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Teachers' Key Competences for Ensuring Inquiry-based Education

Jirí DOSTÁL[1]

Abstract

Inquiry-based education has long been used to teach science-based and technical subjects. However, problems often arise during the process of implementing this educational concept into school practice. One cause of this problem may be a lack of development of substantial competences: educational theory does not yet provide a generally valid competence framework, except in a few limited studies. This problem causes difficulties during teachers' initial and life-long education and is the primary motivation for our research. Based on our results, we created a competence model for identifying the key competences for realizing inquiry-based education may be concluded. In the first phase, published research conclusions connected to the competences of teachers of science-based and technical subjects—accentuating inquiry-based education—were analysed. Accordingly, we conducted research that helped both to establish the importance of individual competences and (subsequently) to create the competence model. The Q-methodology was used for the purpose of obtaining data, and statistical methods (e.g., Cronbach's alpha, split half, chi squared and Spearman's correlation coefficient) were used for the purpose of evaluating that data. The research took place in the Olomouc region of the Czech Republic, with 54 expert teachers (from basic schools) participating.

Keywords: *Teacher's competences, inquiry-based education, constructivism, science education, Q-methodology.*

1. Introduction

Globally, the educational process has experienced many changes. One important momentum factor of those changes is the individual's needs

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in relation to integrating into society, living in society, and developing a perspective on society. In a society's historical development, requirements, needs and social values change. Therefore, it is possible to encounter different educational focuses during different historical eras, emphasizing, e.g., physical development, artistic development, the acquisition of a vast amount of knowledge, the development of manual skills, perception, thinking, and the possibility of applying acquired knowledge to everyday life. Current social needs emphasize educating individuals to have creative minds that are able not only to discover problems but also to solve them effectively. These individuals should be cooperative, active, competitive, tolerant and protective of the weak.

There are methods available to determine how different people's requirements and ideas about the "ideal" individual are achieved. To choose appropriate educational content, one can use modern didactic technology, organizing forms, teaching methods and suggestive educational environments. A positive climate is also created, along with new ways to train teachers, etc. If we focus these segments in a manner that corresponds to current social needs—i.e., to contribute to satisfying those needs in the field of individual education—we arrive at a definition of inquiry-based education (see, e.g., [26]). The need to apply non-traditional approaches is also caused by modern children's differences from previous generations. The information media influence children's lives more than ever; therefore, today's children can independently acquire a larger amount of knowledge without the help of a teacher. Following changes in families' child-rearing styles, children are more critical, and their acceptance of transferred knowledge is not comparable with that of previous generations, which were significantly influenced by teachers' authority. In addition, modern children's interests have changed, diverging from technology and science, as evidenced in their career choices (see Ministry of Youth, Sport and Education of the Czech Republic [10].

These facts place new emphasis on the development of educational theory, primarily focusing on the teacher, who is a designer of the educational process and significantly influences its concrete form. Teachers' quality and competences become crucial to the final concept of educational process, their results and the fulfilment of social needs connected to them. A teacher's professional or expert knowledge set provides a base for deeper understanding and competent solving of practical problems in real educational situations. This issue has long been the focus of professionals at the international level (cf. e.g., [6], [18]).

2. Problem Statement

For teachers, the realization of inquiry-based education (IBE) is quite difficult even in the project stage. IBE requires appropriate competences, as evidenced by Fazio, Melville & Bartley [13], Rikmanis, Logins & Namsone [27], and documented in Science Education in Europe: National Practices, Policies and Research [28], Inquiry and the National Science Education Standards: a guide for teaching and learning [21], or Evolution of Student Interest in Science and Technology Studies, Policy Report [22].

The remarkable discovery was made by Fazio, Melville, Bartley and Jones [13]. They found that teachers' ability to practise IBE depends both on their own experience with it and on their ability to think about the possibilities of transferring the inquiry activities into their lectures. Therefore, the authors pose the following question: What kind of experience with inquiry activities do education students (i.e., pre-service teachers) gain, and do they obtain sufficient experience in IBE for its application in their future teaching practice? Duncan, Pilitsis and Piegaro [9] report a demand for high-quality teacher preparation. This request seeks to facilitate future teachers' competences that are necessary both for critical thinking and for the creation and modification of teaching materials to be more inquiry-based.

The teachers themselves take a positive approach to the realization of IBE, as can be concluded from, e.g., the TALIS 2013 investigation [29, p. 397]. The teachers' conviction about the need for IBE is more than positive; however, there is a conflict between that conviction and pupils' results on the PISA tests, which are (more or less) average. This was confirmed by research (e.g., Gonzalez Thompson [15]) indicating that teachers' conviction might not always correspond with the teaching approaches that they apply. Teachers' influences may vary with respect to, i.e., their above-noted lack of competences.

During IBE, the role of the teacher is changing—he or she becomes a warrantor of the method, not the warrantor of the truth (cf. Tomková, [30]). The teacher becomes a facilitator of pupils' learning, helping pupils find effective approaches to learning, i.e., via the use of scale of activating educational methods, which primarily activate the pupil's thought processes, and the cooperative strategies of the instruction. In the educational process, the teacher's primary tasks are to create and assign "good" problems (thus stimulating research) and to create group activities that moderate and facilitate the process of knowledge construction [31: p. 48]. As Prawat [25] stated, during IBE a teacher must avoid playing the role of either a dispenser of knowledge or a mere facilitator.

3. Aims of the research

From the above findings, there has emerged a requirement to focus research on teachers' competences connected to the realization of inquiry-based education. Analysing relevant research conclusions, a gap can be found. It is desirable both to fill that gap and to connect it with contemporary theoretical knowledge. Educational theory remains unable to adequately reflect a requirement connected to the formulation of teachers' competences to provide the realization of IBE in technical and science-based subjects at basic schools. Therefore, we formulate the primary question of this work as follows: Which competences should be possessed by a teacher of technical or science-based subjects in connection to the realization of IBE?

In this research, we follow up on the results of sub-research whose aim was to define (via suitable approaches) the competences of teachers of technical and science-related subjects for the realization of IBE at the basic schools. The results of this sub-research are available in Dostál [7].

The aim of the research presented in this article was both to discover attributes of the proposed set of competences and to specify which competences of teachers of technical and science-based subjects are important for the realization of IBE at basic schools. It was also essential to determine which of the investigated individual teachers' preconditions are considered substantial components of the set of competences that are important for the realization of IBE. The goal is also to present created the competence model based on the obtained results.

4. Research Methods

It was desirable to perform the research of attributes of the theoretical proposal of a competence model during the second sub-research via methods that do not work with a large sample of respondents. Nevertheless, these methods enable us to see the research object from different perspectives. This requirement was fully met by the Q-methodology [24: p. 138-143]. The Q-methodology consists of a combination of rating, psychometric and statistical procedures that serve to determine not only respondents' statements (Q-shorters) but also the correlation of different respondents' reactions (or answers) related to the submitted Q-types [3].

To satisfy our research needs, Q-types were prepared in physical form, sort sheets and a questionnaire. A traditional (i.e., non-electronic)

method of sorting was used, and it was this context in which the materials for the investigation were prepared.

All of the defined Q-types were labelled according to number for purposes related to their possible statistical processing. Because of the possible negative effect of their conveyance (even accidental) to respondents together with the Q-types (by influencing respondents' decisions related to card sorting), these numbers were placed on the back side and they were not visible.

The form of this criterion was created together with five teachers, who were also participating in the investigation. Emphasis was placed on understandability for teachers in educational practice, who formed the research sample. During the conversation (in a form of expert panel), we arrived at the final formulation of the criterion. The form (sort sheet) consisted of 11 fields in which it was possible to place an allowed number of cards (Q-types): 4, 6, 10, 13, 17, 20, 17, 13, 10, 6, 4.

The anonymous questionnaire was a part of every sort sheet; the purpose of the questionnaire was to obtain the necessary data from the respondents (i.e., their age, sex, length of practice, workplace (school, etc.)) so that statistical tests could be performed. One part of the questionnaire always provided a space in which the respondents could communicate their existing experience, make comments and express their opinions on the area of research; in addition, they could indicate whether they understood all of the submitted statements.

The questionnaire was distributed to basic schools in the Olomouc region. Specifically, it covered 156 basic schools (from first to ninth grade – levels ISCED 1 and 2). It was sent to the heads of schools. Eighty-five completed questionnaires (out of 156 sent) were returned. However, only 54 expert teachers agreed to cooperate further (in research using Q-methodology) via a subsequent contact (either by phone or e-mail).

The overview of the structure of the research sample is observable from the following table:

Table 1. Structure of the research sample

Gender of respondents	Frequency	Relative frequency (percentage)
Female	30	55.6
Male	24	44.4
Total respondents	54	100

Before presentation of the gathered results, the degree of reliability and accuracy—i.e., the reliability of the measurement instrument used—was

assessed. To prove the reliability of the measurement, we used Cronbach's alpha, which assesses inner consistency. To confirm this calculation, the Split-half method was used.

Table 2. Reliability of the questionnaire

Validation method	Calculated reliability
Cronbach's alpha	0,97
Split-half	0,95

The results of an analysis of the reliability stated in Table 2 provided sufficiently high reliability. In both cases, the value is considerably higher than the minimal required threshold of 0.70 (in the case of Kline's rule) or 0.94 (in the case of Helmstader's rule), which evidences a very high reliability of the measured results.

5. Findings

When applying the results of the performed research and further testing (see Dostál [8]), a competence model can be created of a teacher in the context of IBE in technical and science-based subjects. By applying suitable research procedures, it is possible to determine the set of competences and discover their attributes, not only of the competences themselves but also of the whole set. The attributes found facilitate the beginning of additional steps.

The created competence model is divided into three areas: key competences, basic competences and threshold competences. The most substantial area is that of the key competences that form the competence core. Without those competences, the individual could neither manage IBE nor achieve the required effects. In addition to those key competences, there are basic competences, which are also important for IBE. However, basic competences are relatively non-specific and are transferrable from the common framework of teacher's competences. Threshold competences are universal and lie at the border of teaching competence. If a teacher does not have these competences, it is a sign of a wider lack of competency.

Based on the results, it is possible with a high level of probability to determine which competences are important for a teacher. However, we cannot adequately assess the location of the borders between the areas of key, basic and threshold competences. This was why we re-contacted 12 randomly selected teachers to participate in the research. They were asked

for an interview that would result in the division of the set of competences into key, basic and threshold competences. Five days before the interview, the teachers were given a file that also contained the evaluation results, with a request both to assess the results of the research and to express dis/agreement with those results. The teachers were also asked to assess which competences would be marked as key, basic and threshold competences and to write their conclusions on the sheets.

Although there were minor variations, the achieved results enable us to divide the model into three areas. After recoding the competences into text form and engaging in additional graphical processing, we arrive at the three-level competence model, which is presented below.

5.1. Area of key competences

The experts' opinions aimed to include the ten most important competences (according to their assessment) into the category of key competences. One can notice that these competences are specific to the field of IBE. Although their application in similar situations is possible, it is not expected.

Table 3. Key IBE competences for a teacher of technical and science-based subjects

KEY IBE COMPETENCES
To motivate pupils to learn via inquiry activities.
To connect inquiry activities with everyday life.
To demonstrate inquiry activities to pupils.
To interpret the process and results of inquiry activities.
To guarantee safety during the realization of inquiry activities.
To develop pupils' individual discovery of knowledge via inquiry activities.
To develop pupils' thinking via inquiry activities.
To realize inquiry activities following pupils' existing knowledge and ideas.
To develop imagination via pupils' inquiry activities.
To connect inquiry activities to theory.

5.2. Area of basic competences

Based on experts' opinions, the next 16 competences can be seen as the basic ones. Again, although these competences are closely related to

IBE, they have a larger potential for transferability into acceptance-based instruction.

Table 4. Basic IBE competences for a teacher of technical and science-based subjects

BASIC IBE COMPETENCES
To use inquiry activities to fix subject matter.
To improve instruction by reflecting the preparation and realization of inquiry activities.
To develop pupils' interest during inquiry activities.
To verify the functionality of inquiry activities prior to instruction.
To use inquiry activities to expose pupils to new subject matter.
To assess the suitability of incorporating inquiry activities into instruction.
To create and maintain a positive learning climate during inquiry activities.
To develop pupils' perception via inquiry activities.
To develop pupils' skill to present the results of inquiry activities.
To manage the learning process during the realization of inquiry activities.
To plan inquiry activities with regard to the possibility of their realization and the means commonly available to pupils.
To plan inquiry activities with regard to their optimal incorporation into instruction.
To justify pupils' realization of inquiry activities.
To educationally influence pupils via inquiry activities.
To develop didactic and subject (and field) knowledge, skills and attitudes connected to the realization of inquiry activities.
To realize inquiry activities on a scientific basis.

5.3. Area of threshold competences

The third area of a competence model contains 14 threshold competences. If a teacher does not have these competences, he or she cannot be considered competent. Although such a teacher can still obtain very good educational results, we can expect him or her to fail at IBE.

Table 5. Threshold IBE competences for a teacher of technical and science-based subjects

THRESHOLD IBE COMPETENCES
To develop cooperation and social relationships among pupils during inquiry activities.
To adjust inquiry activities to individual pupils (individualisation).
To integrate interdisciplinary findings and apply interdisciplinary relations via inquiry activities.
To shape pupils' career orientation via inquiry activities (career choice).
To use inquiry activities for diagnosing (checking) the acquired subject matter.
To consider the various styles of pupils' learning during the realization of inquiry activities.
To obtain the physical means necessary for the realization of inquiry activities.
To coin terms via inquiry activities.
To plan inquiry activities in accordance with regulations and orders.
To plan inquiry activities with regard to the possibility of their continuation outside the instruction environment (e.g., at home).
To obey ethical norms during the realization of inquiry activities.
To plan inquiry activities in accordance with curricular documents delimiting educational content (Framework Educational Programme).
To share findings about inquiry activities with other teachers.
To create curricular documents in connection with the realization of inquiry activities (School Educational Programme).

6. Discussions

First, we incorporate our results (linked to the teachers' approaches to realizing IBE in teaching their subjects) into the context of the selected empirical investigations.

Kirschner, Sweller and Clark [17] note that it is important for teachers to have certain competences. They state that if teachers are convinced that IBE is more contributive than transmissive, they need the competences to manage the inquiry process. Without these competences, there is both a lack of high-quality management and a lack of feedback in the inquiry process, which simultaneously is becoming less effective. Colburn

(cf. [4: p. 42]) reaches a similar conclusion, drawing attention to the fact that one of the reasons teachers do not realize IBE is that they do not feel sufficiently trained and do not have the appropriate competences. From those works' conclusions, we can infer that it is inadequate to affect the quality of instruction from the outside, e.g., via curricular documents, a change of conviction, or a development of competences. Instead, it is also necessary to include a teacher's conviction, which is reflected in his or her (also very substantial) attitudinal level. This fact was also noted by Eick and Stewart [11] and Forbes and Davis [14], who state that attitudinal level plays a significant role not only in the design of an educational process but also in its final form. Similar findings emerged from the research presented in this paper.

It can be legitimately stated that previous studies confirmed the need for teacher competency as a crucial factor influencing the quality and form of IBE. However, the question remained of which competences a teacher should have. Many researchers—e.g., Alake-Tuenter, Biemans, Tobi et al. [1]—strived to discover the answer to this question, analysing the elements discussed in the contemporary literature. Those authors uncovered a considerable conflict in that there is no unified opinion about the form of the essential competences. This issue has also been evidenced by Kim and Tan [16], who state that experts have a shared opinion about the lack of unambiguous agreement related to the competences required of teachers engaged in IBE. The implication of this conflict is the absence of a verified competence model for IBE.

The authors mentioned above—Alake-Tuenter, Biemans, Tobi et al. [1]—identified 23 sub-competences (recalling the issue of the ambiguity of opinions about teachers' competences for realizing IBE), which they later differentiated into three groups: subject-related knowledge (linked to the educational content), pedagogical knowledge, and attitudes. Although the author of this paper followed up on the findings published by those authors, he reached different, but partially overlapping results (e.g., knowledge of the content, pupils' motivation, etc.)

Performing the "return to theory" in connection with the created competence model of a teacher of technical and science-based subjects, it is noticeable that based on the theoretical analyses, only three of ten proposed competences belong among the most important ones. The proposal of all of the other (from the ten stated most important) competences is based on practice. Nevertheless, the three stated competences were reflected by practice. It appears to be an imaginary moat (barrier) between the educational theory and practice is manifesting itself; however, the discovery

of this moat contributes to the creation of additional works which can help increase their connection (cf. [20: p. 260]).

It is also important to consider the connection (or coherence) of the created competence model to existing ideas reflected in European Commission documents. Both our analysis of foreign governing documents and the results of various research investigations (i.e., Paaso & Korento [23]) permit the conclusion that previous (partial) efforts to create a competence model have not been fully compatible with conditions in the European Union. This author strove to address this issue by considering the existing framework (cf. [12]).

Based on both the achieved results and the findings from abroad (e.g., Australian Institute for Teaching and School Leadership [2]; Commission on Teacher Credentialing [5]), we conclude that IBE and its realization should be reflected not only in the curricular documents but also in the documents that standardize a teacher's activity.

7. Conclusions

By resolving the delimited problems, we contribute to enriching both the theory of education and the discipline of didactics (which can be seen as a theory of teaching). The general findings are also applicable in individual subject and field didactics, where they can reflect the level of instruction planning, aims (both methodical and organizational) and material provision of the instruction. They can also be used as either "prepared" findings or a base for continuing research investigations. The findings geared towards technical and science-based education are applicable within the didactics of these subjects and therefore can positively contribute to their development.

The results (especially those results related to teachers' competences) may be applied to the teacher-oriented pedagogical subject (pedeutology). Although our opinion is that the pedagogical theory lies within the field of competences at a high level of quality, the aspects that overlap the level of didactics are only slightly worked up. This imperfection was partially overcome by our focus on teachers of technical and science-based subjects. However, it would be appropriate to continue this work in the context of different subjects.

The most important contribution is the proposal, construction and verification of the competence model of a teacher of technical and science-based subjects in relation to the execution of IBE. The result of this research activity contributes to multiple levels of not only theory development but also educational practice. The first contribution relates to the level of teacher

training provided during undergraduate study; however, it is also a component of teachers' lifelong education. In accordance with trends in the technical and science-based education, it is possible to purposefully develop future teachers' competences, as currently required by educational practice. The second contribution relates to the educational process at basic schools, in which the competence model may become a part of the evaluation process to identify areas for teacher development and to improve education as a whole, positively influencing pupils.

In connection with problem solving, there emerged numerous facts deserving of attention, along with other questions that have a potential to develop both educational theory and practice. Below, we note some of the more serious issues.

First, there are didactic situations in which pupils engage in inquiry. It can be concluded from this observation that these situations are specific, they have inner principles and they have an order, all of which are subject to outside influences. We consider didactic situations a crucial factor influencing the success rate of a pupil's development; however, they remain unexplored, especially with respect to approaches to their induction, their dynamism, effective management procedures, etc.

The second option involves focusing on modern educational technologies, which involves the increasing incorporation of inquiry activities into instruction. It would be appropriate to mention that IBE is not bound to the environment in which it is performed. This environment might be a common school classroom or a specialized school laboratory. Recently, electronic educational environments, in some cases including elements of virtual reality, have been used more frequently. Therefore, electronic support for instruction is not inconsistent with IBE and presents no conflict. It would be beneficial to use electronic means to support pupils' inquiry activities, i.e., activities that encourage pupils to think actively, pose questions and seek answers, and work with the subject matter on their own (even work of a manipulative nature, when the situation requires that kind of work to develop competences). Electronic-based learning is often lacking on the emotional side. Much hope has been inspired by remote laboratories (remotely controlled laboratories) and virtual laboratories.

The third option is to transfer the findings into the didactics of different subjects (i.e., not technical and science-based subjects) and to conduct further research to modify the proposed and constructed competence model. The form of instruction is different in other subjects, as are teachers' competences related to induction; the management and assessment of pupils' inquiry activities may differ. At the next level, the

research may continue not at the level of different subjects, but during non-formal education, which is also important for each individual's development.

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