Lessons Learned Report

TaTaBooks - Talking Tactile Books for Visually Impaired

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Content

1 Introduction

Globally, around 2.2 billion people experience a visual impairment (World Heatlh Organization, 2019). It is estimated, that within (geographical) Europe, 30 million individuals are blind or at least partially sighted.[1] Hence, visual impairments or blindness is not a minority issue but affects around 4 percent of European citizens. Further, the integration of persons with disabilities is not only a humanitarian imperative, but rather a logical and necessary step to increase the diversity to the greater benefit for everyone. Education plays a significant role in guaranteeing and enabling participation as well as integration. This is also conveyed through the UN-Convention on the Rights of Persons with Disabilities, which enshrines the right to inclusive education.[2]

Discussions with school teachers from four European countries in preparation of the project made the need for adequate teaching tools as well as the desire to benefit from common transnational efforts highly evident. The Erasmus+ project "*TaTaBooks – Talking Tactile Books for Visually Impaired Children*" addresses these requests, considering the special needs of blind and visually impaired pupils for comprehensive, knowledge-transferring and fun-to-use learning materials by developing tailor-made 3D-based teaching tools supplemented with audio and online learning contents.

The *TaTaBooks* project sets critical steps to foster a better inclusion of blind and visually impaired children across Europe and beyond. By supporting teachers with teaching tools, by expanding their digital competencies and by interconnecting them with colleagues abroad who are facing similar challenges, the project aimed to improve the teaching and learning experience of teachers and students and additionally strengthens (international) integration.

The development of the *TaTaBooks* (teaching contents, tactile 3D prints, audio and digital supplements) was a highly interactive process between schools from four European countries (Austria, Czech Republic, Hungary, Slovakia) and engaged professionals in all relevant fields – 3D, IT, didactics, natural sciences, science communication. Most importantly, the final beneficiaries – teachers and children – took part in tool development by testing and commenting on intermediate prototypes.

This report is divided in three main sections. First, in section 2 some background information based on peer-reviewed literature on teaching blind and visually impaired students is given. Further, some recent

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[1] Facts and figures | European Blind Union (euroblind.org)

[2] https://www.ohchr.org/en/documents/general-comments-and-recommendations/general-comment-no-4-article-24-right-inclusive

general statistics on blind and visually impaired persons and students are outlined. The section is then concluded by the results of two small surveys about i) the students and teaching and ii) the situation at the schools and of the teachers among the four project partner schools.

The second part of the report in chapter 3 focuses on the project itself. First of all, an overview is given, describing the results, tasks, timeline, technologies and the involved participants. Following this, chapter 4.1 goes into detail about the various heterogeneities among the beneficiaries of the project ranging from languages, different types of students, different focuses of schools and teaching (outcomes), different technological skills and usage. Chapter 4.3 describes in detail the actual procedure, issues and how they were handled throughout the project also with reference to the background information of chapter 2. Potential issues are identified, and their handling is described and further discussed. In addition to the overview on those topics, feedback of the teachers and other project partners was also incorporated in this report.

The aim of the report is to be a guidance for future transnational cooperation among heterogeneous partners, especially if persons who are blind or visually impaired are involved.

2 Background – teaching visually impaired students

Section 2 gives a literature-based background on teaching visually impaired children. This is followed by the results of a small survey which was conducted among the participating schools at the very beginning of the *TaTaBooks* project.

Visually impaired children are children first and foremost. Like any other child, a blind or visually impaired one has individual talents and interests. For every child, learning is an important part of their personal development. Teaching visually impaired children poses special challenges, since the use of visual tools is limited or impossible. Teachers in dedicated schools know “their” children and know how to approach each of them. They have also built up an individual repertoire of teaching tools and strategies. “Externals”, however, rarely come into contact with visually impaired people in their daily lives and therefore have, at best, a rough idea of how teaching and learning activities are organised. A more intensive exchange between visually impaired and non-impaired people and institutions, including schools, is highly desirable. This would not only promote inclusion, but also access to innovative tools and technologies regardless of disability.

2.1 Literature background

The scientific literature gives background knowledge and important inputs on teaching visually impaired persons (foremost children) as well as on learning behavior and special needs in general. This section is a brief introduction to various topics of interest related to the development of teaching tools for visually impaired children and their teachers. At the end of every subsection, a short linkage to the *TaTaBooks* and how the respective thematic is incorporated in the different results is carried out.

2.1.1 Visual impairment and sensory capabilities

Visually impaired people tend to have a heightened tactile sense (Picard et al., 2014). Furthermore, Mazella et al. (Mazella et al., 2018) observed that identifying tactile pictures by touch improved with age and was mainly depended on the improvement of shape discrimination skills.

What is more, unlike people with unimpaired sight, whose tactile perception declines with advancing age, blind people maintain their tactile capabilities (Legge et al., 2008). This advantageous characteristic is otherwise known from pianists, and Legg et al. (Legge et al., 2019) summarised that “lifelong experience with focused attention to touch acts to preserve tactile acuity into old age for both blind and sighted subjects.”

Further, blind children outperform their sighted peers on tactile memory as well as verbal memory tasks (Withagen et al., 2013). The superior short-term memory, also seen in adults, can be partially explained by differences in coding modalities. Thus, visual deprivation contributes to cognitive advantages (Arcos et al., 2022).

The *TaTaBooks* are highly tactile. Teaching material is printed by a 3D printer in relief form, allowing the students to touch and feel the contents. Any writing is in braille, further, control buttons have tactile elements that show which function they have (play/pause, changing contents, etc.). Throughout the project, it became evident, that blind and visually impaired persons have heightened tactile senses compared to seeing persons. Recognizing what can be felt on a plate was rather hard for those that can see, but visually impaired students and teachers easily recognized forms, shapes and surfaces. Additionally, they gave valuable remarks on how to improve certain shapes and surfaces to improve the usability.

This leads to two conclusions; first, tactile materials are highly suitable for blind and visually impaired persons. Second, integrating them into the process of creating those materials is important, since blind and visually impaired people – the users – have heightened tactile skills and thus can give valuable and necessary insight.

2.1.2 Children with special needs

Undoubtedly, visually impaired children have special needs. These needs vary qualitatively and quantitatively, depending on several factors, such as the degree of (partial) vision loss. Whether a child had been blind at birth or lost vision later on makes a difference (Withagen et al., 2013). An ophthalmological examination can determine the degree of vision loss. However, the result provides only limited information on a person's actual impairment in managing daily tasks. There is a clear need for standardized and experimental tools to assess spatial cognition in visually impaired children (Aprile et al., 2020).

Learning implies memorising lesson contents. People who lack vision cannot rely on a visual memory, nor can they recognize visual patterns between previously seen and new objects. School can be difficult for children with compromised visual memory. Visual memory skills usually accompany the learning progress[3]:

- Visual sensory memory involves information that comes from any of the five senses (hearing, sight, smell, touch and taste). This type of memory enables you to remember a word or image that was shown for just a brief period of time and then easily recall that information.
- Visual working memory helps you to remember information for short periods of time, for example, when you are asked to repeat a sentence in a story, or put the events of the story in the right order.
- Visual spatial memory allows you to create a picture of the information in your mind. This is necessary for many skills, such as understanding sequences of events, recalling text and images in a story, and remembering the correct spelling of a word.
- Visual sequential memory helps you to remember the sequence of letters, objects and events in the correct order. This is essential for both spelling, comprehending text.

Visually impaired children are generally more comfortable in their familiar environment (school, home). Teaching in this environment, among known schoolmates, ensures the child's full attention as there is less distracting uncertainty / discomfort.

The *TaTaBook*s (tactile, audio and digital content) can be used in the familiar environment. The book itself is rather immobile due to size and weight. However, the individual plates can be moved and carried around if necessary. The users are not only blind but also visually impaired teachers and students. So, visual memory partly still plays a role. Therefore, the 3D-printed materials do not only rely on tactile

[3] https://www.optometrists.org/vision-therapy/guide-vision-and-learning-difficulties/guide-to-visual-information-processing/visual-memory/

characteristics but also incorporate visual aspects (e. g. realistic colouring or stark differences between used colours).

2.1.3 Teaching tool design principles

Raising and maintaining a child's interest – irrespective of any personal impairment – is key to progressive learning. Learning should be fun, not a duty. Yet, subjects taught should be solid and serious. The concept of microlearning (see for example Goeschlberger 2022) helps to prevent an information overload and thus to maintain a child's interest. Another important, effective approach to minimize the risk of losing a child's attention is to address/stimulate multiple sensory organs. Such approach would also support memorizing learned content. The following subchapter summarizes studies on design and performance of teaching tools for visually impaired children.

2.1.3.1 Tactile teaching materials

Blind people have developed strategies to compensate their lack of vision. They use the remaining senses more intensively, resulting in a respectively higher perception. Their heightened tactile competences are a good starting point for teaching material design. Several studies have developed and tested tactile tools for children at various age. Material, size and complexity matters in order to use the increased capabilities the best. Tools can be as complicated as a human brain model to teach core concepts of neuroanatomy (Diniz & Sita, 2019). Most published examples originate from some teachers´ creativity, and each piece is unique, often hand-crafted (Baumer et al., 2021; Diniz & Sita, 2019; Horton et al., 2017).

2.1.3.2 Special aspect: Orientation

Navigation and injury avoidance in the context of poor vision has received special attention in research. As outlined in a recent review article, visually impaired people use different mechanisms for daily tasks such as crossing a street (Cloutier & DeLucia, 2022). A better understanding of that mechanism enables the development of more suitable tools and – in the long term – traffic infrastructure. In any case, an understanding of street and traffic infrastructure design is crucial for independent mobility for blind or visually impaired individuals.

When comparing different orientation aids, Papadopoulos et al. (Papadopoulos et al., 2017) observed that audio-tactile and audio-haptic maps were particularly effective for orientation and mobility compared to simple verbal descriptions.

2.1.3.3 Current teaching materials and desirable improvements

Current schoolbooks primarily consist of text (braille). In numerous instances, letter profiles are suboptimal. Figures displayed in schoolbooks often have one type of object outlining, making it challenging to differentiate between objects within a figure. Though having been "made for the blind", these books are of limited use, as special needs and capabilities of the target group had not been considered. In the design of more appropriate tactile teaching materials (images), we need to consider the following features based on feedback from our four partner schools:

- Different outlining (e. g. dotted, straight line) as well as different object height (e. g. 2 mm flat or 5 mm) should be considered.
- Colour choice is crucial: a strong contrast is desirable to help children with residual vision differentiate between objects more easily.
- Any tactile teaching tool is to be understood as a basis for teaching. It does not stand for itself but need to be supported and "enlivened" with additional input such as audio content (texts, sounds), interactive extra materials and interrogative sections.
- Tactile objects should maintain a balance: they should not be overly fragile but kept simple. To ensure durability and focused learning, figures should emphasize important content without excessive detailing of less important aspects.
- Teaching tools belonging to a kind of series should share common, reappearing features.
- A design principle that begins rather roughly and becomes empirically more refined is recommended.
- Quantitatively evaluating specific teaching tools or formats poses challenges due to the comparatively small size and heterogeneous nature of the target group.

Above recommendations and observations align with findings from published studies:

- Avoid sensory overload and redundancies (Kristjánsson et al., 2016).
- When designing tactile images for the classroom, teachers can use the parts that students touch when using the object as reference features for the images, e. g. the handles of cups and scissors. (Wu, Wu et al. 2020).
- Target groups, i. e. in that case visually impaired and blind children, shall be engaged in regular evaluations during teaching tool development (Tuominen, Kangassalo et al. 2008).

TABLE 1: RECOMMENDATIONS ON DESIRABLE FEATURES AND STRATEGIES FOR DEVELOPING AND TESTING TEACHING MATERIALS

Optimal device characteristics	Design methodology recommendations
Multimodal: providing both tactile and auditory feedback to the user is often most effective, especially for conveying complex information.	**User-centred design:** employ an iterative design process, in which users are involved in every stage of the planning and prototyping process, to ensure the final design is best adapted to user needs.
Adaptable: utilizing simple and flexible platforms for various different applications.	**Usability testing:** test the device with at least five users with visual impairments to identify significant usability issues.
Portable and affordable: using hardware platforms such as adapt touch screens or computers, when	**Large sample size:** test with a larger group of users with visual impairments if statistically significant

possible, as opposed to more expensive pin matrices and force feedback technologies.	results are required, or if the device will have many different applications.
Refreshable: displaying new information rapidly and responsively.	**Sighted users:** include blindfolded users in the study design to serve a clearly defined purpose, such as a pilot group or a control group.
Multitouch: providing as many points of contact as possible and allowing the users to explore freely, ideally using both hands.	

Source: from ***(Horton et al., 2017)***

Diniz and Sita (Diniz & Sita, 2019) recognized the benefits of 3D tactile teaching tools and developed a tactile brain model for teaching neuroanatomy. A special benefit of such tools arises from the fact that visually impaired and blind have heightened tactile capabilities (Goldreich & Kanics, 2006) and a pronounced hand cortical representation leads to better spatial perception through touch (Gentaz, 2013). Further, tactile materials can increase the interest of students, as studies have shown for science classes (Jones et al., 2006; Lancioni & Singh, 2014). However, the authors see a key limitation in high costs of individual teaching tool development. The efforts and costs could be reduced if tools or tool design were reproducible and adaptable.

"Both teachers, users, and scientific literature provide suggestions for designing suitable teaching materials for blind and visually impaired students. The project emphasized user-centricity by integrating scientific concepts and feedback from target groups during both the conception and project phases, drawing from previous experiences with blind and visually impaired individuals and involving educators. Despite the observation of numerous concepts, shortcomings remain in achieving optimal teaching material design. Subsequently, the following section will briefly discuss key recommendations concerning the TaTaBooks:

- Multimodal: The *TaTaBook*s are using tactile, audio and digital learning contents.
- The contents are adaptable to various teaching styles and can be adjusted to different content variations, as long as a general connection exists. The microlearning platform has been designed to accommodate various forms of content, a principle followed throughout the project.
- Portable and affordable: The online and audio contents are portable, while the 3D printing process remains comparatively affordable. New parts can be easily added, and individual broken parts can be replaced. However, a clear limitation of the physical book is its limited portability owing to its size

- Refreshable: The microlearning content is easily refreshable. Also, the written and read texts may be adapted with only a little effort.
- Multitouch: The book is a tactile material which can easily be explored with both hands. Nevertheless, the material itself is hard plastic. For some contents, some complementary materials with different feelings are added.
- User-centred design: the user-centred design approach was a core element of the project. It was seen as essential due to the different needs and capabilities of the users. Most of those needs and capabilities could only be traced by the project team in a limited way (e. g. being blind)
- Usability testing: Usability testing was done throughout the whole project.
- Large sample size: The sample was relatively large (different classes in four schools). However, the students were very heterogeneous in regard to age, visual abilities and other impairments. This is something that should be considered when selecting a sample.
- Sighted users: Blindfolded, sighted users tested some of the materials. Their remarks were – in comparison with actual blind and visually impaired persons – of limited use, though. An important sighted group were the teachers, since they were the ones that integrate the book and the other materials into their teaching.

Remarks from both teachers and students were incorporated, with many of them focused on specific features of the books or other outcomes, making them easily implementable.

2.1.4 Concluding remarks

Visually impaired or blind individuals often possess unique capabilities compared to those with full sight. However, these abilities can also be influenced by factors such as age or the onset of blindness. Additionally, children with impairments have specific educational requirements that extend to the design and utilization of teaching materials. These materials should aim to be multisensory, avoiding excessive complexity. User-centricity plays a pivotal role, emphasizing the necessity for extensive usability testing, ideally conducted with the target group.

2.2 Survey

For the survey, the four partner schools were asked to fill out a short questionnaire focusing on teaching (role, number of teachers per class, class size, subjects, teaching formats, material) and the students (impairments, age, concentration, issues). Further, the expectations in regard to the *TaTaBooks* were part of the questionnaire, which was conducted at the beginning of the project. The questions were asked in English; however, the respondents were free to answer in their respective language.

In total, six teachers from three partner schools answered. All were actively involved with the *TaTaBooks* project with administrative and / or content related tasks.

The first set of questions addressed the composition of classes. The answers showed that one school (one respondent) differs greatly from the other two schools (5 respondents) regarding the class composition. Thus, there will be a brief description of the two different types of class composition.

TABLE 2: COMPOSITION OF CLASSES

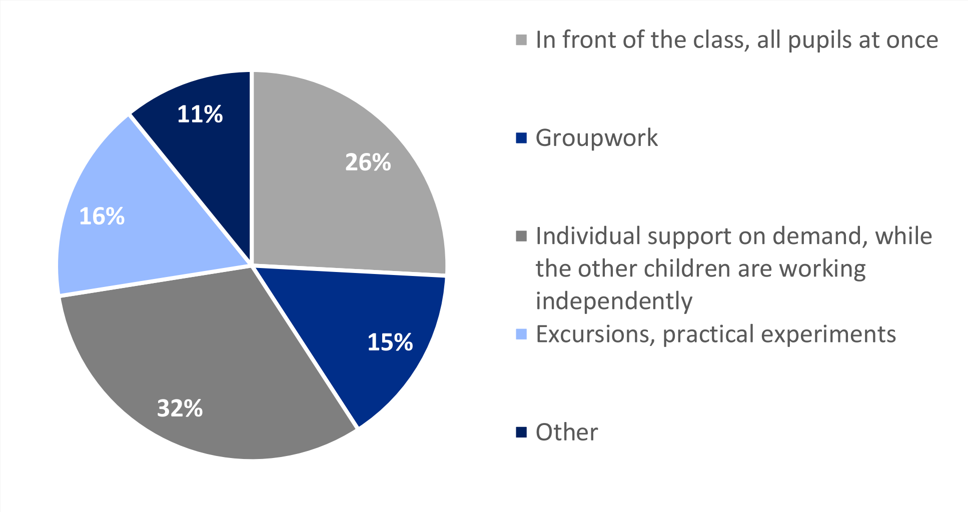
	Type 1	Type 2
Number of students	12 students	5–6 students
Share with visual impairments	20 %	70 % - 100 %
Share with other impairments	8 %	45 % - 90 %
Types of other impairments	Learning difficulties	All kinds of physical and mental impairments
Age of students	12	Mixed classes (3 to 16 years)
Number and role of teachers / in-class personnel	2 teachers	1 teacher, 1 support

Source: Economica

The table shows that on the one hand, there is a (larger) class with students of the same age with and without (visual) impairments. On the other hand, students with visual and other impairments are in one small class irrespective of their age. In those classes the number of students per staff is smaller, however it is usually one teacher and one supporting person and not two teachers what is the case in the larger and mixed class.

Figure 1 shows the distribution of the different teaching styles. There is no significant difference between the two types of class composition. Individual support has the largest share, followed by classroom teaching.

Figure 1: Teaching Style



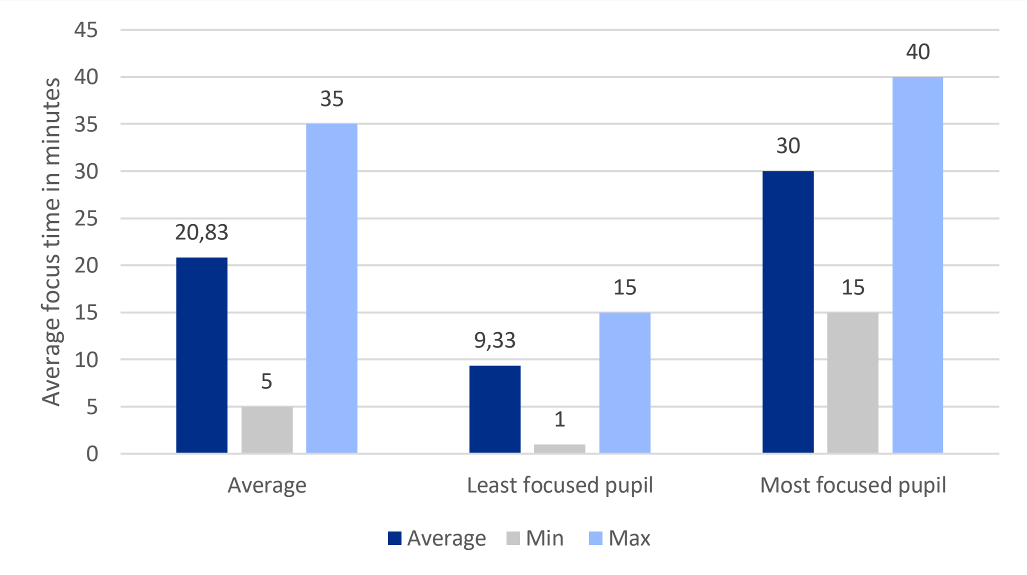
Source: Economica

According to the survey, the taught subjects cover everything from languages (native and foreign) to mathematics, social and natural science as well as sports. Further, some special classes in orientation and mobility, special needs and individual exercises are part of the curricula.

All teachers use tactile materials in their classes, like for example building blocks or some real-world objects. Audio content is used by four teachers, followed by braille books (3 times mentioned) and odours like herbs (2 times). Online teaching content is used by one teacher only.

The questionnaire also focused on the students, particularly in relation to teaching children with visual impairment. On average, the pupils can concentrate for about 20 minutes, however, the least concentrated child can only stay focused for 9.3 minutes (Figure 2). The responses show again two distinct groups. In the one group, students can focus between one and 25 minutes, in the other one they have a focus time between 15 and 40 minutes.

FIGURE 2: AVERAGE FOCUS TIME OF STUDENTS



Source: Economica

Teachers were also asked to indicate what they consider to be the greatest obstacles in teaching visually impaired children. More general, a lack of students was mentioned, but also a lack of institutions and expertise and integration. Another issue is that many students have multiple disabilities and sometimes a lack of motivation. With regard to teaching and learning, it was noted that time but also suitable materials are insufficient or not available at all.

Teaching blind and / or visually impaired children differs from teaching students without disabilities in some aspects. According to the teachers, differences occur mainly in relation to:

- Verbalization
- Provision of learning materials / special devices
- Individual attention and time availability
- Students with visual impairment work more in micro-space than macro-space
- identify, to know and to be respectful of dissimilarities and needs

As the project was in its early stages, when the questionnaire was carried out, the teachers were asked to provide some insights into the teaching materials, what they thought was important and what they expected from the *TaTaBooks* and the online tool. They were also asked to think about potential barriers.

The following conclusion were drawn:

Teaching tools for blind and visually impaired children should support individual learning and understanding. Further, usability and handling for visually impaired students must be given. The teachers also emphasized, that a teaching tool should be attractive and fun to use, as well as stimulating interest and creativity. The expectations of the *TaTaBooks* were rather similar. A beneficial factor is the possibility to print individual material directly related to the specific needs and preferences of every single school.

The digital learning platform was seen as an added value that can enhance the learning experience, but also further motivate students. It was also noted that digital content and materials are linked to the use of technology in student's everyday lives.

Potential obstacles were seen in three areas

1. Time to teach the students how to use the book and to integrate it in the lessons
2. Care must also be taken to integrate the book into existing lectures (how, when, for what)
3. Tactile material must be "readable", however, the connection to corresponding 2D objects and teaching content may be difficult.

Overall, the survey shows that teaching blind and visually impaired students takes more time and more individual adaption to their needs and circumstances. Furthermore, visually impaired students may have other impairments, or are in classes together with children with other impairments. There are different approaches to teaching visually impaired students. All kinds of teaching styles, but also materials are used. It was emphasised that there is a need for additional material with a focus on teaching visual impaired students is, and that these materials must be fun to use and able to motivate students.

3 The project

The *TaTaBooks* project is dedicated to advancing the inclusion of blind and visually impaired children. To achieve this, the project focuses on empowering educators with effective teaching tools. The development of the *TaTaBooks*, which encompasses various elements such as learning content, 3D prints, audio materials, and digital supplements, was a highly collaborative effort involving schools from four European countries (Austria, Czech Republic, Hungary, Slovakia) and experts from diverse fields including 3D technology, information technology, pedagogy, natural sciences, and science communication. Notably, the project actively engaged teachers and children, the ultimate beneficiaries, in the development process. They played a crucial role in testing and providing feedback on intermediate prototypes.

3.1 Overview

The project itself was an Erasmus+ project (KA2-Cooperation among organizations and institutions, school education). The chosen priorities and topics were:

- Inclusion and diversity in all fields of education, training youth and sport
- Supporting teachers, school leaders and other teaching professions
- Addressing digital transformation through development of digital readiness, resilience and capacity

The duration was 24 + 1 month, running from November 2021 to the end of November 2023. The total granted budget amounted to 307.163,60 Euros.

In total, eight partners from four countries were part of the project (Figure 3). This includes four schools for blind and visually impaired students located in Vienna (Austria), Brno (Czech Republic), Budapest (Hungary) and Bratislava (Slovakia). Further, an NGO experienced with the building of the book's corpus (including the audio devices) and 3D-printing, a translator with knowledge of the project languages German, Hungarian, Slovakian and Czech as well as with experiences formulating audio text for blind and visually impaired persons were involved. Both located in Bratislava (Slovakia). The digital content and online social microlearning platform were built and set-up by an Austrian research organization, which focuses on the topic of social microlearning. Another Austria-based partner was responsible for the scientific support with regard to the teaching content, translating content to English and the general project management.

FIGURE 3: LOCATION OF THE PROJECT PARTNERS

Source: Economica, created with datawrapper

3.2 Outcomes

In total, four results were planned as outcomes of the *TaTaBooks* project: learning content in five languages for four topics (print and audio format), six physical *TaTaBooks* which consist of a corpus with drawers and an audio player, and four-time four 3D-printed topics (7 plates each) for every school as well as two-times one (prototype) topic for the remaining two books. The third result is the digital platform, which in turn is divided in two parts – a social microlearning platform and a sharing platform for the first result. The fourth outcome is the lesson's learned report at hand.

3.2.1 Teaching content

Teaching content has been developed around four themes:

- The Journey of Magellan (Austria)
- The Human Body (Czech Republic)
- Orientation and Mobility (Hungary)
- Geology (Slovakia)

Each of the four topics (selected by the school of the indicated country in brackets) was elaborated comprehensively and adapted to the needs of the target group as well as to various technologies and implementation methods (3D printing, audio and digital). Schools reviewed and commented on each other's themes. The final results included the design of each plate for each topic, a descriptive text for each plate, and the corresponding audio record of the text. For some topics, further texts and audios with additional teaching content were created. Further, some additional materials like textiles, herbs and spices, as well as sounds, were selected for the specific topics. Every text and audio were translated in English and the four project partners´ languages (Czech, Hungarian, German, Slovakian). In addition, some microlearning questions were created by each school and later translated for the others.

3.2.2 Physical *TaTaBook*

The physical *TaTaBook* (the corpus) has seven drawers that can hold the plates covering all four topics (in total 28 plates) fit in. In addition, the book includes an audio player, also equipped with all four topics and all five languages. Additionally, each plate is linked to the digital platform via an individual QR-code.

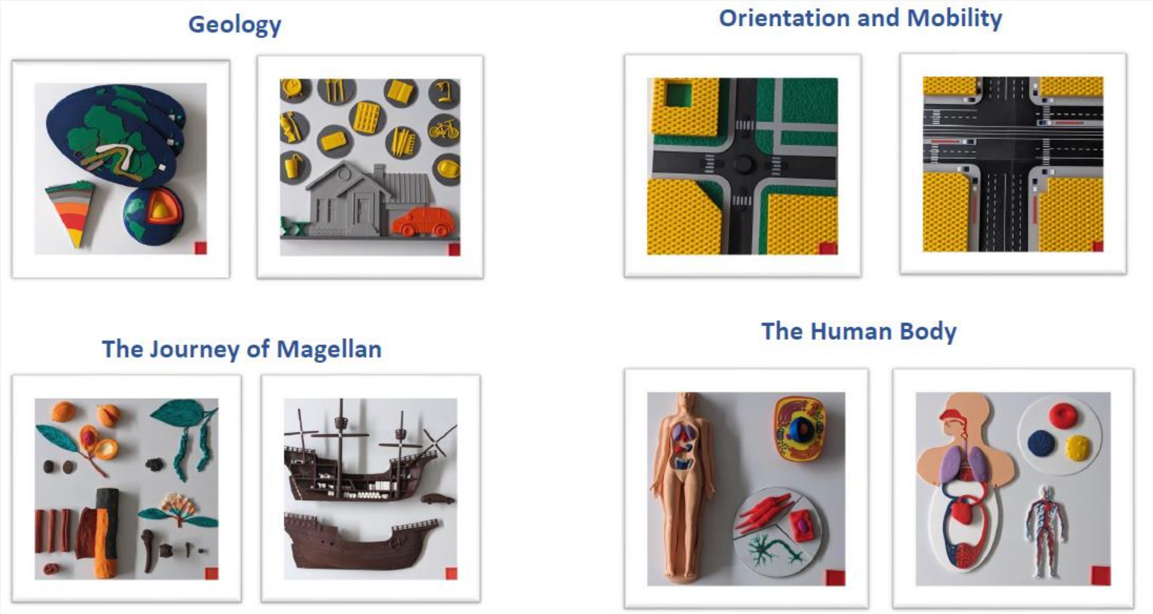
The final book is depicted in Figure 4.

FIGURE 4: THE *TATABOOK* CORPUS

Source: Economica, Erasmus+ TaTaBooks Project

The seven plates per topic can be used individually or "read" page by page, starting from the top to the bottom of the book. The audio content changes automatically each time a new book drawer is opened. Some examples of the 3D-printed learning content are given in Figure 5.

FIGURE 5: 3D-PRINTED TOPICS – EXAMPLES



Source: Erasmus+ TaTaBook Project, Economica

The development of the book, ranging from the topics and content to the design of the tactile book, was done in collaboration with the target group and the beneficiaries (teachers and pupils) themselves and with the support of relevant professionals. Each of the four schools also received a 3D printer, donated by the Czech company Prusa[4], so that they can reprint parts or to start new projects. The combination of tactile, audio and online, developed jointly by experts and the target group, is a technological and social innovation. The physical *TaTaBook* can be reprinted without further adaption. All you need is a 3D printer and the appropriate material. Printing plans can be easily shared and are also available on the digital project platform[5], on *Thingiverse*[6], and on *Printables*[7].

3.2.3 Social microlearning platform and exchange platform

The idea of adding digital components was based on the desire to make the book even more accessible, fun and flexible. Additionally, digital skills (practical use of a digital platform) of the teachers and especially the students can be trained and improved with it. In order to bridge tactile learning content

[4] https://www.prusa3d.com/

[5] https://soml.economica.eu/

[6] Thingiverse - Digital Designs for Physical Objects

[7] https://www.printables.com/de/@tatabooks_1155457

and students with visual impairments into the digital space, the resulting problems were explored in this outcome and transformed into a social microlearning platform. The final platform itself was preceded by several research activities, starting with a detailed needs analysis: The special needs of visually impaired students required new concepts and questions dealing with (a) how learning content can be enriched with non-linear audio content to meet the current standards of the Accessibility Guidelines. (b) How to enable visually impaired students to cognitively and psychologically grasp physical 3D objects through this learning content. (c) Using the currently available accessibility tools implemented on mobile devices. (d) Furthermore, the necessary new types of learning content must be stored to be able to share and use them in a social context. The need-based research activities were on the one hand based on existing literature, on the other hand on close collaboration with and consultation of actual users. Once the platform was set up, regular testing with users was done. Further, teachers – who were asked to create questions, were actively supported. All features and questions were translated into the five project languages.

In order to store all the learning content (text, audio) as well as the 3D files and to make them accessible to the interested public, a sharing and storage function was created within the platform. For each existing plate, there is also a learning card with the corresponding text and audio. Furthermore, the 3D models were uploaded to the 3D-printing platforms *Thingiverse* and *Printables* and linked to the respective topic within the platform.

Since the project works with a vulnerable group of people – blind and visually impaired children – who can access the platform, a barrier in the form of a registration and log-in was installed. This ensures that contents can be traced back to the person uploading them and, if necessary, the contents can be erased and persons can be blocked.

3.3 Procedure and timeline

To create teaching and learning materials that are inclusive, usable and motivating for blind and visually impaired students and their teachers, the process was set up as an inclusive collaboration between all partners, but also as one in which students and teachers gave regular feedback. What is more, the teachers were responsible to come up with a topic and to design each plate (page of the book) on their own. Additionally, teachers from the other schools were asked to provide feedback on texts and plates.

This cooperative procedure was chosen since it is user-centred and needs-based. Firstly, teachers know best what they want from a teaching tool, how they want to use it, and how to integrate it into the teaching process. Second, the involvement of blind and visually impaired students helped to design everything such that it fits best for the actual users. Having blind children and teachers as test persons was crucial because blindfolded adults have a very different tactile understanding. However, the downside of the intense cooperation and integration of many parties is that it was time-consuming and required a lot of organizational effort.

In general, the timeline was set up for 24 months, with five transnational project meetings for organizational topics and bi-monthly online-meetings. Additional, five “learning, teaching and training activities” (LTTA) were planned: one with all project partners with a focus on 3D printing and one for every school to develop the relevant content together.

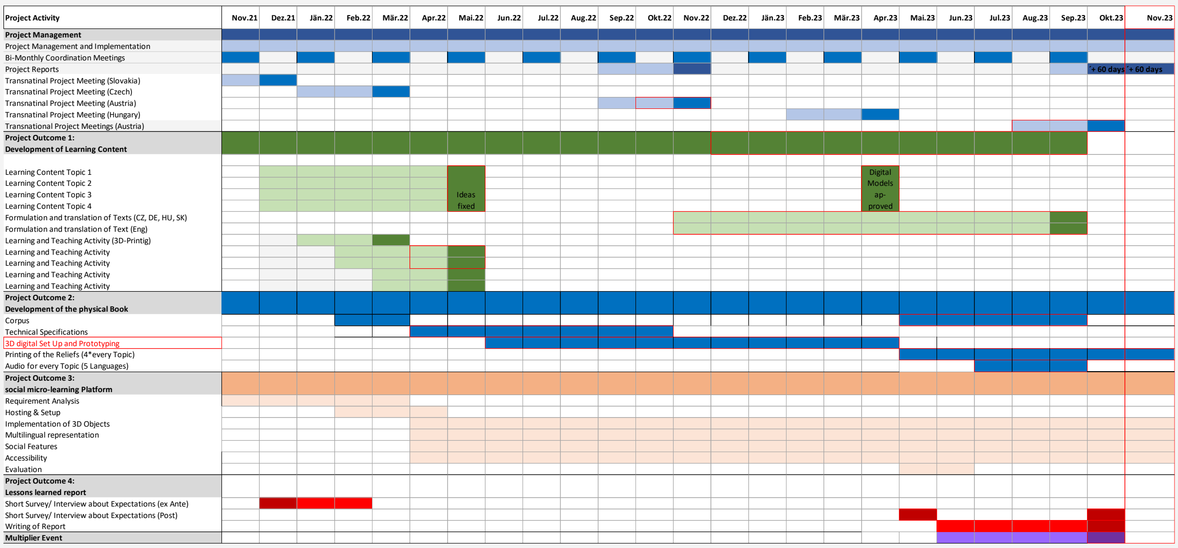
The first year focused on the development of the learning content, as well as the formulation and translation of texts. Regarding the technical parts of the project (3D printing), continuous work throughout the two years was planned, the same applies to the digital learning platform.

The intense cooperation and the emphasize on a needs-based and user-centric teaching tool, together with technical complexity, led to adjustments in the actual compared to the planned timeline. Much more time was needed to develop the ideas and the content of every plate, the same applies to the translation of the ideas into 3D-digital models (again with intense coordination among project partners). To design the complex and detailed ideas and wishes of the schools regarding their respective topics, took more time than was anticipated. Additionally, some tasks could only be started once final decisions were made regarding some other tasks / results. Therefore, to write the descriptive texts for the audios was only possible once the 3D-models were printed (at least as prototypes). Thus, the writing was postponed as well, which in turn postponed the translations.

Further adjustments compared to the original planned timeline were made regarding the bi-monthly online-meetings and one of the transnational project meetings. The latter was slightly postponed such that the results that were up for discussion were available at that date. The bi-monthly project meetings turned out to conflict with the general school schedule and availabilities of the teachers. Extensive and differing holiday and exam periods made it impossible to stick to accurate bi-monthly meetings. Furthermore, in the course of the project, it turned out the more needs-based and smaller (just selected partners) meeting were much more appropriate and led to better results. Also, the exact timing of the LTTAs was adjusted such, that they fitted better to the respective school schedule (holidays, exam periods).

The actual timeline is given in Figure 6, deviations from the planned timeline are marked with a red frame around it. The additional prototyping and programming of the 3D digital models as well as the consecutive character of some tasks and approvals by every partner led to the most significant adjustments in the time frame. However, sticking to the original plan would have resulted in less cooperation and less user-centric results.

FIGURE 6: ACTUAL TIMELINE



Source: Economica

4 Challenges and lessons learned

In chapter 4, the lessons learned – based on upcoming issues and challenges – throughout the project will be discussed. The first part focuses on a more general topic, the heterogeneity of the beneficiaries and the related challenges and lessons learned. The second part goes into detail, describing specific tasks, procedures and results, including the respective challenges and lessons learned. Therefore, the feedback of project partners was asked, once shortly after the midterm report and once around the time of the multiplier event.

4.1 Heterogeneity among beneficiaries

Although the project focused on the group of visually impaired students and their teachers and had partners from only four countries, there was considerable heterogeneity in various aspects, which posed many challenges. This section will briefly present the differences that were encountered during the project period, as they are an important factor when it comes to the actual and detailed procedure, as well as to the lessons learned.

Language and language capabilities: partners from four countries with four different languages participated in the project. Czech and Slovakian individuals were able to understand each other when needed in their mother tongue. The official project's language was English. However, not everyone was capable of speaking or even understanding English at a sufficient amount. Some partners were capable of understanding German to some extent. This led to the situation of a heterogeneous language mix without a common language understood by everyone involved. To approach these issues, additional teachers translated at meetings, the communication was carried out in German and English and automatic translations were used whenever something was written. However, those solutions had two downsides: first, it was rather time-consuming and second, misunderstandings or translation errors were something that happened occasionally and needed special attention. A third, more general issue was that not everyone felt comfortable communicating in a foreign language and therefore did not actively participate or raise questions / ideas / comments.

The lessons learned from the challenge of language heterogeneity was, first of all, to make sure, that everyone could understand everything to a sufficient degree – either through human or technical support. Reformulating text or actively asking for feedback was a good way of ensuring that everything was understood. Further, giving partners the opportunity to communicate in their native language (and having a translator) was more comfortable for most partners. Also, talking to the partners more privately (e. g. 1:1) and not in front of all partners increased the comfort and therefore participation.

Regarding financial or organizational topics, a translator was necessary to ensure that every detail was known to every partner and understood by everyone. Less formal communication was also possible using digital translations or with the help of project partners that were able to communicate in the necessary languages.

Schedules: The partners' daily working routines differed, as did the planning and scheduling of the school year. Foremost, the partners were employees, self-employed, teachers and headmasters, all with different working hours and holidays. The fact, that four countries were involved did not make it any easier. This was most obvious during holidays and exam periods, but also during "normal" times when the preferred working hours and days tended to vary between partners. As a result, planning and scheduling was difficult and required more effort, especially when more than two partners were involved.

The lessons learned from the challenge of varying schedules and types of employment were twofold. Firstly, meetings that included all partners were planned early using the help of digital planning tools or were dependent on the confirmation of every single partner. Regarding the planning of whole group meetings, it was helpful that usually two or more persons from each partner organization were involved in the project. This made it more flexible and reliable also in the event of sicknesses.

In cases where only a few or even a single partner was involved (individual deadlines, meeting with special questions, etc.), the schedule was adapted to these partners to respond to their working hours, holidays and so on. Coordinating meetings with only a few partners was much easier, so meetings were kept as small as possible. Often this meant that a meeting on one specific topic was held several times – each time with different partners. This not only had the advantage of reducing organizational issues but also allowed more focus on the needs and questions of each individual partner. A good example of such a meeting was the individual discussion of each topic in each school, including the respective school and the other partners involved in the content creation. The overall discussion of all topics and with everyone was then postponed to the next transnational project meeting or to an online meeting.

Blindness and visual impairment: blindness and especially visual impairments can take many different forms – partial loss of sight, reduced field of vision, colour blindness and so on. Further, it also depends on when the sight loss happened. All types of visual impairments were represented in the four schools, so both the *TaTaBook*s and the digital content had to be suitable for them all. The solution to this problem was extensive testing of materials, colours and sizes together with students and teachers.

The lessons learned from the challenge of various types of blindness and visual impairments is to integrate as many future users as possible during the whole process and to test every feature.

Types of students: apart from the different types of blindness and visual impairments, the students differed across or even within the four schools in some general aspects. First of all, some had multiple disabilities – both physical and mental, while others only had minor visual impairments. Second, the age varied considerably across the schools ranging from primary school children to teens or even young adults. Further, the socioeconomic background of the students varied and in some of the four schools, the share of students with the respective language (German, Hungarian, Slovakian or Czech) as a non-native language was considerable.

The lessons learned from the challenge of heterogeneity between and within schools were, firstly, to be even more user-centered and to involve as many students and teachers as possible in the process. Giving them time and asking for feedback was essential. Further, each school designed their content and the other materials in a way that best suited their students. However, this meant that not all topics may be used in the planned way for all students (e. g. because topics were too complex or parts were too small). Individual adaptations of the texts or the teaching method were a solution and are planned in some schools. It may also be useful to use the book in other classes or contexts.

Focus of schools: related to the various types of students is the different focus of the four participating schools or, more precisely, the different focus of the classes that were involved in the project. Overall, the schools differed in their general orientation.

- School 1: integrative school with blind and visual impaired but also children without impairments together in one class. The school covers children from the first to the eight year (age six to 14). The school offers additional afternoon care, but in general children came for the lessons / school day. Most of the students were living close to the school.
- School 2: school and boarding school for children with visual impairments as well as other disabilities. The school offers lessons and classes from kindergarten to primary school and vocational training. Apart from teaching the focus is also on special education, diagnostics, (mental) support and consultations.
- School 3: kindergarten, primary and secondary (vocational education and high school) school for children with various disabilities including blindness and visual impairments. The school offers special education (e. g. music therapy, orientation and mobility) and afternoon care. The classes taking part in the *TaTaBook*s project were vocational education classes in the subject of massage therapy
- School 4: kindergarten, pre-school, primary and secondary school (special vocational education). The school is also a boarding school and a children's home. In total 220 students from the age 3 to 23 are learning and / or living at the school. Classes also include special education for blind and visually impaired students.

Furthermore, the education of the teachers working with blind and visually impaired students and the working conditions vary across countries.

As with the heterogeneity of students, the different focuses of schools led to the fact, that an even more integrative and user-centered approach was needed during the project. The teachers had a clear understanding of how and where to use their *TaTaBook*. Feedback from pupils and teachers from other schools was welcomed and often provided a new perspective. However, the final decision rested with each respective school. As a result of the different focuses of the schools and classes involved, but also because of the heterogeneity of the students involved, the topics varied not only in content, but also in the actual design and teaching focus.

Technical skills and use of technology: 3D-printing but also the digital platform require some (basic) technical skills. With regards to 3D-printing, the technology was new to almost all teachers involved. The social microlearning and the digital platform required a device (smartphone, tablet, computer) to access the platform. What was used (if at all) varied from school to school, and the availability of e-mail addresses for students was not a given. Furthermore, not all students had a digital device or were allowed to use one in class. Those who did, are using different devices and different tools (screen readers).

The lessons learned from the variety of technology use and the technical skills is to make each type of technology as open as possible (e. g. not specifically adapted to one tool or technology). Also, specific support – especially in the beginning – on how to use certain technologies was very helpful. The involvement of additional teachers, such as IT-teachers or technicians, also worked well.

4.2 Results – challenges and lessons learned

4.2.1 Teaching content and topics

The teachers were responsible for choosing the topic and the content of each plate. They were free to ask for help and to draw from external expertise. The latter was done by two schools. Further, each school was also responsible to check the translated teaching content of the other topics and if necessary to adjust it.

Initially, it was planned to have a descriptive text per plate and some teaching content per plate. However, the opinions on that differed between teachers, also in respect to the length and detail of the texts. Thus, the available texts (description, teaching content) and the length of them vary from topic to topic (and also from plate to plate).

The main reason for choosing the respective topic was a lack of specific materials. Most teachers had a clear idea in mind what they needed but so far, no opportunity to get it (e. g. a 3D map of a nearby street, tactile material on geology). Another reason was the thematic focus of some schools, for example massage therapy. Also, the exact and individual structure of a topic (exact content and how the content was presented) was an important factor.

The topics of each school are available to every school. Only minor changes in the content were made by the schools regarding the other topics.

Overall, the remarks by the schools showed that there is a need for individual teaching material for blind and visually impaired students. It appears to be crucial to adapt the material to the specific needs of each school and / or group of users. The teachers had clear ideas of what they wanted. The materials designed by the other schools are seen as a nice benefit, but not as the core of the project.

The process of creating the content – alone, with external experts – depended strongly on the knowledge and available time of the teachers. Translations but also handing out the translations to each school proved to be important, since the actually used style of language and specific words or teaching content differ slightly between the countries and schools.

With regards to the necessary time to create the content, teachers stated that it was enough. One comment was, though, that sending audios (and this may also apply to the texts and translation) should have been sent one by one to test and not altogether. From an organizational perspective, sending everything together was much easier and required less monitoring and checking on everyone, that everything is completed. Since many parties and documents were involved (four-times at least 7 texts in four languages), handling documents topic-wise was much more efficient and required less e-mail traffic. Although, a platform to share documents was set up and sharing document by document would have been possible, it showed, that e-mailing documents was working much better.

Teachers were also asked if they were thinking about additional topics. Overall, the possibility to extend the book with more topics was seen positive. One school noted that they would even add plates to the existing topics.

The main lessons learned were that the partner schools participated in the project because they had a need for specific teaching materials for a certain topic, and the 3D-printed book was seen as a possible solution to this need. The challenge was – at least in the beginning – to bring also the other topics closer to the teachers and to explain why they were chosen and how it is planned to use them.

Also, re-checking the translations (and texts if written by someone else) proved to be important, since specific wordings but also certain contents may differ per topic, language and school.

Finally, following the user-centric approach turned out to be important not only in terms of the actual content but also in terms of the style of the text. For some schools, having some teaching content – in addition to the descriptive text – was important, others only need the description and will do the teaching content verbally and situational.

4.2.2 The physical *TaTaBook*

The physical *TaTaBook* is the heart of the project and unifies the other parts (content, text, audio, 3D printing, digital contents). Although the general look of the book was set, some things were still up for discussion at the beginning of the project (types and amount of audio buttons, access to digital content, number of drawers, configuration of drawers). Due to technical reasons, most of those features needed to be identical for all schools; otherwise, the topics would not be usable in all schools. To have a prototype at disposal was very useful, and compromises on all topics could be reached. The integration of a connection to the digital content proved to be an important part. Now the book can be used as starting point and additional content, including the texts and audios, can directly be accessed via QR code.

The book was designed in such a way that it is usable by more than one student at a time. Students can touch the contents with both hands at their own speed. The corresponding audio (included in the book) reads the description of the plate in use. Further, some audio-teaching content is available for some topics as well as additional materials (e. g. cloth, spices).

Throughout the project, teachers but foremost students tested prototypes or similar, existing books. This proved to be crucial and gave valuable insights regarding shapes, colours, structure, usability, touch and durability.

Example – colours, shapes and structures

The book is for blind and visually impaired students. Thus, colours, shapes and structures play an important role especially since visual impairments can be various. Therefore, the testing also included various visually impaired persons (and not only blind students), focusing on the chosen colours.

Further, an important aspect is to stay consistent with respect to chosen colours, shapes and structures. A line symbolizing a grass line must always have the same colour, shape and structure.

The books will all be integrated into existing lessons. Although, the book has an ongoing story, most teachers will only focus on one plate / topic per lesson (or even in a longer term). It will either be used to introduce a particular topic or to provide a “theoretical” background, as in the case of orientation and mobility.

Depending on the students, the teaching style will mostly be individual (1 by 1). The book may be used by more students at once, and the audio content can be played without a teacher explaining everything. However, from today's view, a more individual and detailed examination and application of each plate appears to be the preferred way.

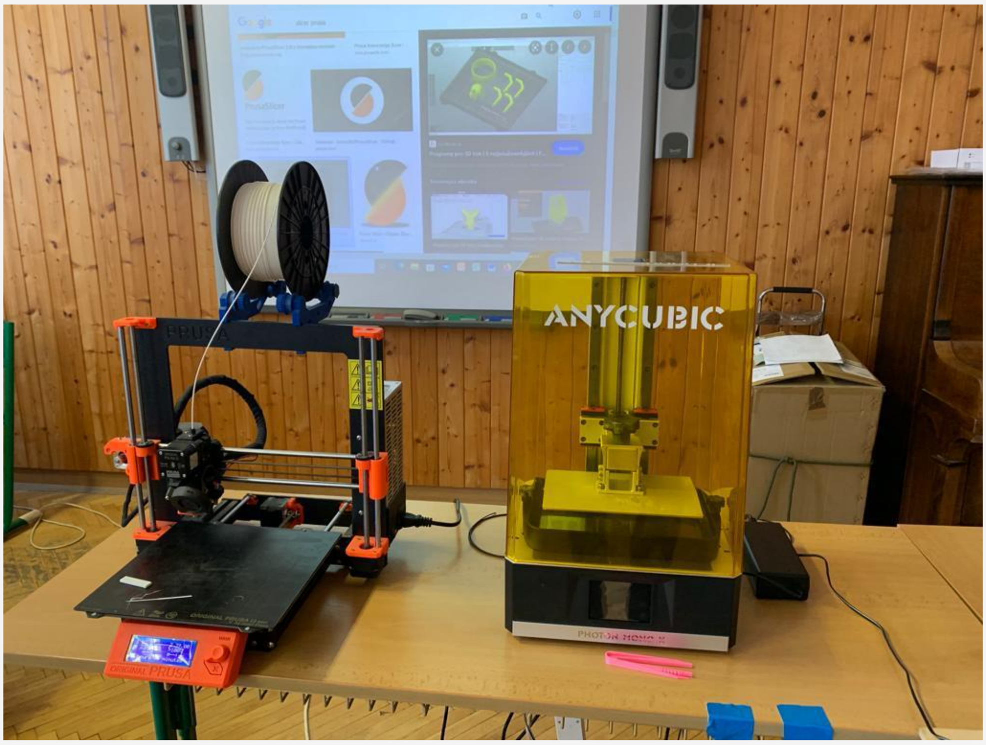
The main lesson learned is to be as user-centric as possible while keeping a certain level of interoperability. Incorporating theoretical background knowledge in the first prototypes is important, however, extensive testing by the actual users were key, even more so if the users are a heterogeneous group (age, degree of visual impairments, type of impairments). The testing and prototyping took considerable time, especially since the printed content was more complex than anticipated. Although, the teachers and students had a general idea about 3D printing and what is possible with it, the technology was rather new to them, further increasing the need to test. For any future project that incorporates new technologies and special user groups, enough time for hands-on testing and prototyping should be given.

An advantage of the physical book (form of a drawer) is that it is rather stable and can be used by blind individuals without support. However, those are no features with a major relevance for schools, as follows from the statements of the teachers. So future projects may focus more on individual plates (e. g. using more and different materials) as well as on additional teaching content and less on the concept of having a “book”. This would also improve the portability of the books. Although the audio content is available within the book, QR-codes make it possible to access any additional content, including audio, with a smartphone. This is further supporting the idea to focus more on the plates and less on the corpus.

4.2.3 3D-printing and 3D-printers

3D-printing was one of the technologies used to create the final and physical book. The use of this technology was a core aspect of the project. Apart from the final book, the four schools also received a 3D-printer (Figure 7, left printer) each to be able to print additional material or to replace any materials. At the very beginning of the project, a workshop was held to familiarize everyone with the new technology. The actual printing programming of 3D models and the printing of the plates was done by experts, however. The main reason therefore was, that while it is comparatively easy to print small and already existing models, it is much more sophisticated to create new models. Here expertise and experience are required.

FIGURE 7: 3D-PRINTERS



Source: Erasmus+ TaTaBooks, Economica

The participating teachers had no to very little experience with 3D-printing, although some already thought about the possibilities it holds for blind and visually impaired students. At the end of the project, one school already printed minor parts on their own with the help of the school's IT specialist. However, they were positive to use the printer without any help in the near future. Other schools were about to increase the teachers´ knowledge with external courses. Some teachers did not feel comfortable using the printer yet but are planning to gain some additional knowledge and to use the printer.

One remark though was that not everything that can be printed is meaningful to print. Very often, there are already existing materials and examples. In general, everyone saw the benefits of the technology. However, since the teachers were part of the project on their own accounts, this is not surprising. The main advantages of the 3D-printing technology – as the teachers see it – is that anything can be printed and that individual needs can be fulfilled. Additionally, it is often faster to print a part than to search for an alternative and to wait until it is delivered. Also, the low costs were mentioned. Another school saw the costs as a disadvantage. A further downside is the extensive technical knowledge that is necessary to start printing and the time to gain this knowledge.

The general lesson learned with regards to 3D-printing is, that the participating teachers were very open towards new technologies and the advantages they may have for their teaching and their students. They are all highly motivated and took first steps to use 3D-printing on their own and to gain further knowledge and confidence. A suggested improvement for future projects with any kind of new technologies would be to have continuing workshops on how to use the respective technology. Once teachers knew, what can be done with 3D-printing, they became much more motivated to try it on their own, here some additional support may be useful. If this accounts to all teachers remains unknown, since the participating schools self-selected them into the project.

Nevertheless, all schools were inexperienced and letting the printing be done by experienced experts was the best decision. Otherwise, the printed materials would most likely not have been as needs-based as they are now, but rather simple and based on existing 3D-printing-materials. Additionally, due to the little experience and technical knowledge, much more time was needed in the beginning but also throughout the project for prototyping, testing and feedback-loops. Further, managing expectations on what can be printed and what not, was important. Knowing and testing technical limitations is also a key element during the design of the actual contents. The main issues with regards to the specific *TaTaBooks* topics were the feeling, the flexibility and the size of some parts.

- Feeling / touch: the material used for printing was plastic, which hardened once it dried. Although two types of printers and thus of materials were in use, only little tactile differences could be printed (compared to the use of different materials). Variations were achieved through different patterns. Further, additional materials were included like cloth, actual stones, etc.
- Flexibility: connected to the "feeling / touch" of the printed material is the missing flexibility. Especially in the context of the human body, some flexible parts would have been beneficial (i. e. for the bladder). Further, flexibility in the sense of movable parts was an issue. First of all, joints or puzzle like structures must be in such a shape, that the joining is not wearing out the material too much. Second – and this was an issue which was only realized by testing it with visually impaired students[8] - once a part was placed in the right spot it must remain there even without a completed puzzle / shape. So, it must be possible to fix every lose part (e. g. a leg, a continent) on its own. This problem was solved by either using magnets in the loose parts or by creating positives and negatives (so a specific hole where only a certain part fits). Often both were applied.

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[8] One prototype was a cell which was cut in different parts. The idea was to have a puzzle and to be able to have every part (nucleus, mitochondrion, …) separately. The individual parts were clearly distinguishable and had straight edges but no joints. The testing with blind people however showed, that although the students were quick in identifying neighbouring parts, it was not possible for them to fit them together, since the individual parts moved around significantly when the students tried to fit the neighbouring part.

- Size: the printers are generally able to print tiny items. However, some issues come with it. First of all, very small parts or to be more precise, the details on them are difficult to feel and to identify, even for people with extraordinary tactile abilities. Second, they are more prone of getting lost (if removable) or even pose a threat to (small) children if they are accidentally swallowed. If they are fixed, however, they might fall or wear of, if touched frequently.

4.2.4 Social microlearning platform and exchange platform

The social microlearning platform is an adaptation of a social microlearning platform (see for example Goeschlberger, 2022) to the needs of blind and visually impaired people. First of all, this means that the platform must be accessible for the blind and visually impaired. The accessibility was tested against the *Web Content Accessibility Guidelines* (WCAG)[9] and the platform reached a conformity level of AA (Duh et al., 2023). Apart from the rule-based approach, also a user-centric approach was chosen. In the very beginning, students and teachers were asked which technological devices they use (in the lessons and privately), later, some students tested the platform and provided valuable feedback.

With regards to the devices, a significant heterogeneity was identified. Only some schools had laptops / other digital devices. Nevertheless, digital technologies are used in one way or another by all partner schools. This ranges from online tools, IT-lessons, digital literacy to digital textbooks and interactive boards. The use of private phones was also handled differently. However, most students owned smartphones and used them frequently. They were familiar with screen readers, voice over programs and so on. The different brands and systems emphasized the need for an open-source technology, so the platform can be used independently of the digital device.

The feedback from the students gave some valuable insights, that were not covered by the WCAG guidelines. Some of the identified challenges were rather technical issues (e. g. automatic translation independent of the used software). Identified issues affecting the usability were:

- Log In with special characters: in this case, the location of the @ symbol posed an issue. This might also be the case for other special characters not frequently used.
- The length of the page: determining how far the page goes down and locating where they are was seen as an issue.

Overall, the students were able to use the social microlearning platform (answering questions, checking answers, reading and posting comments) and thought the platform easy to navigate (Duh et al., 2023).

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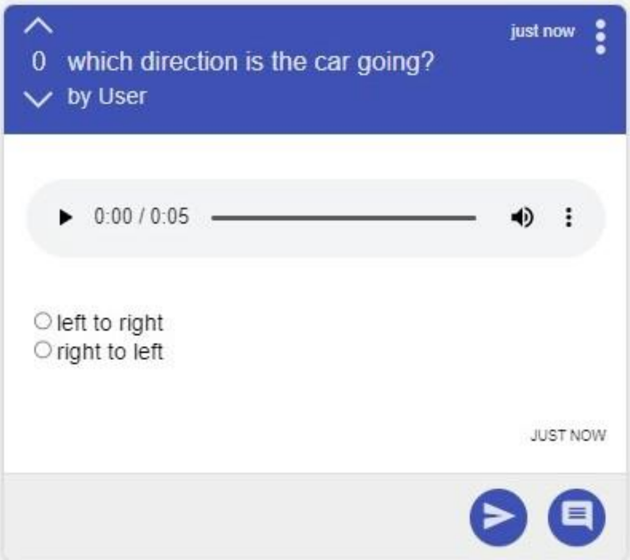
[9] WCAG levels of conformity: A (25 criteria), AA (37 criteria), AAA (60 criteria).

Initially, a separate platform for the upload and sharing of the contents (3D printing files, audio and text) was planned. Throughout the project, however, it became clear that it is preferable to have everything together, such that students and teachers can access questions and for example the audio on one and the same platform. To achieve this from a technical point of view, new plugins were created for the new types of contents. Now, the QR code on each plate leads to the corresponding group of questions, the audio file, the text file as well as a card with a thingiverse-link[10] for the 3D printing plans. Thus, all contents can be accessed directly and are easy to find and use.

FIGURE 8: AUDIO CONTENT



Source: Erasmus+ project TaTaBooks, Research Studios Austria FG

So far, there are questions for every topic and plate created and set up by the teachers. Once a new question was created, it was translated into the other languages such that all questions exist in all languages. The handling of the platform and the creation of the questions took a little exercise, but was doable for all involved teachers. One remark although concerns the translation of the questions: for some questions a straightforward translation is not feasible. Either because the topic is too specific (e. g. some local knowledge required), or a meaningful translation is not possible for some words / questions.

[10] Thingiverse is the biggest online sharing platform for 3D printable models. To make the models available to a wide range of users they are uploaded to thingiverse and linked to the learning and sharing platform of the TaTaBook.

Example – a synonym for "volcano"

In Slovakian, there exists a synonym for the word "volcano". One geography question was to identify the synonym. Although the translation of the question and the answers was technically possible, it was not meaningful, since no synonym for the word volcano exist in most other languages and thus both words would have been translated to "volcano".

At the end of the project, teachers were asked for their opinion on the social microlearning platform. The microlearning platform and the possibility to connect it with the book using a smartphone was seen as a benefit that motivates students. From the technical point of view, using an open-source technology is beneficial, since it allows everyone to take part and to access the platform.

Some of the teachers are not yet sure, how to integrate the microlearnings into other classes / use it for more topics, but generally, everyone saw the benefits and was positive on further usage.

The lessons learned are including various aspects. First of all, the use of digital devices and technologies is also done on an everyday basis by blind and visually impaired persons and both is integrated in the teaching curricula. So, when it comes to offering digital tools, no difference between seeing and to blind or visually impaired students should be made. Especially since all the teachers saw this learning tool as a good opportunity to make learning more interesting and fun. Checking the accessibility is an important and using guidelines like the WCAG is a good starting point. However, testing the tools with the actual users is also very helpful that gives valuable and additional insights.

Due to the variation in used soft- and hardware, open-source technologies are preferable. Also, a so called one-stop-shop is favoured over having multiple platforms.

Apart from the students – who tend to be digital natives and frequent users of digital technologies – also the teachers must feel comfortable using the platform.

Besides the topic of accessibility, also the multi-language features were a concern. Although, automatic translation improved very much, there may be some technical issues but also some other issues like non-existing synonyms or differing formulations. So, a final check – best by a native speaker or the final native-user – is necessary.

4.3 Procedures and organization – challenges and lessons learned

Apart from the actual results, the procedure and organization – the road to the results – are important factors as well. As opposed to the results though, visual impairments are less at the center of interest but rather general organizational factors of heterogeneous stakeholders (language, types of employment or working style, timelines, (technical) skills, and so on).

Overall, the greatest challenges were the scheduling and timing under the constraints of technological uncertainty and a high complexity, as well as the different types of employment and working environments (e. g. schools in four countries, full-time, part-time employment, self-employed). Further, some language barriers posed challenges.

4.3.1 Project management, contractual and financial topics

The project's framework was given by the contractual and financial rules and factors given by the type of the project (Erasmus+ project). First of all, only due to the financial support of the EU, the project with it all the results were possible. The little organizational requirements for the schools were very beneficial, as were cost categories with lump sum amounts. Cost categories based on actual costs or working days were less easy to plan and required more management and monitoring effort. In general, the clear rules and guidelines were helpful.

Nevertheless, some challenges related to project management, financial and contractual rules were faced in the course of the project. Firstly, the innovative character of the *TaTaBooks* led to the fact of some, at the time of the proposal writing, unknown developments. The most striking was the increased technological complexity of the printed content as well as the necessity to have some tasks in consecutive steps and not in parallel, especially if user-centricity were to remain at the core of the project. Further, technological improvements also led to changes. For example, AI-based audio recording improved significantly with regards to accessibility, quality and usability in all languages. Thus, the challenge was to tackle the unknown (technological) developments within the contractual framework whilst keeping the users and the goal of the project at the center.

The second challenge was language barrier, especially within the context of contractual texts in English. Most partners were able to communicate either in German or English at least at a basic level, however, legal or contractual details were sometimes challenging.

The lessons learned from those challenges, were to apply the user-centric approach, as it was the case for the results, also to the project management. The challenges led to a much more active and "caring" management throughout the project as was initially anticipated. Instead of waiting for the partners to ask questions or to hand in results / bills / timesheets / etc., the management actively and regularly approached partners (usually 1:1) to discuss specifications, ask questions and to anticipate potential issues. This proved especially helpful for those partners with greater language barriers and / or greater contractual requirements. Further, the 1:1 (partner:partner) approach was more suitable to discuss specific organizational tasks, than group meetings, since the language and the topics could be adjusted to the respective partner. Upcoming topics, relevant for everyone, were, of course, discussed with everyone.

With regard to the uncertainty and complexity an innovative technology holds, the lessons learned were, first of all to be open to the new possibilities without losing the focus and goal of the project, as well as the financial and contractual frame. Second, to have all partners aboard – meaning to see the new possibilities in practice, to test them and to discuss the development also in terms of financial implications and changes to the timeline. In the end, the users had to decide how or if to integrate those new developments. Individual decisions (every partner could decide for their own topic) were favored. If this was not possible, a suitable compromise was found. The testing and discussing proved to be crucial, since the schools were the final users and – rather often – had a different approach to technologies.

Example – audio records

The initial plan was to work with professionals or with teachers and students, in any case with humans to record the texts for the TaTaBook. The improvement of AI audio-programs in all the necessary languages (Czech, English, German, Hungarian, Slovak) however offered new possibilities.

The advantages of the AI programs were speed, adaptability and less costs. The disadvantage was the still artificial voice and less opportunities to create a lively and thrilling record. The scientific and professional partners favored the human audio records (quality, more human, etc.). Most teachers however, were in favor for the AI. As they noted, most students are familiar with artificial voices (e. g. from screen readers) and the possibility to make changes to the texts and let them easily be re-recorded, as well as the quicker results were seen as more important.

4.3.2 Timeline

The timeline and changes to it were strongly connected to the technological complexity, challenges and the resulting adaptations. Those topics were already discussed in chapter 4.3.1. With special respect to the effects on the timeline, the lesson learned of those challenges was that user-centricity and this includes foremost the close cooperation and intensive testing and prototyping should be at the core, although if this leads to changes in the timeline (within a reasonable frame). All teachers noted, that prototyping and testing was essential to them, since most had no clear idea of what was possible and how the material would look and feel.

Another challenge concerning the trimline and scheduling were the heterogeneities between the partners with respect to:

- Own schedules (holidays, exam periods)
- Types of employments and resulting ways / times of working
- Prioritizing of the project and with-it speed
- Internal organization of project teams, testing, hierarchy
- Preferred communication style and response times

Apart from those more technical and organizational challenges that also had technical and organizational solutions, the main issue was connected with the consecutive testing and approving of everyone (e. g. texts, audios, 3D printing plans). The schools handled and prioritized those tasks differently, which in some cases led to waiting times and even to some frustration of those partners that were rapid and needed to wait for the others. The lesson learned from this challenge was to create a personal connection between all partners involved (physical meetings). Knowing who is behind some ideas and tasks and how important those things are to the others (and why) led to a common understanding.

4.3.3 Learning, teaching and training activities

The learning teaching and training activities were an important part and essentials for the development of the topics. Also, the teachers identified them as very helpful and significant. The success of the workshops led to the fact, that later transnational meetings were partly designed in a similar way – intensive topic and / or school-wise working groups.

The learning teaching and training activities (LTTAs) were designed as workshops. One was for everyone with a focus on 3D printing. To create the contents per plate, every school had a workshop focusing on its respective topic. Here only one school and the non-school partners participated. The focus on only one school and topic at a time was very fruitful since it was possible to work on the content, ask questions, test and discuss together. The project partners from the schools stated that those LTTAs were helpful and creative. Further, they also gained a more profound understanding why the other schools had chosen their topic[11] and what they considered as important. Although, it was also mentioned that there was not enough time to finalize everything. One remark from one partner that participated at all workshops was, however, that some schools were prepared very well and used the workshop to discuss details and the technological implementation, while others were less prepared and used the workshop to generate first ideas.

There were no general challenges with the LTTAs, nevertheless, some lessons learned occur. Within the context of the *TaTaBooks* project, the focus on one specific topic with only a small group of persons was very effective. It was important to discuss in person (with all experts being available) and to work hands-on, e. g. testing prototypes, drawing models, listening to text. The workshops gave the teachers time and room for discussions, questions, and therefore allowed or sometimes obliged them to work intensively on the topic. Since the workshops were efficient and effective, some parts of the agenda of transnational project meetings were held similarly. Topics relevant for everyone (e. g. organizational matters) were presented to everyone, tasks that were only relevant for some partners were held in the

Example – last transnational project meeting

The last transnational project meeting was held in a hybrid style mixing workshops and group meetings. The partners all had different tasks left to do before the project could be finalized. Further, some general (organizational) topics needed to be communicated to everyone. The meeting was started and closed with some general and organizational topics. During the day, the schools were allocated to different workshop-like stations and had the time to finalize open tasks individually.

	School 1	School 2	School 3	School 4
Checking own TaTaBook	X	X	X	X
Checking TaTaBook of the other Schools	X	X	X	X
Correcting Audio Files individually	Already completed	Already completed	Already completed	X
Correcting Audio files together with expert	Already completed	X	X	X
Answering questionnaire	X	No time, sent answers per mail	X	No time, sent answers per mail
Other open issues	none	Preparing the presentation	X	Preparing the presentation

[11] In the beginning of each workshop, the ideas and thoughts of the other schools were presented.

style of the workshops. So, every school / partner could work on specific tasks whilst being able to discuss the results or open questions with other partners. An additional benefit of this procedure was that everyone could use the time in a meaningful way, depending on where they were standing in the project.

4.3.4 Organizational meetings

The organizational meetings were the transnational project meetings, planned bi-monthly partner meetings and meeting of the involved employees of the project coordinator. Throughout the projects, it became evident, that following the set meeting schedule is not always meaningful. Rather, a needs-based approach was chosen. The partners had specific topics and questions, also the spoken language varied, thus having everyone together in every meeting was not purposeful. Additionally, there were times when more or less intense coordination was needed (e. g. finalizing the texts vs during the summer break). The meeting within the team of the project coordinator took place in an informal, often daily routine and whenever the project became more intense with specific and scheduled meetings.

As noted in chapter 4.3.3, some of the transnational meetings were held in a hybrid form (classical and workshop style), also to focus on the specific needs of the partners.

5 Conclusion

The *TaTaBooks* project with all the components of the book but also with the diverse partners involved, was a learning journey for everyone. Both, from the results and contents, as well as from the management and organization of the project, many lessons could be learned.

What became clear throughout the whole project, and was further supported by the literature, is to follow a user-centric and needs-based approach. The teachers, but even more the students know best what they need and how they will use certain results. This is always true, but especially for groups with special needs. On a practical side, the user-centric approach requires a lot of prototyping, testing and corrective loops. Which in turn requires a significant amount of management, organization and time.

Applying new technologies increases the complexity as well as the likelihood of unknowns. However, it is a great way to create something innovative and beneficial. Gaining a hands-on understanding of what is possible and what is feasible is an essential starting point.

The needs-based and user-centric approach was also chosen regarding the organization and coordination. This was grounded in the heterogeneity (requirements, languages, different working style and speed) across partners which made coordination rather complex. In practice, this led to many 1:1 meetings or meetings with only some partners and only a few sessions with everyone (discussing topics relevant for everyone at that point in time). Further, focused working groups with specific tasks, the necessary time and experts usually yielded better results as a more general scheduling of tasks and deadlines per partner.

The positive and even excited reactions of people outside the project – the book was already presented at conferences, in the media, at the multiplier event and to politicians – emphasizes the need for such learning material, not only in the context of blind and visually impaired children but in general. The technology of 3D printing enables to have tailor made and tactile materials which pose the user in center of attention.

List of figures

List of tables

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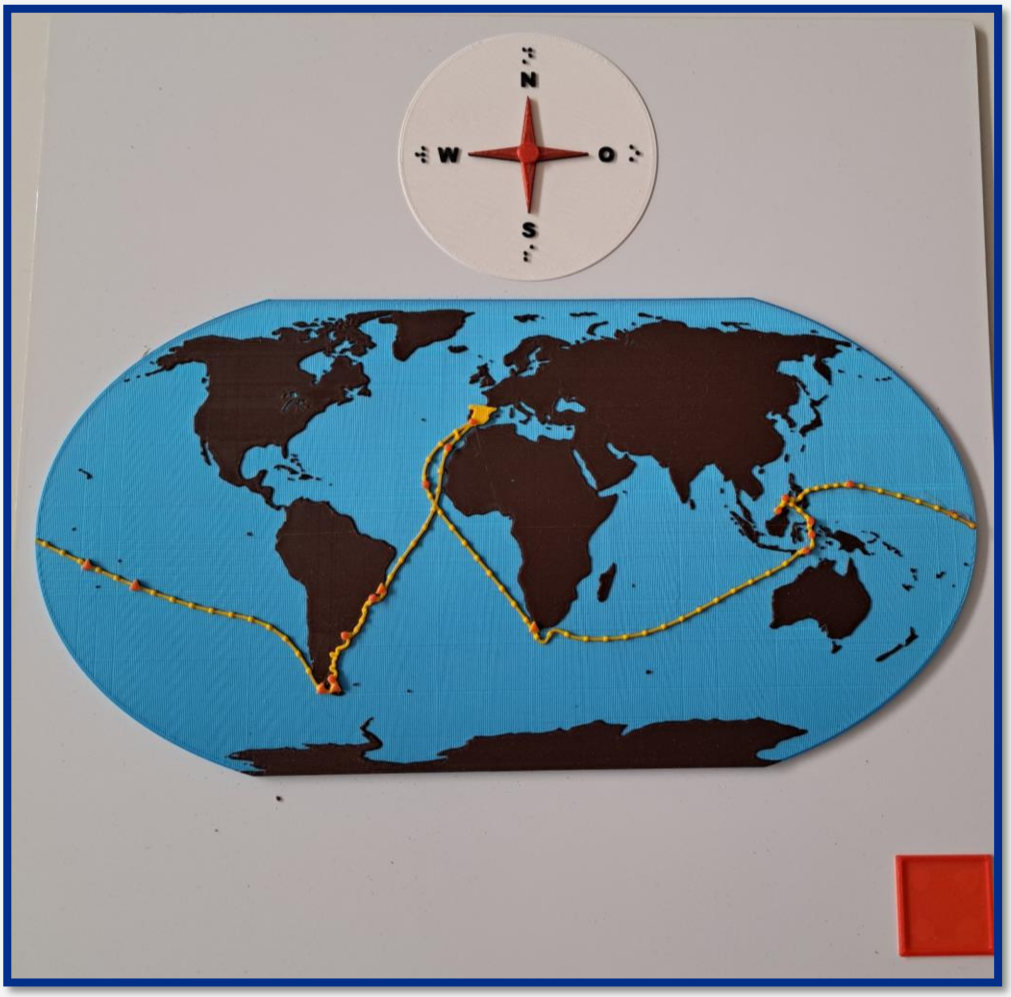
Appendix

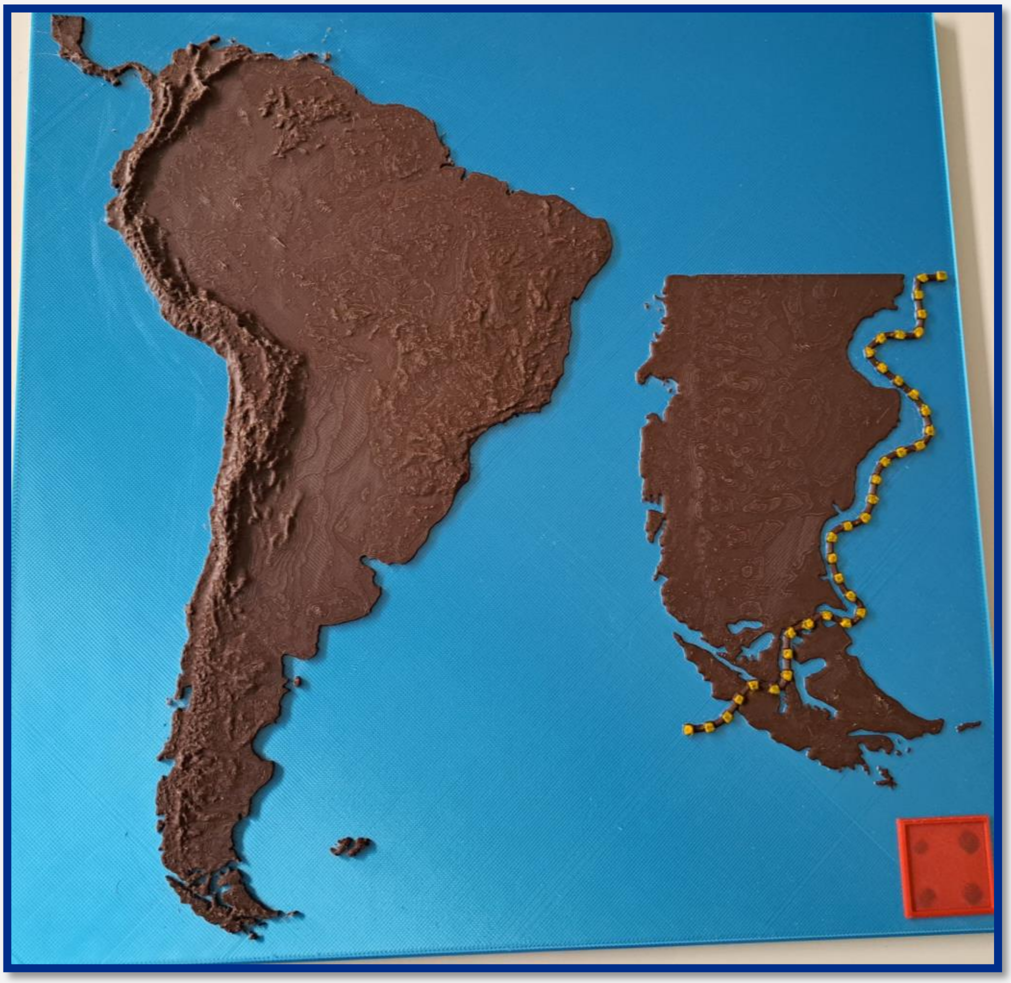
The journey of Magellan

FIGURE 9: WORLD MAP



Source: Erasmus+ TaTaBooks

FIGURE 10: SOUTH AMERICA



Source: Erasmus+ TaTaBooks

FIGURE 11: SHIP OUTSIDE

Source: Erasmus+ TaTaBooks

FIGURE 12: SHIP INSIDE

Source: Erasmus+ TaTaBooks

FIGURE 13: PERSONS

Source: Erasmus+ TaTaBooks

FIGURE 14: HERBS AND SPICES

Source: Erasmus+ TaTaBooks

FIGURE 15: ANIMALS

Source: Erasmus+ TaTaBooks

Human body

FIGURE 16: HUMAN BODY AND CELLS

Source: Erasmus+ TaTaBook

FIGURE 17: SKELETON AND MUSCLES

Source: Erasmus+ TaTaBooks

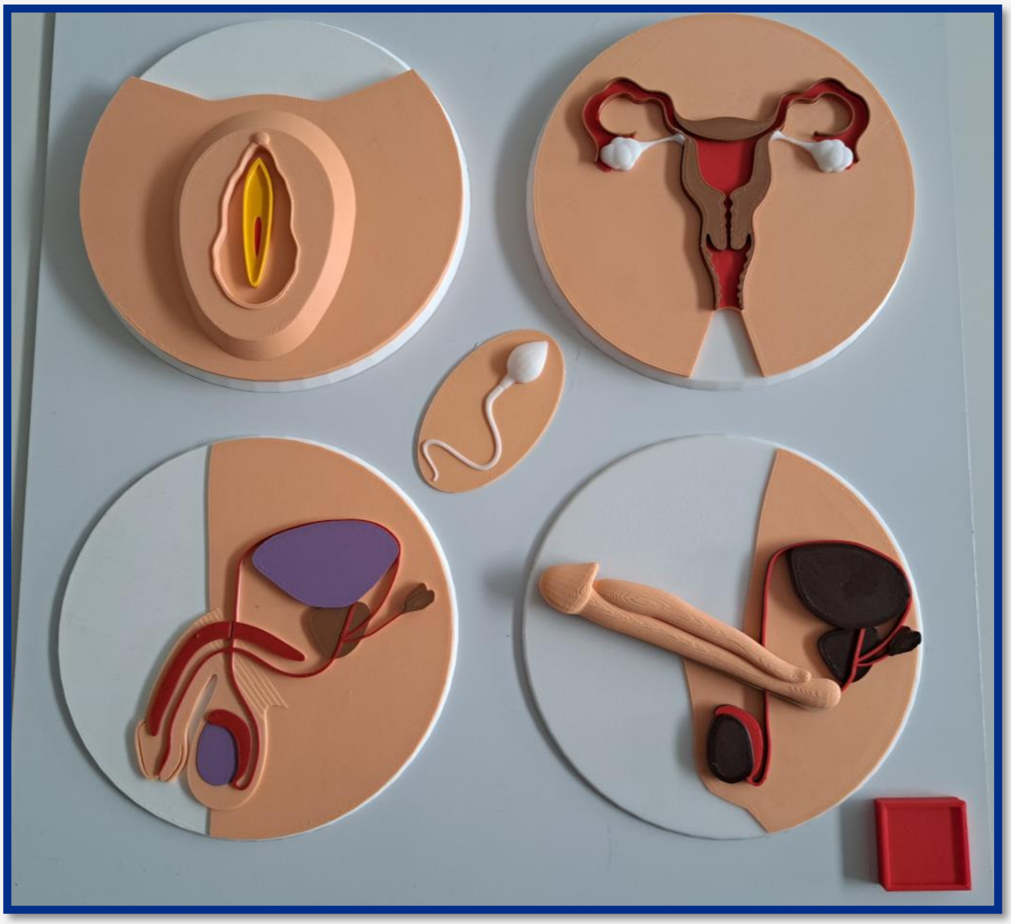
FIGURE 18: BLOOD CIRCULATION AND RESPIRATORY SYSTEM

Source: Erasmus+ TaTaBooks

FIGURE 19: DIGESTION

Source: Erasmus+ TaTaBooks

FIGURE 20: REPRODUCTION

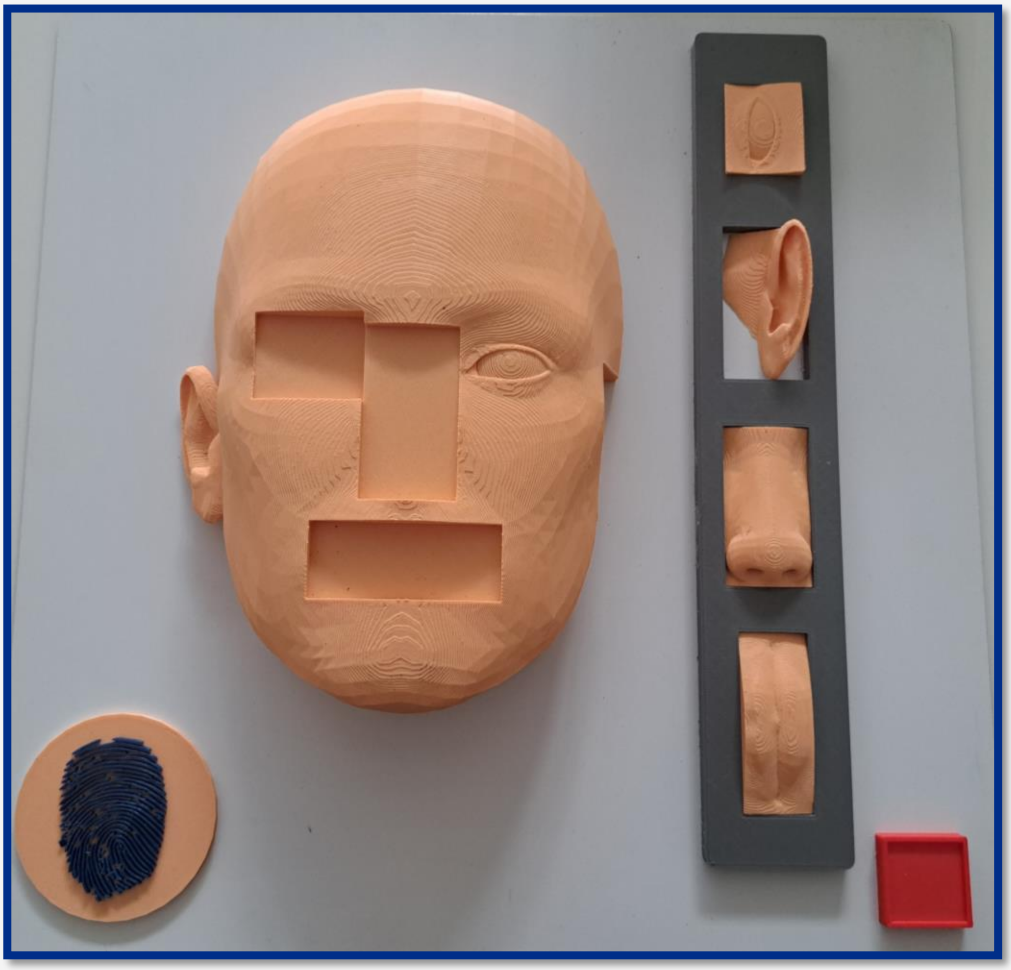


Source: Erasmus+ TaTaBooks

FIGURE 21: BRAIN, NERVES AND SPINE

Source: Erasmus+ TaTaBooks

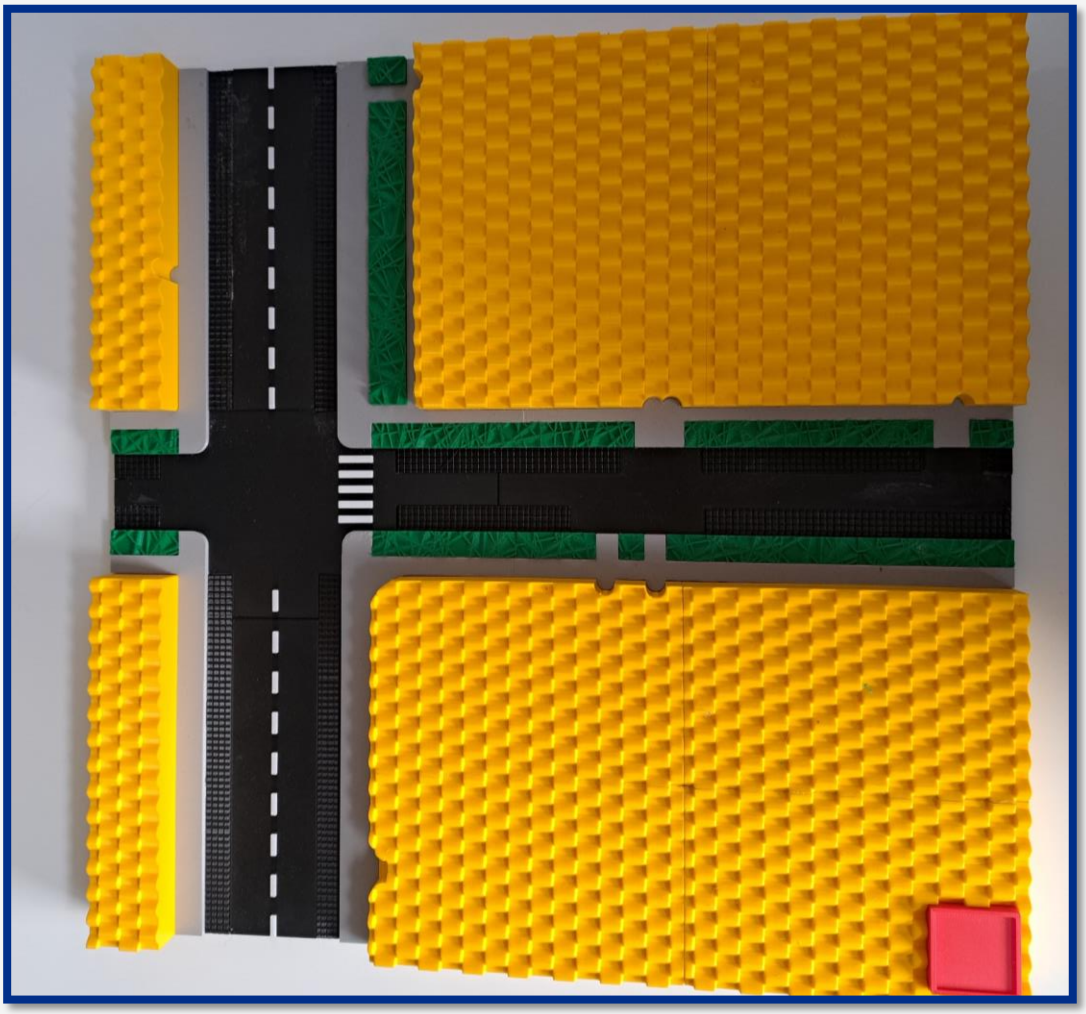
FIGURE 22: SENSES



Source: Erasmus+ TaTaBooks

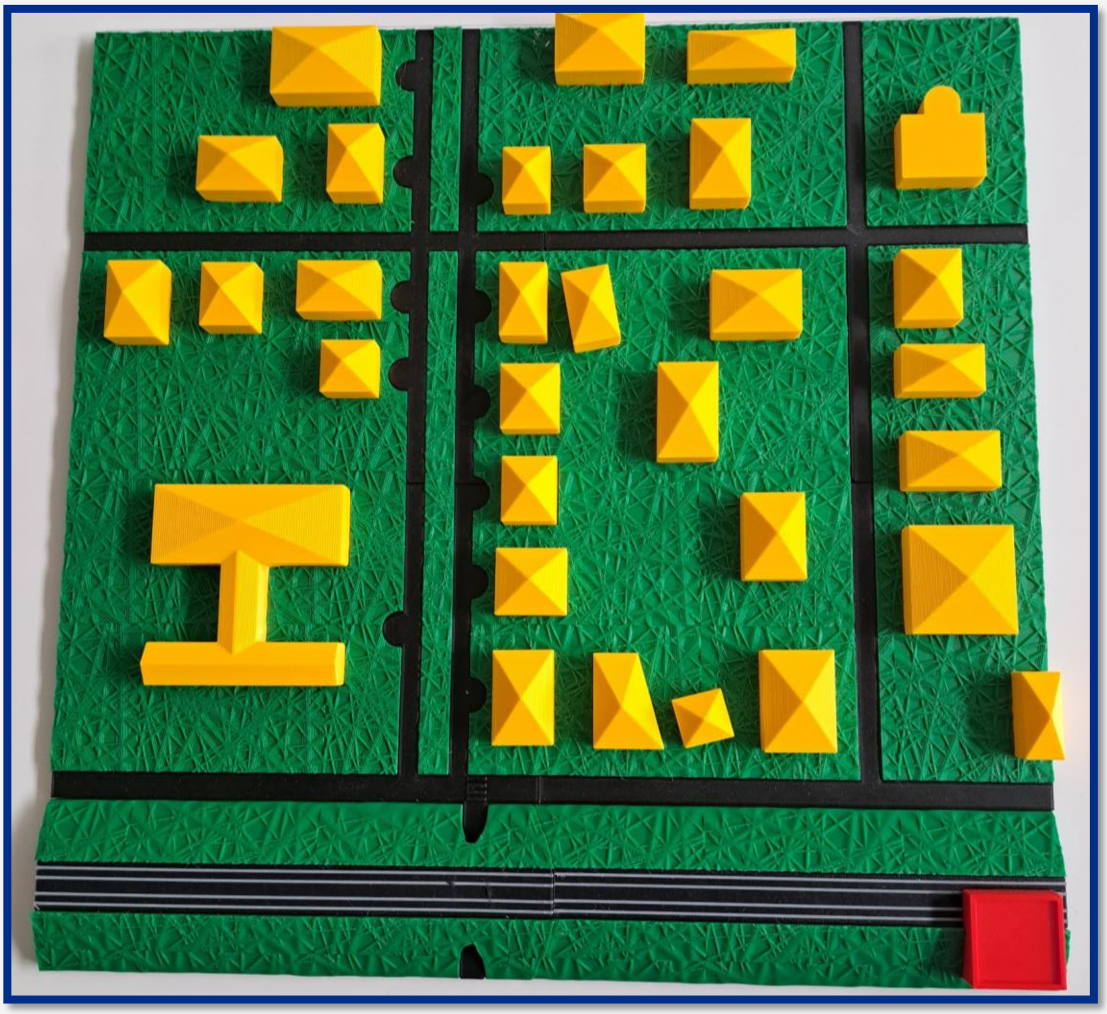
Orientation and mobility

FIGURE 23: STREET



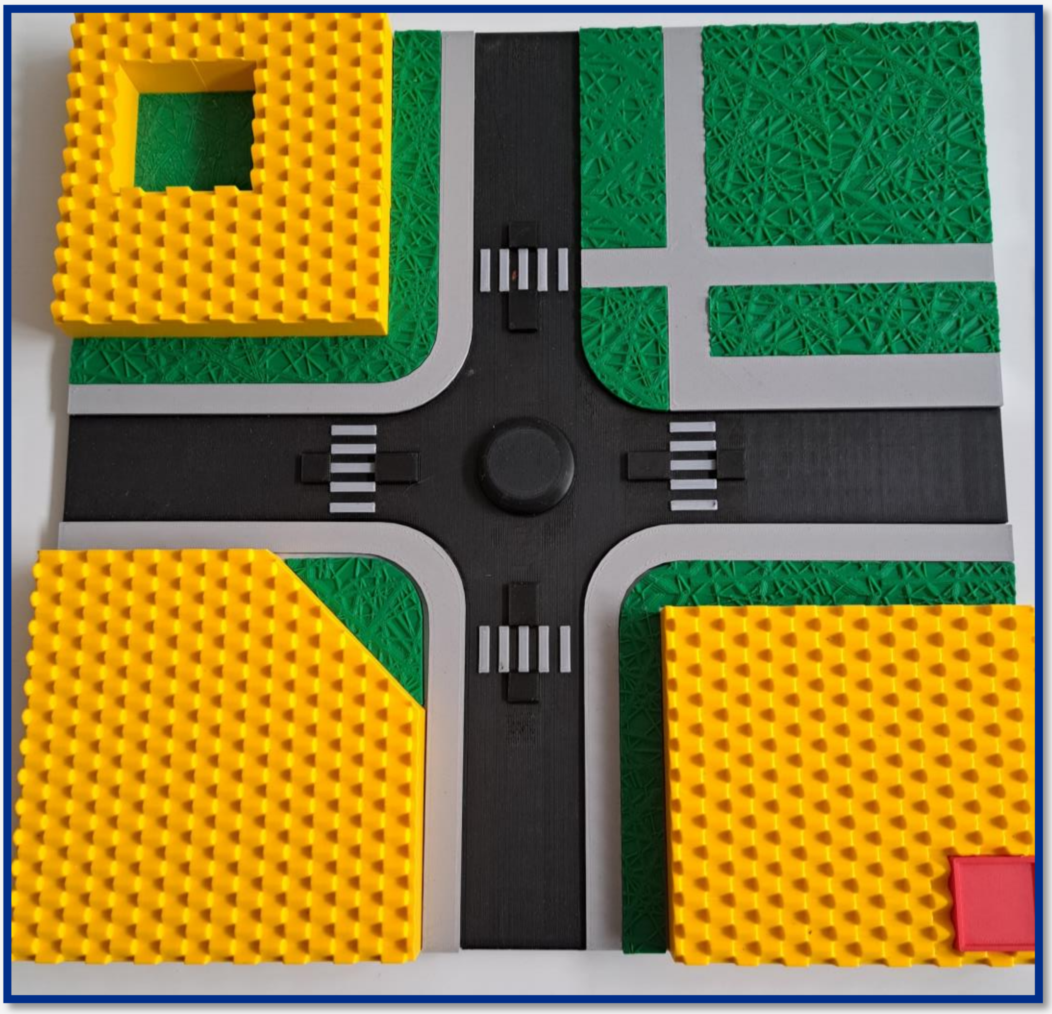
Source: Erasmus+ TaTaBooks

FIGURE 24: BLOCK OF HOUSES



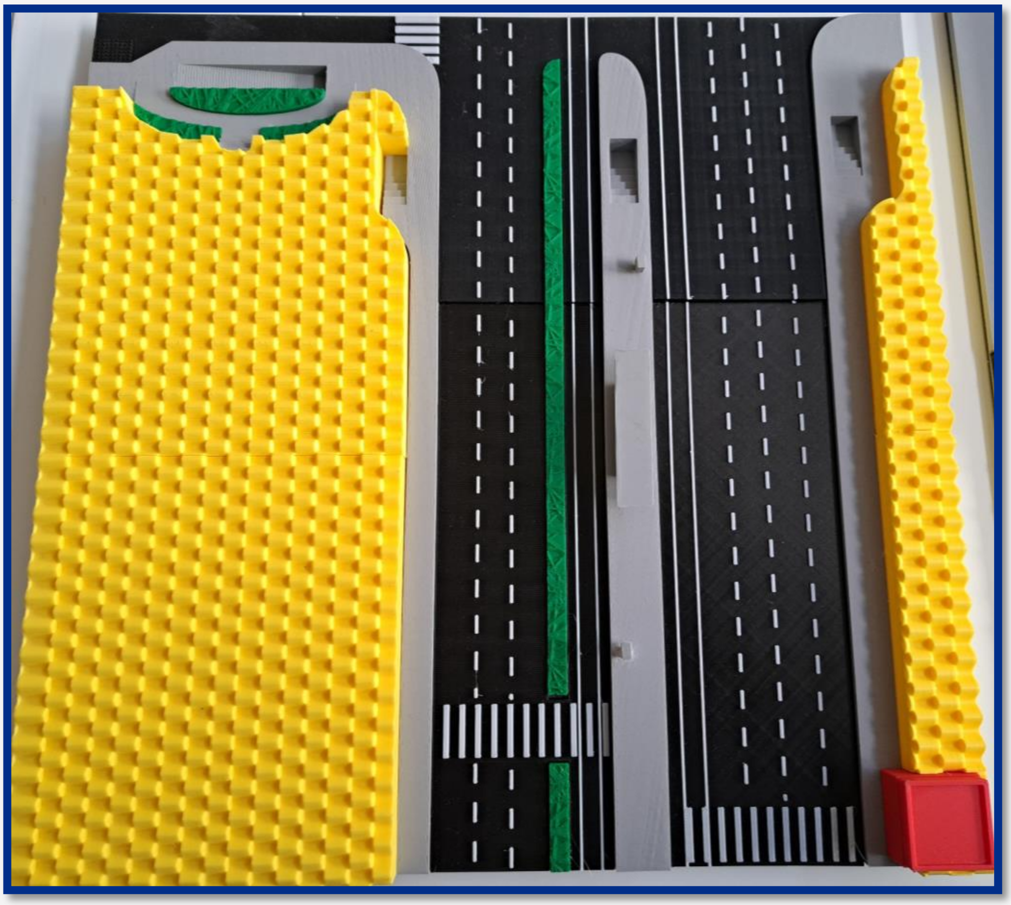
Source: Erasmus+ TaTaBooks

FIGURE 25: ROUNDABOUT



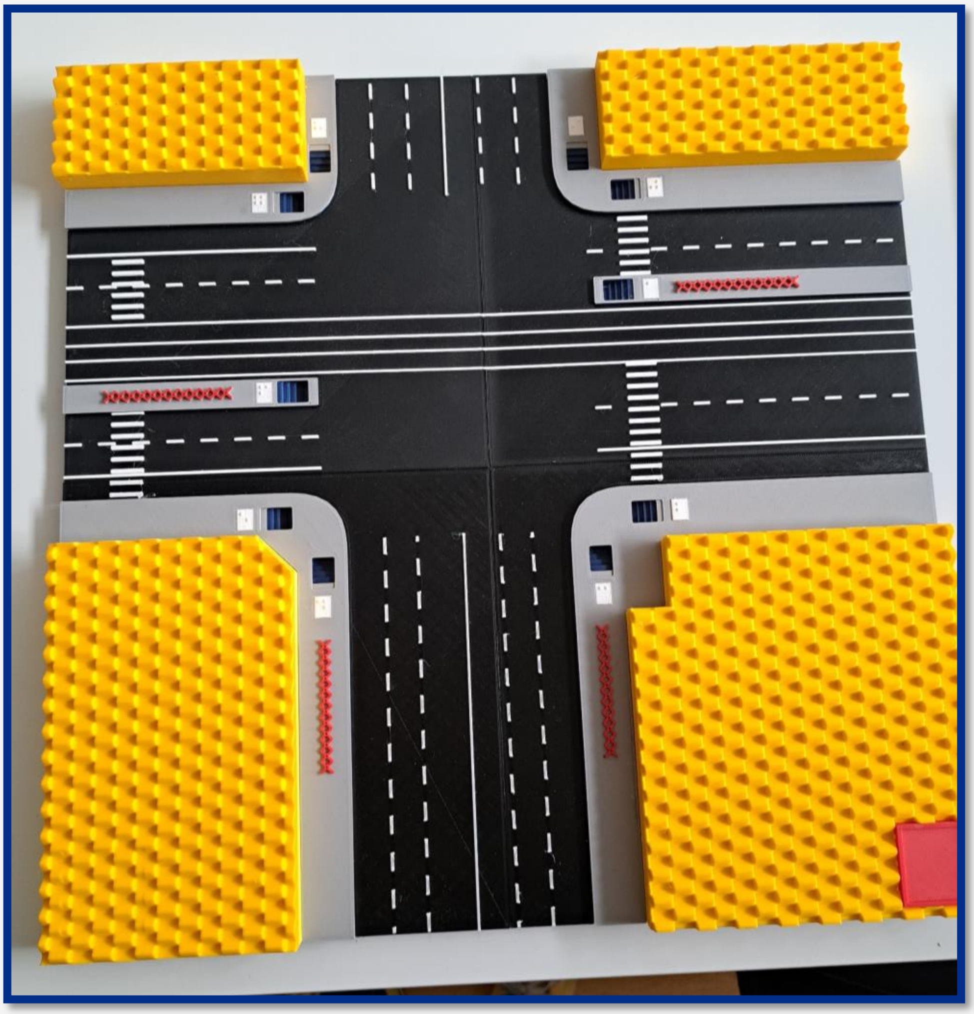
Source: Erasmus+ TaTaBooks

FIGURE 26: CROSSING AND BUS STOP



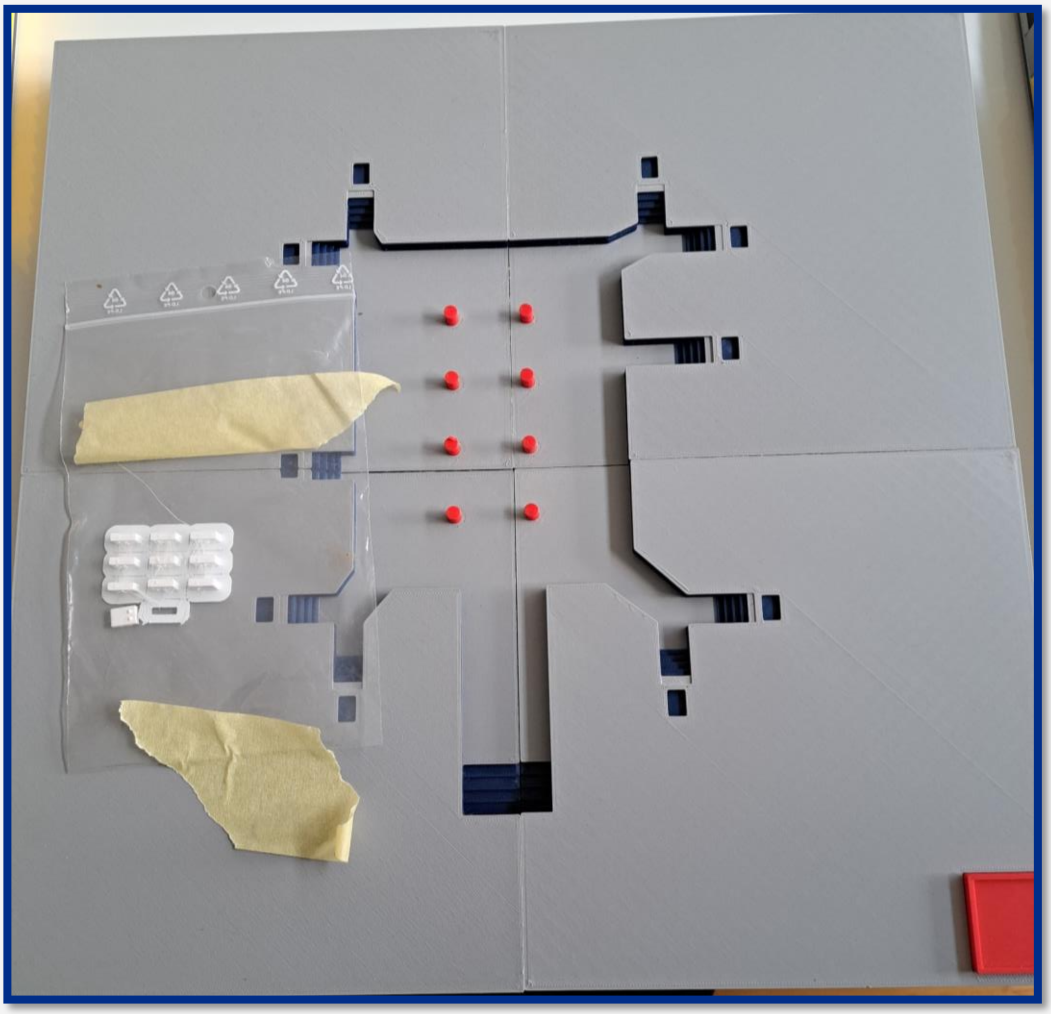
Source: Erasmus+ TaTaBooks

FIGURE 27: CROSSING



Source: Erasmus+ TaTaBooks

FIGURE 28: UNDERGROUND



Source: Erasmus+ TaTaBooks

FIGURE 29: TRAIN STATION

FIGURE 30: TRAIN STATION

Source: Erasmus+ TaTaBooks

Geology

FIGURE 31: EARTH AND CONTINENTS

Source: Erasmus+ TaTaBooks

FIGURE 32: GEOLOGICAL PROCESSES

Source: Erasmus+ TaTaBooks

FIGURE 33: FOSSILS

Source: Erasmus+ TaTaBooks

FIGURE 34: CAVES

Source: Erasmus+ TaTaBooks

FIGURE 35: GEOLOGY AND EVERYDAY LIFE

Source: Erasmus+ TaTaBooks

FIGURE 36: SCALE OF HARDNESS

Source: Erasmus+ TaTaBooks

FIGURE 37: ARTS AND CULTURE

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