Delphi study on the term ‘students’ conceptions’

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Abstract. The concept of students’ conceptions is central in science education and research. However, a concise and accurate definition of the German term ‘Schülervorstellungen’ (engl. students’ conceptions) is still absent. Therefore, a Delphi study, inviting more than 200 professors and postdoctoral researchers in the field of German-speaking physics education research (PER), was conducted. Main purpose was to find opinions about the necessity for a general definition and if possible, definitions used implicitly in the scientific community of PER. First results indicate a need for a concise definition, especially for its use in physics teacher education. Based on our results, a broader discussion among other subject educational research communities dealing with this term is necessary.

1. Introduction

For more than 30 years, the concept of students’ conceptions has been an important part of science education research. In physics teacher education the curricula often cover the concept of students’ conceptions already in introductory physics didactics courses. Additionally, following the model of educational reconstruction [1], students’ conceptions play a main role in designing learning arrangements. Therefore, students’ conceptions are central in physics education and research.

However, a precise definition or at least a characterization of the term and its essence is still missing, particularly but not exclusively in the German-speaking literature. This poses a problem as the term students’ conceptions is abstract and theory loaded. It may be difficult, especially for novices, to grasp its essence, without any definition behind. For recipients of research literature, it is difficult to draw concrete conclusions if its meaning, and theoretical ties are not explicitly mentioned. Both may result in misunderstandings and hinder progress, either in the context of teacher professionalization or in the context of research. In general, the purpose of a definition is to avoid the “risk of misunderstanding” and to contribute “an obvious gain in clarity and precision.” [2].

In the German-speaking literature, Wodzinski [3, 4] further developed the first attempts to define the term students’ conceptions by Schecker [5] and Niedderer and Schecker [6]. In Wodzinski’s definition, “...this [refers] in general to students’ understanding before they receive formal instruction [...]” (transl. [3]), the terms pre-conceptions (German ‘Präkonzepte’) and students’ conceptions are used synonymously and both have a temporal dimension to a cognitive status prior to formal instruction. Additionally, the term misconception that categorises a student’s conception as per se wrong is used. Within the German-speaking community, Wodzinski’s understanding of students’ conceptions as e.g. a cognitive status before formal instruction has not been explicitly discussed or adopted although it is implicitly used to describe a cognitive status even after formal instruction. Possible explanations for this fact could be either the missing attempts to define the term on a normative level or the fact that still no
studies have been published to empirically grasp the construct of students’ conceptions and its characteristics [7].

This holds true if we look to other disciplines like chemistry education [8], biology [9] or science education for primary schools [10, 11]. Research on students’ conceptions can be found for every discipline and are an integral part of teacher education in those disciplines [12].

Having a closer look on the term students’ conceptions we find different notations with similar meaning in the English literature. From student ideas and naïve ideas to pre-instructional ideas a lot of variations are used. Similar to the German-speaking literature, these terms are not explicitly defined and are often used synonymous (e.g. [13-15]).

Concerning physics teacher education, the concept of students’ conceptions is a basic concept taught in physics didactics courses in Germany and Austria. It is also a key knowledge in physics teacher training in the US [16]. First evidence shows that teacher students may develop an insufficient understanding of students’ conceptions during their education [17, 18]. Therefore, a concise definition of the term students’ conceptions for physics teacher education seems helpful.

To close this research gap a Delphi study was conducted. The initial assumption for our Delphi study was based on empirical hints found in physics teacher education that showed physics teacher students’ hold insufficient and misleading ideas about the term students’ conceptions [17, 18]. However, we additionally identified the issue to gain broader knowledge on the ideas of the term students’ conceptions which physics teacher students hold during their studies. Therefore, prior to the Delphi study we conducted an explorative study researching physics teacher students’ ideas about the term students’ conceptions. On the one hand, to consolidate and collect more empirical hints to enhance knowledge concerning the ideas of the term students’ conceptions held by physics teacher students. On the other hand, to clarify the importance to define the term students’ conceptions for physics teacher education.

Within the next sections, the methods and the results of an explorative study as well as the Delphi study will be described.

2 Research Design & Methods

The main purpose of the presented Delphi study is to clarify (1) whether a concise definition of the term ‘Schülervorstellungen’ (engl. students’ conceptions) has been established implicitly in the German-speaking PER community and if not (2) whether the community explicates the general need to formulate such a concise definition for physics education research as well as for teacher education. In addition, the Delphi method helps to (3) get an overview of all the different specifications experts have in mind, when they speak about students’ conceptions. Generally, the purpose of a Delphi study is to find a broad consensus in judgement of an expert panel, in our case the idea is (4) to arrive at some kind of common description of the construct students’ conceptions. However, we are aware that the specification of elements charactering the construct students’ conceptions may differ a lot from expert to expert and it may be unlikely to find consensus on the different specifications of the elements that determine the term. However, we think that we can extract at least essential categories that are necessary to describe students’ conceptions (in research and in teacher education). An overall aim of our work is (5) to produce awareness among physics education researchers and university lecturers of physics didactics, that it is necessary to reflect and discuss the term in their work. Because it is not self-explanatory and needs to be defined and described. Although there is a broad discussion about the nature of students’ conceptions [19, 20], at this stage, we do not intend to operationalize the construct students’ conceptions. We rather focus on a general descriptive level.

As the Delphi study is based on the assumption that physics teacher students’ have difficulties to grasp the term students’ conceptions or misinterpret it in a way that does not go along with any usage in literature, we had to empirically check whether this assumption holds up to reality. So, an explorative study on physics teacher students’ co-constructions about the term students’ conceptions was conducted. This exploratory study aimed to collect data to analyze physics teacher students’ ideas of students’ conceptions. With this explorative study we intended to identify the degree of the need to define the
term for teacher education. The timeline for the explorative study and the Delphi study can be seen in Figure 1.

The explorative study of physics teacher students’ ideas about the term students’ conceptions comprises an open questionnaire that was administered at two Austrian universities. During a seminar, the students completed a 20-minute questionnaire with a total of six questions about students’ conceptions. The focus of these questions was, on the one hand, on the elementarisation of the term students’ conceptions (what?) and its assignment to certain target groups (who?). On the other hand, the importance of the topic of students’ conceptions for their future teaching activities and teaching was investigated. The second part of the questionnaire aimed to find out whether students can name documented domain specific students’ conceptions and how they paraphrase them in their own words. For this article we focus on the first three questions of the questionnaire.

1. How would you explain the term students’ conceptions to your fellow students?
2. Who (which persons) has students’ conceptions?
3. Who (which persons) do not have students’ conceptions?

The other questions asked for typical students’ conceptions on Newtonian mechanics. The results of the explorative study (see 3.1) underlined the need for a clarification of the term students’ conception for physics teacher education. So, from the teacher education point of view it’s necessary to clarify the term. Consequently, as a next step a Delphi study was conducted within the German-speaking community, inviting over 200 professors and postdoctoral researchers in the field of physics education research to take part.

The classical design of the Delphi study according to the literature [21] consists of three phases. In the first phase a set of open-ended questions was distributed in an online survey. There were four main topics in the survey. The first topic was the definition for the term students’ conceptions, which the participants use in their research and their teaching. The second topic was centered around the question of distinction and specification: How do similar terms differ from the term students’ conceptions? How are differences between certain terms e.g. misconception and preconception described? The third topic focused on the question of teaching the topic of students’ conceptions to teacher students of physics. And the last topic was interested in which ideas teacher students have about this term and how they think the idea of students’ conceptions can affect teaching in schools.

The answers of the first phase of the Delphi study were qualitatively coded separately by two members of the research team and discursively brought into agreement. In this process we were looking for similar answers which were grouped together. The results of the first phase are presented below (see 3.2). They served as basis for the second phase. There, the categorized answers of the experts were reformulated, and the resulting statements were returned to all the experts. The experts were asked if they can approve the statements or if they disagree with them. This second phase of data collection has just been finished. The qualitative and quantitative analysis of the experts’ answers will provide the basis for the third phase of the study. In that phase the aim is to reach consensus in the community or to extract consensual elements defining the construct students’ conceptions. The distribution of the questionnaire of the third phase is planned for the beginning of 2020.

In this article we focus on presenting results and implications of the explorative study and the first phase of the Delphi study.

![Figure 1. Overview of the timeline of the project.](image-url)
3 Findings
In this chapter we firstly present the results of the explorative study on physics teacher students’ ideas on the term students’ conceptions. Then the results of the first phase of the Delphi study with physics education researchers on the term students’ conceptions are described. Finally, a glimpse into preliminary results of the second phase of the Delphi study is given.

3.1. Exploratory study of teacher students’ ideas about the term students’ conceptions
Ahead of presenting the results the sample will be described in more detail.

3.1.1. Description of the sample.
Physics teacher students of two Austrian universities filled in the questionnaire. All students (n = 110, 4th - 6th semester) had already had instruction about the topic of students’ conceptions in their introductory physics didactics courses. The sample was not randomized so the results we conclude are not generalizable. An overview of the whole sample is shown in Table 1.

Table 1. A detailed description of the sample of the exploratory study.

|                | 4th Semester | 6th Semester | Overall |
|----------------|--------------|--------------|---------|
| Vienna         | 37           | 29           | 66      |
| Graz           | 16           | 28           | 44      |
| Total          | 53           | 57           | 110     |

3.1.2 Results.
As mentioned above, in this paper we report the results of the first three questions of the questionnaire.

1. How do you explain the term students’ conceptions to your fellow students?
2. Who (which persons) has students’ conceptions?
3. Who (which persons) does not have students’ conceptions?

We wanted to extract the physics teacher students’ ideas about students’ conceptions. The analysis of the answers to the first question showed that teacher students explain the term students’ conceptions by the characteristics and the group of people who are typically affected by students’ conceptions. Further, teacher students mention the origin of students’ conceptions as well as a few ways how to deal with students’ conceptions in physics classes (see Figure 2 – Diagram 1). In detail teacher students characterize students’ conceptions as:

- Misconceptions, which can be corrected. (see Figure 2, category 3)
- Mainly held by students. (see Figure 2, category 2)
- Changeable into correct conceptions. (Figure 2, category 3)

Results of the exploratory study show that teacher students mainly describe students’ conceptions as false ideas. Additionally, we found hints, that teacher students may think that students’ conceptions can be fully eliminated by instruction. Furthermore, most teacher students connect students’ conceptions just with students as target group.

Additionally, most of the teacher students answered question 2 with “everybody” and question 3 with “no one”. There are two surprises hidden in these answers. First, the answer “everybody” is contradicting to the result of the first question. The teacher students answered in question 1 that students’ conceptions are held by students. This contradiction is not explainable for us. The second surprise is that not all teacher students combined the answer “everybody” with “no one” (see Table 2). Furthermore, there is a great variety in teacher students’ explanations of the term students’ conceptions. A network analysis of the identified categories in the answers to question 1 points to a fragmented concept of the term students’ ideas (Figure 2, Diagram 2). The purpose of a network analysis is to examine relationships among categories. In our case we investigated the different combinations of the categories from question 1 and how often they are mentioned together.
3.1.3 Summary.

The results of the explorative study with teacher students supports the assumed problem that the understanding of the term students’ conceptions is very blurred and unspecific. The term students’ conception has no precise definition, and this may lead to the problem’s teacher students have, when they are asked to explain the term. They put different foci on various facets of the term students’ conceptions in their explanations. Some teacher students focus on the origin of students’ conceptions, other on the group of persons who have them.

All in all, the results have encouraged us to start the Delphi study in order to investigate the ideas of the second group being involved in physics education: How do professors and post-docs in the field of PER, explain the term?

3.2 Results of the first phase of the Delphi study

The first phase of the Delphi study is already finalized. 27 experts - professors and post-docs in the field of PER - completed the online survey. Three questionnaires were excluded from the data analysis due to too many missings. First our findings show a disagreement about the need for a concise definition. About half of the participants (13) were in favor of a concise definition, the rest saw no need for such a definition.

The first part of the questionnaire provided us with different definitions of the experts concerning the term students’ conceptions. The definitions for the term students’ conceptions given by the experts vary considerably but the qualitative content analyses points to different forms of constructivism as one core component of the definition. In detail, in our analyses we found various clusters concerning the nature of the description of the definition of the term. Furthermore, these clusters are differently connected to each other. A schematic representation of the identified clusters is shown in Figure 3.

![Diagram 1 frequency distribution](image1.png)
![Diagram 2 network analyses](image2.png)

**Figure 2.** Analyses of the answers of the first question of how to explain the term students’ conceptions to fellow students

| Question | Frequency |
|----------|-----------|
| 1. What? (Definition) | 32% |
| 2. Who (has SC)? | 24% |
| 3. Which characteristics? | 17% |
| 4. Origin? | 24% |
| 5. What to do with SC? | 3% |

**Table 2.** Answers to question 2.

| Answer | “everybody” | other answer |
|--------|-------------|--------------|
| “no one” | 37 | 29 |
| other answer | 16 | 28 |

| Diagram 1 frequency distribution | Diagram 2 network analyses |
3.2.1 Description of the clusters

- **Cluster A**: Definitions in this cluster use the term students’ conceptions in the same way as misconception.
- **Cluster B**: Definitions in this cluster use a differentiation strategy between certain similar terms and students’ conceptions. The term students’ conceptions is in the majority of cases not explicitly defined.
- **Cluster C**: This cluster contains the statements that there is no need for a common definition of students’ conceptions.
- **Cluster D**: Definitions in this cluster are based on or refer to existing definitions in literature.

![Figure 3. Visualization of the different clusters.](image)

It is also interesting for us that the second task of the survey (differentiating various terms from the term students’ conceptions) seemed to be a big challenge for the experts because the results show a lack of clarity. Only the term misconception (German ‘Fehlvorstellung’) is clearly distinguished from the term students’ conceptions by most of the experts (more than 80%). The term prior knowledge (German ‘Vorwissen’) is regarded as similar to the term students’ conceptions. For all the other terms we provided, like everyday concept (German ‘Alltagsvorstellung’) or naïve ideas (German ‘naïve Ideen’), the judgements about synonymity varied.

In the third part of the first Delphi phase, there was agreement about the positive and negative aspects of the usage of the term students’ conceptions for teacher education. There is broad agreement concerning the assessment of the strength of the term for teaching pointing out its neutrality, because the term students’ conceptions is not judgmental. In addition, there is a very broad spectrum concerning the benefits of the term, ranging from references to the high prevalence of the term in physics education to the fact that the term can be easily taught to students. Nevertheless, no uniform picture is seen.

In contrast, the collection of negative aspects of the term students’ conceptions provides a clearer picture. Nine of the 24 experts state that the term establishes a clear link to the social group of students. Therefore, the risk of restricting the term to students and not to everybody is more likely. The second point of agreement is the inconsistency or blurriness of the term, which is seen as a weakness by the experts.

In addition, the data reveal that the lack of knowledge about students’ conceptions is seen as an obstacle for planning and executing lessons. On the other hand, it is pointed out that there is still little research on teacher students’ ideas on students’ conceptions at university level. The simple terminology may give the impression that the term itself is trivial.
Concerning the fourth topic – problems with teacher students’ ideas on students’ conceptions – the experts mentioned some very interesting points. The most frequent problem named is that teacher students equate students’ conceptions with misconceptions. This problem implies that it is hard to see for teacher students that students’ conceptions are sometimes a viable source for learning. Another frequently observed counterproductive notion of teacher students is that a students’ conceptions can simply be fully changed and corrected by more or less intensive instruction. Experts describe, that teacher students deny the possibility of the coexistence of a students’ conception and an adequate concept after formal instruction.

A problem for teacher students, according to the experts, is the identification of students’ conceptions in classical physics classroom situation at school. Sometimes wrong answers or simple ad-hoc constructions uttered by high-school students are interpreted as students’ conception. Surprisingly, some experts have either had no experience with teacher students’ misinterpretation of the term students’ conceptions or have not observed teacher students’ ideas of this term yet.

All in all, the experts gave good insights into the present situation concerning experts’ ideas and knowledge on the term students’ conceptions. Thus, our hypotheses that the term is far from consistent holds true.

So, as already mentioned, in the second phase of the Delphi study statements based on these results, like experts’ definitions and descriptive elements of the term students’ conceptions, of the first phase are formulated into statements. The experts had to judge them only in terms of agree or disagree. All in all, 87 statements had to be rated in the second phase. Those statements were grouped in four parts like we did in the first Delphi phase. In the end, 53 experts completed the questionnaire of phase two. The aim of the second phase is to identify statements that are consensus among the experts, who are again professors and post-docs in the field of PER in German speaking countries.

As a first result we see that the question about the necessity of a concise definition was answered in a more decisive way. 33 experts agreed that a definition for the term in teaching and research is necessary. Only 14 experts denied this statement. 6 experts split the answer (yes for research, no for teaching or vice versa). This encouraged us to continue the study and strengthens the hypotheses that a concise definition is necessary and can be helpful.

Further results of the second phase are not ready for publication yet. We hope to publish them soon after concluding the third phase of the Delphi study.

4 Discussion
In general, the results of the first phase of the Delphi study as well as the preliminary results of the second phase do not reject the overarching hypotheses of the study. The term students’ conceptions is far from concise within the community of German-speaking experts in PER. The term is seen as problematic as well as helpful concerning physics teacher education. As one of the most important problems we identified the issue that the term is undistinguishable from terms with similar meaning, even for experts.

The ongoing analyses of the second phase and the upcoming third phase of the Delphi study should help to get a clearer picture. We hope that we are able to extract some features of the term students’ conceptions that are accepted by the majority of the experts. Our results suggest however, that this is more likely possible for the area of physics teacher education than for the realm of research. We are also making progress on the issue of the distinguishability of the term students’ conceptions from terms with similar meaning. Therefore, in the second phase of the Delphi study we asked for examples for students’ conceptions that are not misconceptions at the same time. We hope to find boundaries of the term that will help teacher students and their educators to better teach and understand the term and the underlying concept.
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