met as in the transmissive method of teaching. This could have suppressed students' independence, as they were in fact performing structured tasks, even if they took the form of research. If students do not have the opportunity to take real responsibility (e.g., deciding on how to proceed with their work), their independence does not develop significantly. In terms of developing subjective perceptions of performance, students' objective results in tests or assignments sometimes did not improve, because inquiry-based teaching promotes deep understanding, collaboration, and creativity more than the quick and accurate completion of standardized tasks. This phenomenon has been highlighted, for example, in a study by Gómez and Suárez (2020). The results of this and many other studies show that competent teachers are a key factor in the successful development of soft skills in teaching (not only in science subjects). Their task is to create an inspiring environment that encourages students' curiosity, stimulates them to ask questions, and to experiment with new ideas. They should also encourage students to collaborate, solve problems, discuss, and present arguments. By asking open-ended questions and assigning tasks that require deeper reflection, they help develop divergent and critical thinking skills, as well as effective problem-solving activities. They can also support students' creativity by allowing them to explore different approaches to solving tasks, experiment, and not be afraid of mistakes, but rather to work with them as a tool for learning. Further research should therefore focus on teachers' ability to develop soft skills in their students and on examining the processes that enable this ability.

Limitations

The presented results should be viewed in light of the limitations of the research, which arise from the quantitatively oriented research design, the quasi-experimental arrangement, and the nature of the research tool used. Limiting is a relatively small number of respondents, resulting from the considerable organizational complexity of the quasi-experiment. Only those classes in which all science subjects were taught by specially trained teachers could be included in the experimental group. Since the 50-hour special training was completely voluntary for teachers, only a limited number participated. This, in turn, limited the number of experimental classes and, subsequently, the number of control classes, which were selected to maintain parity between the two groups. The number of respondents was also negatively affected by the fact that only those participants who had completed the pre-test, teaching intervention, and post-test were included in the research study. The students in the experimental group were aware that science subjects were being taught using a different teaching method compared to the one to which they were accustomed. This could have led to a novelty effect or the Hawthorne effect. In some cases, the experimental and control groups were drawn from the same school, so the students in both groups could communicate with each other and thus become aware that some of them were participating in experimental teaching. Given the length of the research study (5 months), the overall results could have been influenced by a number of intervening variables that could not be effectively eliminated. These include, for example, the influence of the teacher's personality, the influence of teaching in other (non-science) subjects, that continued

to be conducted in a transmission instructional manner even in the experimental group, the curricular specifics of individual schools, and material and technical equipment. Intervening variables may have also included the students' previous experience, e.g., with group or project-based teaching, which may have influenced the level of soft skills achieved.

The limitations of the research study also include the nature and capabilities of the research tool used. This tool was used to assess the self-evaluation of the level of individual soft skills achievement. Thus, it was not the actual level of a given skill that the student achieved (in some cases, this would be very difficult to measure adequately), but the student's perception of the extent to which they mastered a given skill. In such a case, we could not rule out the influence of social desirability, where the student would respond as they thought was expected of them. Thus, they may have overestimated their level of soft skill mastery. The study was purely experimental and limited in time and its results are not automatically transferable to contexts where inquiry-based teaching is implemented systematically across all subjects (i.e., not only in science subjects) over extended periods (e.g., throughout the entire four-year ISCED2 period), or with teachers who have extensive experience using this strategy. The research was conducted exclusively in the Czech Republic, where the targeted development of soft skills in science education is still in its early stages. Research-oriented teaching occurs only sporadically, unsystematically, and its frequency decreases significantly from ISCED1 to ISCED3. There is still insufficient experience with the targeted and deliberate development of soft skills in the Czech Republic, and there is limited evidence regarding the impact of specific strategies for managing student learning activities on soft skill development.

Conclusions and Implications

Despite these limitations, the results of the research demonstrate a significant impact of IBSE on the development of students' self-assessment of certain key soft skills, including communication, teamwork, problem-solving, creativity, and the ability to learn new things. The experimental group showed a significant positive shift in how students perceive their level of achievement in these competencies compared to the control group. IBSE, therefore, appears to be an effective strategy for managing students' learning activities to foster the development of essential soft skills. More reliable results could be obtained through direct, objective measurement of students' actual soft skills, rather than relying on self-assessment. The problem, however, is that suitable diagnostic tools are lacking. In addition to its results, the study also provides other benefits. It has been proven that the systematic development of students' soft skills using IBSE can be integrated into the existing science education curriculum without the need to reduce educational content or increase the time allocated to teaching science subjects. The study examined the development of the entire complex of soft skills (not just one isolated skill) necessary for students' future studies and professional careers. The results are also beneficial in that they show which soft skills need to be focused on and point to the need to find ways and methods to develop these soft skills. The benefit of the research study can also be seen in the fact that students themselves perceive and evaluate the development of their own soft skills. This can increase their self-efficacy, metacognitive abilities, and self-teaching skills. The inclusion of self-assessment gives students the opportunity to reflect on their own learning, strengths, and weaknesses and develops their metacognitive abilities. The results suggest that some aspects of inquiry-based teaching can also be implemented in the transmission instructional model of teaching to contribute to greater soft skills development. These include, for example, group teaching, a higher degree of cooperation between students, and the inclusion of problem-based teaching elements in lessons.

The results of this study lead to several key recommendations. In terms of curricular changes, a greater use of inquiry-based education, which enables the development of the

required soft skills, necessitates more profound changes in school education. Above all, the systematic integration of inquiry-based education into the existing curriculum at all levels of education is necessary. The development of soft skills cannot be limited to certain school subjects. In this context, the integration of educational content into interdisciplinary school subjects or school projects appears to be appropriate. In the area of student learning management strategies, teachers often fail to adapt to the individual characteristics of the learning process and its dynamics, relying heavily on conformity and routine learning. To develop soft skills in an authentic context, it is advisable to support strategies that use active and experiential learning, which can be implemented through inquiry-based education, problem-based learning, or project-based learning. However, in order to effectively apply these strategies in the educational process and explicitly focus on the development of soft skills, teachers must be guided during their undergraduate training and later in lifelong learning. They should be able to effectively guide, evaluate, and support their students in the comprehensive development of their personalities, including the development of soft skills. In the area of developing relevant assessment methods and specific diagnostic tools, it is necessary to develop explicit and valid methods for assessing the level of soft skills that are not based solely on subjective (self-) assessment by students, teachers, or researchers. This may include quantitatively focused psychometric inventories as well as mixed or qualitative research methods such as in-depth interviews, structured observations, analysis of student activity products, and action research. Valid and verified research tools for the objective assessment of soft skills are still largely absent.

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Declaration of Interest

The authors declare no competing interest.

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