Students’ perspectives on 3D-vision

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Abstract. The perception of our surroundings is determined by vision to a large extent. Human vision is not only able to generate a three-dimensional impression of three-dimensional objects, but also of two-dimensional objects. Nowadays, 3D-technologies even provide additional opportunities to trigger visual 3D-perception. 3D-vision provides a context for teaching and learning several topics in physics. In order to develop a learning environment for high school students, following the framework of educational reconstruction, students’ perspectives must be considered. As we could not find any documented students’ conceptions on 3D-vision, an exploratory study was conducted. Main aim of this study was to provide a broad overview on students’ perspectives on 3D-vision. Therefore, the questionnaire mainly consisted of open questions. The questionnaire was administered to Austrian secondary level students of two schools and was finally filled in completely by 215 students. Data was analysed by the means of qualitative content analysis and an inductive category system was developed. The results show that students mainly connect 3D-vision with 3D-technologies in cinemas. However, differences between junior and senior high school students were detected. While junior high school students mainly associate 3D-vision with cinemas, senior high school students additionally mention the physiological process of 3D-vision as well as 3D-technology.

1. Introduction

The topic of 3D-vision is gaining increasing relevance in our everyday life. At times, when 3D-technology, 3D-printers or Virtual Reality have represented something completely new to students are nearly over. Not only because most movies are 3D nowadays, but also because students encounter for example 3D-technology in schools (for example 3D-printers). Therefore, 3D-vision is a relevant topic which is worth to be taught. Especially in physics, the topic of 3D-vision is connected to several phenomena that be taken up for teaching and learning optics.

In order to promote the topic of 3D-vision in school, in a first step an out-of-school learning environment on 3D-vision for year 11 students was developed and implemented at the Open Labs Graz [1]. The design of the first version of the learning environment is mainly based on optical phenomena to introduce key ideas of 3D-vision. The learning arrangement focuses on the following key topics concerning 3D-vision: (1) the basic concept of binocular disparity, namely the generation of two different images on the two retina (2) basics about image formation (3) human visual perception (4) procedures of light separation (e.g. anaglyph method, polarization method). The concrete design comprises a short introduction covering the above-mentioned key topics and four different quests,
following an inquiry-based approach, where students can deepen their knowledge concerning 3D-vision. All in all, the learning environment was designed for four lessons (3 full hours).

The learning environment at the Open Labs Graz was first evaluated in 2018 with two high school classes [1]. Focus of the first evaluation was on students’ general motivation concerning the topic 3D-vision. Before the instruction, the students filled in an open questionnaire where they had to explain terms like 3D-vision, real and virtual image and hologram. At the end of the intervention they had to do the same questionnaire extended with additional questions on their intrinsic motivation [2, 3]. So, we gathered information on students’ intrinsic motivation regarding the learning environment on 3D-vision. Additionally, by comparing students’ explanations given at the beginning and at the end of the intervention on the terms 3D-vision, real and virtual image, and hologram, we found hints on students’ conceptual learning gains. All in all, the evaluation results of the first intervention are very positive. The two high school classes showed good values concerning students’ intrinsic motivation and we found that several students’ improved their conceptual understanding. However, the results regarding the development of conceptual understanding about 3D-vision still indicate room for further improvement of the learning environment. Detailed information on the pilot evaluation of the learning environment on 3D-vision can be found in [1].

As the detailed analysis of students’ answers indicates, students’ conceptions on 3D-vision were obviously not considered sufficiently in the design of our learning environment. However according to the framework of educational reconstruction [4], the mutual consideration of subject matter clarification and domain specific perspectives of the learners plays a major role in designing a learning environment. To improve the effectiveness of our learning environment it seems to be necessary to better integrate students’ perspectives on 3D-vision.

Physics education research has accumulated a vast knowledge of students’ conceptions in different subdomains of physics. This is also true for introductory optics, for example, there are a lot of findings on vision (e.g. [5–7]) that are relevant for our project. However, as far as the aspect of 3D-vision is concerned, we could not find substantial findings for our purpose. This situation leads to the goal of our study, namely, to uncover students’ perspectives on 3D-vision. The term students’ perspectives is used in this paper in a broader view and means “conceptions and views about the content as well as affective variables” [4]. In contrast, the term students’ conception is mainly connected to the view and understanding of a certain physics content. Among other, the goal to uncover students’ perspectives on 3D-vision was pursued in a diploma thesis with the help of a study with secondary level students [8].

This paper outlines the exploratory study we have conducted and presents the findings on students’ perspectives on 3D-vision. First, the studies’ theoretical framework is described mainly focusing on already known students’ conceptions of introductory optics which are relevant to the topic of 3D-vision. Furthermore, the research design and methods are outlined before selected results are presented. Finally, the findings are summarised, discussed against the background of the limitations of the exploratory study and an outlook on further research is given.

2. Theoretical framework
In general, this Design-Based Research project on 3D-vision is based on a moderate constructivist approach towards teaching and learning. On a more general level, the intentions of this project are to design a teaching and learning environment that guides students from their everyday ideas about 3D-vision to more adequate ones. The model of educational reconstruction is one theoretical basis that guides the design of constructivist learning environments that aim at triggering conceptual change. The following subchapters are thought to make our theoretical basis explicit and to explain how our design was shaped by this basis.

2.1. Educational reconstruction
The model of educational reconstruction can be seen as “a conception of science education research that is relevant for improving instructional practice” [4]. Its emphasis lies on three main aspects for the development of teaching and learning environments: The clarification and analysis of the subject matter,
the investigation of related learners’ perspectives and the design and evaluation of the learning environment. Following the framework of the model of educational reconstruction, all these aspects have to be considered when developing and improving a learning environment. [4]

When designing the first version of the learning environment on 3D-vision, students’ conceptions on optics related to the topic 3D-vision were considered. However, the first evaluation of the learning environment showed room for improvement. Especially, several students’ explanations concerning 3D-vision lack of the concept of disparity. Furthermore, students showed difficulties in explaining real and virtual images as well as the term hologram [1]. From these results we concluded that students’ perspectives on 3D-vision must be investigated.

2.2. Students conceptions on vision

Due to the close connection of the topic 3D-vision and vision, first, research results on students’ conceptions on vision were analysed according to our focus. Vision is a topic that is related to several school subjects like Biology, Psychology and Physics. Research concerning students’ conceptions on vision or visual perception can be found in the area of physics and biology education research (e.g. [5, 6, 7, 9]). In the field of physics education research, Guesne [5] found in her research on students’ ideas on light several students’ conceptions related to the process of vision. Teaching experiments revealed that teenagers aged between 13 and 14 “make a very strong association between light and the fact of being able to see.” ([5], S. 186). Some teenagers also may think, that one can see an object just when it is surrounded by a flood of light [5]. Moreover, the students assign an active mechanism to the eye so that we can perceive things, when we look actively at them [5]. Galili and Hazan [6] additionally found in their study with high school students and teacher students, that learners at this age groups also think “light is a supportive background which improves vision” and the eyes have to be illuminated for functioning properly.

In the area of biology education research, students’ conceptions on vision were for example investigated by Gropengießer [7]. He conducted an interview study and identified three main mental figures students hold: common realism (“objects exist and we see them as they are”), evidence (“when we look at an object, we see what is there.”), instruction (“the object influences visual perception”); ([7], transl.). Furthermore, Dannemann [10] developed a diagnostic tool concerning visual perception for biological aspects, where the topic 3D-vision is not covered.

To sum up, in research literature several students’ conceptions on vision and light are described. Nonetheless, currently no students’ conceptions on 3D-vision or explicit connections to 3D-vision can be found. Neither were we able to identify research findings on much broader perspectives, like students’ perspectives or even associations on 3D-vision. Following the approach of educational reconstruction, it was necessary to investigate students’ perspectives on 3D-vision. We thought it to be a reasonable strategy to get a broad view on students’ ideas first and to dig deeper in a second step. Therefore, an exploratory study on students’ perspectives on 3D-vision was conducted.

3. Research design and methods

In this section the research questions as well as the questionnaire and the sample of the study are described in detail.

3.1. Research questions

Main aim of our exploratory study was to get a very broad view on students’ perspectives on 3D-vision. Our study was guided by the following research questions (RQ):

RQ 1: What do high-school students associate with 3D-vision?
RQ 2: What is 3D-vision for students?
RQ 3: Are high-school students confronted with the concept of 3D-vision in school settings or in out-of-school contexts?
RQ1 and RQ2 distinguish between students’ general associations with the term 3D-vision and their personal interpretation of the meaning the term has. RQ3 investigates if students have any experiences with 3D-vision in school contexts and/or out-of-school contexts.

3.2. Questionnaire
In order to address the research questions above, a paper and pencil questionnaire (10-15 minutes) was developed. The questionnaire consisted of four main questions:

1. What comes to your mind when you hear the term 3D-vision? – Write down everything that comes to your mind.
2. What is 3D-vision for you? – Explain.
3. Was the topic 3D-vision already covered in school? Yes/No
   a. If yes, in which subject?
4. Have you already encountered the topic 3D-vision out-of-school? Yes/No
   a. If yes, in which way? Where?

The first and second question of the questionnaire operationalize the different intentions to collect students’ general associations and their personal interpretation on the term 3D-vision. To guarantee that the intended association process initiated by question one is not interfered by the other questions of the questionnaire, question one was on the front side of the sheet and all other questions were on the back of the questionnaire. The students were asked to fill in the first question first and only then, they were allowed to turn to the next page.

3.3. Description of the sample
The questionnaire was administered in five junior (grade 7-8) and six senior (grade 9-12) high school classes of two Austrian high schools (see Table 1). In total 215 students filled in the questionnaire; half of them attended junior high school. 70 % of the participants were female students. In both subsamples there are more female than male students (62 % female students in junior and 78 % in senior high school). This unequal distribution of male and female students may be attributed to the special focus of one of the schools, which is economics and traditionally preferred by girls.

|                      | Female | Male | In total |
|----------------------|--------|------|----------|
| Junior High School   | 66     | 41   | 107      |
| Senior High School   | 84     | 24   | 108      |
| In total             | 150    | 65   | 215      |

3.4. Data Analysis
The answers to all questions of the questionnaire were analysed with qualitative content analysis [11]. An inductive category system was developed that was defined in detail in a coding manual. About 10 % of the data was coded by a second person following the coding manual. The intercoder reliability for all main categories showed a Cohens Kappa of $\kappa = .859$. So, the two raters showed a very high agreement [12] and the category system is regarded as appropriate.

4. Selected Results
In this section the descriptive analysis of the data is presented following the research questions. Additionally, the inductive categories will be described in detail.
4.1. Students’ associations with the term 3D-vision

The first question of the questionnaire collects associations with the term 3D-vision. Applying qualitative content analysis, 14 main categories were found. An overview of these categories and the percentage of students, whose answers were attributed to these categories, can be seen in figure 1.

Not surprisingly, 87% (n = 188) of the students’ answers could be assigned to the category *cinema/movie*, which is the largest category. The second largest category is *3D-technology*, this category contains all terms connected to 3D-devices, except the terms cinema or movie. The answers of 64% of the students (n = 138) could be summarized in this category. Typical answers were e.g. 3D-glasses, Virtual Reality glasses, 3D-printer, 3D-television, etc. At this point it is important to mention, that multiple answers of a student attributed to one category were counted only once for this category. *Spatial aspects* (this category includes all terms connected to anything spatial) like depth, estimation of distance or spatial orientation were mentioned by 62% (n = 134). Furthermore, the category *perception* was detected. This category includes all terms and phrases which are explicitly related to any kind of perception and emotions connected to this perception (e.g. exciting perception, depth perception (this falls also in the category spatial), fascinating, exciting, feels real, feels like an optical illusion, seems touchable, etc.). 53% (n = 115) of the students mentioned aspects which were aggregated in the category *perception*. The fourth largest category summarizes *physiological process*. This category includes answers connected to parts of the visual system and the mention of the physiological process of vision which is connected to 3D-vision e.g. eye(s), brain, humans usually see 3D, etc. 44% (n = 94) of the students made contributions to this category.

Other categories extracted of the students’ answers were:

- **art & architecture** (33%, n = 71) including terms like street-art, perspective drawing (also drawings which represent perspective drawings), spatial images, photos, etc.
- **school subject** (29%, n = 63) including Mathematics, Physics, Biology, Arts, etc.
• others (15%, n = 32) including optical devices like contact lenses, microscope or terms which cannot be reasonably attributed to other categories connected to 3D-vision (skeleton, shortsightedness etc.) and drawings which could not be properly interpreted in the context of 3D-vision.

• everyday life & (3D) objects (12%, n = 25) including answers like everyday life and or objects which relate to everyday life other than objects connected to 3D-technology (e.g. mirror, figures, etc.)

• animals (11%, n = 24) mentioning animals that can see 3D or 2D (e.g. cats, dogs, cows, …)

• comparison with 2D/4D (11%, n = 23) including comparisons of 3D with 2D or 4D (4D is mentioned in terms of cinemas where in addition to 3D-vision also seats are moving).

• caused by two images (8%, n = 18) including phrases which indicate that two images are needed to perceive three-dimensional.

• light & shadow (7%, n = 14) including terms related to light and/or shadow

• no answer (2%, n = 4) students who gave no answer.

Differences comparing junior high (7th-8th grade) and senior high (9th – 12th grade) school students were found. On average junior high school students mentioned less terms (∅ = 9.5 terms) than senior high school students (∅ = 13 terms). In average each senior high school student mentions more different categories than a junior high school student.

In terms of the categories, a significant difference between junior and senior high school students occurs in the category 3D-technology (χ² = 38.038, p = .000, φ = .421). While only 44% (n = 47) of the junior high school students’ answers contributed to this category, 84% (n = 91) of the senior high school students did. It seems that older students associate 3D-technology with 3D-vision more frequently. Almost the same effect is detected concerning the category physiological process (χ² = 50.258, p = 0.000, φ = .483): 20%, n = 21 of junior and 68%, n = 73 of senior high school students gave answers attributed to this category. So, physiological processes seem to be in the background and not that important for junior high school students in comparison with senior high school students. In terms of the category cinema/movie we found that junior high school students tend to mention terms attributed to this category more often than senior high school students (χ² = 7.021, p = 0.008, φ = -.181, 93%, n = 100 of the junior and 81%, n = 88 of senior high school students). So, for senior high school students the cinema or movies are not that present in their minds concerning 3D-vision as for junior high school students.

4.2. Students’ ideas on 3D-vision
Research question 2 focuses on students’ individual ideas on 3D-vision. An overview of percentage distribution of the categories can be seen in figure 2.
Figure 2. Students ideas on the term 3D-vision for junior and senior high school students

For research question 2 the same category system as for research question 1 was used. Students’ answers differ from the overall associations in RQ1. Most of the terms mentioned belonged to the categories **perception** (42 %, n = 90), **spatial aspects** (34 %, n = 74) and **physiological process** (33 %, n = 70). Terms connected to the category **cinema/movie** seem to be less important for the students (19 %, n = 40) compared to their associations in question 1.

Comparing junior and senior high school students’ ideas on 3D-vision, differences are detected. A significant difference ($\chi^2 = 56.563, p = .000, \phi = .513$) was found concerning the category **physiological process**. The category **physiological process** fits to answers of 61 senior high school students (87 % of all students gave answers attributed to this category) and just in answers of 9 junior high school students. Thus, the physiological process seems to be more important for older students concerning 3D-vision. Additionally, junior and senior high school students’ answers significantly differ concerning the categories **perception** ($\chi^2 = 7.968, p = .005, \phi = -.193$) and **cinema/movie** ($\chi^2 = 4.163, p = .041, \phi = -.146$). Both categories are more often detected within the answers of the junior high school students (perception: 51 %, n = 55, cinema/movie: 24 %, n = 26) than within the answers of the senior high school students (perception: 32 %, n = 35, cinema/movie: 13 %, n = 14). A detailed graph of the comparison of junior and senior high school students’ ideas on 3D-vision can be found in figure 2.

4.3. Engagement with the topic 3D-vision in school and out-of-school

The topic of 3D-vision seems to be partly covered at school. Half of all the students (n = 110) stated that they heard of 3D-vision in school. About three quarters of senior high school students and one third of the junior high school students state the topic was covered in school. 31 students (29 %) of the junior high school and 79 students (73 %) of the senior high school confirmed that the topic 3D-vision was covered in school. These students connected several subjects with 3D-vision (see figure 3): Mathematics (25 %, n = 28), Arts (22 %, n = 25) Physics (33 %, n = 37), Biology (21 %, n = 23) and Psychology (35 %, n = 39). Additionally, other subjects like Music, Informatics, Physical Education and Handicrafts were named once. This suggests that the topic 3D-vision is addressed in a broad variety of school subjects according to the students.
Figure 3. Students’ answers concerning subjects where 3D-vision was covered in junior and senior high school

In out-of-school context students also encounter with the topic of 3D-vision. 57 % (n = 123) of the participants state to have engaged with 3D-vision in out-of-school context. When we look at the two subsamples, 64 % (n = 68) junior high school students and 51 % (n = 55) senior high school students engage with 3D-vision out-of-school. Most of the students get in contact with 3D-vision in the cinema (83 % of junior and 69 % of senior high school students). Additionally, 3D-technologies as well as Arts are named by the students when dealing with 3D-vision out-of-school. So, the engagement of students with 3D-vision out-of-school is greatly present.

5. Conclusion
The aim of this exploratory study was to find out more about students’ perspectives concerning the term 3D-vision. The presented study gives a glimpse into students’ associations, students’ ideas and their engagement with 3D-vision. A paper pencil questionnaire covering open questions on the term 3D-vision and students’ engagement with 3D-vision in school and in out-of-school contexts was conducted. In total 215 students of junior and senior high school filled in the questionnaire. The data was analysed by the means of qualitative content analysis [11]. An inductive category system with 14 main categories about associations and students’ ideas concerning the term 3D-vision was derived.

In terms of students’ associations with 3D-vision, a broad spectrum of associations was found. Most frequent categories detected are the cinema/movie, as the commonest category, followed by the categories 3D-technology, spatial aspects, perception and physiological process. Regarding students’ ideas on 3D-vision most terms and phrases apply to the categories perception (e.g. 3D-perception as a fascinating phenomenon), spatial aspects and physiological process. Furthermore, when comparing students’ associations and students’ ideas on 3D-vision differences were identified. While students associate 3D-vision mainly with the cinema/movie, students’ ideas concerning 3D-vision mainly involve perception as well as the physiological process.

The collected data also show interesting differences between junior and senior high school students. Senior high school students mention more terms on 3D-vision than junior high school students. Additionally, more senior high school students mention that the topic of 3D-vision was covered in school. So, this is a hint, that senior high school students are already confronted more often with this topic and therefore, their associations are wider. Additionally, physiological process seems to be more important for the older students while the cinema/movie and perception is rather named by junior high
school students. This is an interesting result since senior high school students have more experience of life and the chance of watching a 3D-movie in the cinema would be higher than for junior high school students. Furthermore, junior high school students mentioned answers attributed to the category physiological process less often than senior high school students. One explanation may be conceptual gaps of junior high school students. Though, especially the comparison of junior and senior high school students must be interpreted with caution due to limitations in our sample: Our data comprises a cluster sample with 11 classes from just 2 schools.

Furthermore, our data show, that 3D-vision is already a topic covered and mentioned in school. Moreover, students also deal with 3D-vision to a considerable range in out-of-school context. This underpins the assumption that 3D-vision is an excellent topic for embedding in teaching and learning.

Nevertheless, when teaching the topic 3D-vision students’ perspectives on 3D-vision must be considered. Emphasising the physiological process especially in senior high school would balance with students’ interests. Additionally, the topic perception and the cinema/movie should be focused when teaching 3D-vision, especially in junior high school.

In terms of our learning environment on 3D-vision, which was developed for senior high school students, physiological processes should be focused. So, the two key concepts (already mentioned in the introduction) of our learning environment ‘the basic concept of binocular disparity, namely the generation of two different images on the two retina’ and ‘human visual perception’ have to be foregrounded.

All our results must be interpreted very carefully, and no general conclusions can be drawn. Several limitations must be considered: Data collection was done in just two Styrian schools and two regions (city and rural area). Additionally, our data only represents one school type (gymnasium). So, we just can interpret our data as first hints on students’ perspectives on 3D-vision. Nevertheless, the identified categories help to develop the learning environment on 3D-vision and adjust it better to students’ perspectives. So, when teaching the topic of 3D-vision several aspects like addressing the physiological process of 3D-vision as well as how 3D-technology works in cinemas should be covered because it seems to be in balance with students’ interests. Especially, the topic of perception (exciting phenomena concerning 3D-perception) and the topic of physiological processes concerning 3D-vision seem to play an important role concerning students’ ideas on 3D-vision. So, these aspects should be considered when designing and developing a learning environment on 3D-vision.

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