Understanding scientific reasoning g

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Research in Scientific Education (2020)Cite this article 732 Access 6 Altmetric Metrics The development of scientific competency reasoning is a key goal of scientific education. To better understand the complex design of scientific reasoning, which includes modeling as one style of reasoning, careful research of the main processes is needed. Therefore, this study developed a typology of modeling strategies for pre-service science teachers. Thirty-two pre-service science teachers were captured on video while taking part in a simulation of a black box investigation. After a qualitative analysis of the content, the sequences of modeling activities were revealed. By converting these activity simulation sequences into state transition graphs, six types of modeling strategies were obtained that differed in the homogeneity and complexity of their modeling processes. Teachers of pre-service science are engaged only in the activities (1) of intelligence; (2a) exploration and development with a focus on development; (2b) intelligence and development with a focus on exploration; (2c) exploration and development, balanced; (3a) reconnaissance, development and drawing of forecasts from the model once; or (3b) exploration, development and repeated drawing of forecasts from the model. Finally, this typology is being discussed with regard to its development process and its capacity to inform and guide further research, as well as to develop interventions to strengthen the competencies of scientific modelling. The development of competencies in the field of scientific reasoning is considered a key goal of the education of the 21st century (Osborne 2013), as these competences are necessary for active participation in scientific and technically oriented societies. Consequently, the competence in scientific reasoning is covered in educational documents around the world (e.g. BCMOE 2019; KMC 2005; NGSS Leading States 2013; VCAA 2016). To support the development of students' competencies, pre-service teachers of science must obtain scientific and logical competence within their professional competencies (Khan and Krell 2009; Matecius et al. 2016). These scientific reasoning competences can be defined as a complex design, which covers the abilities needed to solve scientific problems, as well as to reflect on this process at the meta-level (Krell et al. 2018, p. 2; cf. Morris et al. 2012), including general cognitive abilities such as analogy use and decision-making (Nersessian 2002), as well as the ability to apply content, procedural and epistemic knowledge to solve problems (And Osborne 2017). According to this definition, research on scientific reasoning competencies is an equally complex issue, leading to a high diversity of studies focused on different contexts and hearpoints, and therefore using different theoretical frameworks and methodical approaches (Koslowski 2013; 2016). In addition, it is argued that there is no single form of form Kind and Osborne (2017), for example, recently proposed six different styles of scientific reasoning that include mathematical deduction, experimental evaluation, hypothetical modeling, categorization and classification, probabilistic reasoning and historical evolutionary reasoning. For some styles of scientific reasoning, especially experimental evaluation (Hammann et al. 2008; Schauble et al. 1991a), the processes, strategies and understandings of individuals have been extensively researched and described in research in scientific education, but others, such as hypothetical modelling, do not have detailed studies (Nicolaou and Constantinou 2014). Thus, a thorough study of the processes associated with different styles of scientific reasoning, and their comparison, can lead to a deeper understanding of the structure of the complex design of scientific reasoning and help to develop a larger picture of what (scientific reasoning) can be (Kind and Osborne 2017, p. 27). This study focuses on the style of hypothetical modeling and adds to research on scientific reasoning, presenting a process-oriented analysis of the strategies of pre-service science teachers in the process of scientific modeling. Analysis of scientific reasoning Studies of dynamic and process-oriented aspects of behavior is often based on the systematic observation of predetermined codes of behavior (Bakeman and Gottman 1997), which are used as fundamental elements of analysis. In research on scientific reasoning, the term activity is most commonly used to describe these elements of analysis (e.g. Khan and Krell 20019; Krell et al. 2019). Thus, different frameworks with specific sets of activities can be used flexibly to take into account different parameters, samples or goals (cf. Rennebeck et al. 2016), levels of detail (e.g. Chinn and Malhotra 2002; Fisher et al. 2014; Lawson 2004), or theoretical emphasis on specific styles of reasoning (e.g. modeling; Giere et al. 2006). By observing and identifying the various epistemical actions of humans in their appropriate order, sequences of activities can be extracted, which simplifies the complex process of scientific reasoning to the level where models can be seen. To date, empirical studies have shown that the activity of scientific reasoning does not follow a strictly predetermined order (e.g., Harwood 2004; Clare and Dunbar 1988; Reiff, etc.), so scientific reasoning can be considered a creative process for problem solving (Timmerman 2005). However, there were systematic differences in the reasoning processes of newcomers and experts (e.g. Sanzula, etc., 2015; Klahr 2002). How Typology of Scientific Reasoning can be useful for research EducationMany aimed at generalizing patterns in scientific reasoning processes by suggesting types or classes of reasoning strategies that can then be used for diagnostic or in targeted activities (Klahr et al. 1993; Schaeuble et al. One example of the analysis of scientific reasoning processes, which can be considered as a central basis in educational research, is the work of Clara and Dunbar (1988), which has been used and adapted in numerous further studies (e.g. Aizpurua et al. 2018; Hammann et al. 2008; Krell 2018; Neumann et al. 2019). Based on case studies, Clare and Dunbar (1988) developed the Scientific Discovery as Dual Search (SDDS). They argue that scientific reasoning is the task of solving problems that arises in two problematic spaces: the space of the hypothesis and the experimental space. They distinguish between two strategies based on the emergence of experimental activity at a certain point in the process of scientific reasoning, classifying the subjects as experimenters and theorists. They also describe differences in the occurrence and frequency of actions assigned to one space or the other between the two classes. When given a scientific problem, theorists look for new hypotheses in the space of hypotheses, while experimenters rely on experiments to cause patterns without directly presenting other hypotheses. Studies have shown that experts behave more like theorists and tend to look for space hypotheses, which may be the result of differences in previous knowledge (e.g. Rasmussen 1981), which allows them to solve scientific problems more effectively (Klahr 2002). Based on the SDDS model, Klahr et al. (1993) described common differences in the reasoning processes between adults and children. They identified various problems children face in developing scientific reasoning skills. For example, children often have problems limiting their search for a hypothesis or experimental space, leading to the testing of inappropriate hypotheses or the development of inappropriate experiments. These findings, based on the application of the SDDS model and their typology of experimenters and theorists, allowed them to draw implications for educational institutions (e.g., whether educational settings should be more limited in terms of the number of hypotheses and possible experiments if they targeted children), which were later included in further studies (Klahr and Nigam 2004). Another study combining the definition of experimental activity with the generalization of these models was carried out by schauble et al. (1991a). They explored differences in the strategies of good and poor students in the pilot environment, focusing on the five classes of student behavior. These classes include a common level of activity and four activities on planning, evidence-gathering, data management and evidence interpretation. The authors distinguish between engineering and a more advanced scientific model for research into scientific phenomena. Subjects using the engineering model conduct research up to effect, and then stops, while subjects using the scientific model study all and their impact on the system. In addition, good students are more likely to use variable control strategies, generate more hypotheses, record more systematically, and develop more purposeful plans than poor students. The authors further used the distinction between the engineering and scientific model of experiments to develop a progression of learning in which students were able to develop their individual experiment processes step by step to increasingly resemble the latter (Schauble et al. 1991b). It was noted that the effect would be stronger if the problems that needed to be addressed were introduced in order to increase analytical complexity. Both examples illustrate the fruitfulness of typology of scientific reasoning for scientific education; typology could guide further research and promote theory (e.g. Klahr and Dunbar 1988) and be used to develop specific educational institutions and activities (Schauble et al. 1991a, b; Klahr et al. 1993; Clare and Nigam 2004). However, while different strategies (and related typology) have been proposed for scientific experiments, such conclusions are not widely available for scientific modelling. Scientific modeling as one style of scientific reasoningThere between scientific modeling and scientific reasoning is widely discussed in scientific research of education. As mentioned above, six styles of scientific reasoning (Kind and Osborne 2017) have been proposed, with each style having a specific set of ontological, procedural and episthetic resources required for reasoning. Species and Osborne (2017) further argue that six styles of scientific reasoning offer a comprehensive scheme for building scientific reasoning. The focus of this study is on one style that has proven itself in scientific research: scientific modeling (e.g. Clement 2000; Gilbert 2004; Windschitl et al. 2008). Although described as one of six Kind and Osborne styles (2017), various other authors specifically emphasize the importance of modeling for reasoning in science; Gire (1999), for example, argues that scientific reasoning is largely based on a model (p. 56). Similarly, Lehrer and Schaeuble (2015) describe scientific reasoning (or scientific thinking, respectively) as a modeling process that encompasses various other practices. Thus, modelling can also be seen as a comprehensive ability necessary for all scientific reasoning processes. For this study, however, the specific relationship between modeling and other styles of reasoning in science (i.e. whether modeling is one of different styles or a comprehensive style covering others) is not central. Therefore, in this article, scientific modelling will be considered as one of the styles of scientific reasoning and thus should be specifically researched in the field of scientific education. With perspective modeling can help achieve three main goals education (Wed. Hodson 2014): study of science by studying basic models as science products; Learn to do science by developing methods for creating and evaluating models; and the study of science, assessing the role of models as hypothetical entities and epistemic tools in science (Justi and Gilbert 2003). Consequently, modelling also stands out in recent training documents as the main scientific practice (e.g. NGSS Lead States 2013), and it is widely recognized that research training essentially consists of the construction, testing, revision and application of models (e.g. Schwarz et al. 2017; Windschitl et al. 2008). Thus, scientific modeling has been identified as a potentially useful and relevant example of scientific reasoning and will be the focus of this article. In the direction of typology modeling strategies in Science Education To determine modeling strategies, this study can draw on an extensive set of studies on models and modeling in scientific education, in which many studies have been published already during the 1980s (e.g. Brown and Clement 1989; Gilbert and Osborne 1980; Nersessian 1992) or more recently (e.g. Clement and Rey-Ramirez 2008; Krell et al. 2019; Passmore et al. 2014). These studies examined various aspects of knowledge and ability related to the models and simulations of different sample groups, such as student knowledge (e.g. Grosslight et al. 1991; Krell et al. 2014a, b), teachers (van Driel and Verloop 1999; Windschitl et al. 2008), and experts (e.g. Beiler-Jones 2002; Clement 2008). Other studies focus on model-based learning and teaching, i.e. the use of modelling approaches so that students can better understand scientific concepts (e.g. Acher et al. 2007; Passmore et al. 2009). In all these studies, one common finding is that most sample groups seem to have difficulty understanding the predictive power of models and their role as epistemtic instruments for scientific reasoning (Krell and Kruger 2016; Passmore et al. 2014). In addition, even where models are used and understood as epistemic instruments, several models representing alternative hypotheses are rarely considered (Grosslight et al. 1991). However, it is this characteristic of models as epistemical forecasting tools that is emphasized in scientific education curricula and standard documents around the world (e.g. BCMOE 2019; KMC 2005; NGSS Leading States 2013; VCAA 2016). In addition, the reviews propose that modelling and modelling studies in science education should focus on cognitive and metacognitive aspects so that meta-modelling knowledge is overestimated (Nicolaou and Constantinou 2014, p. 72); Detailed and analysis of modeling strategies that can be used for diagnostic purposes or interventions (cf. Klahr et al. 1993; Schauble et al. 1991b), mostly absent from educational research (Louca and zacharia 2012; Nicolau and Constantine 2014). One One is a study by Sins et al. (2005), which examined the types of reasoning, conversation hotspots, and types of reasoning used by beginners during computer simulations. The authors found that more successful students tended to justify their reasoning with previous knowledge and consider the model as a whole, while less successful students showed model-slinky behavior (wed. engineering model experiments; Schauble et al. 1991a). While the Sins et al. study (2005) shows how sequential activity analysis can be further quantified through, for example, z-accounts, they do not distinguish between different strategies or types of modeling processes that could potentially provide further insight into the nature of the different modeling strategies used, for example, by pre-service science teachers. The current paper aims to fill this gap by developing typology of pre-service teacher modelling strategies, which can then be used in science education to distinguish between individual simulation processes and allow researchers and teachers to identify leverage points for intervention at the individual level. To ensure the quality of analysis and to ensure comparisons between this study and the processes and strategies of reasoning involved in other styles of reasoning, the methods of analysis and development of typology and its interpretation should be as transparent as possible. Various criteria for assessing the classification and development of typologies are therefore considered. The analysis is evaluated on the feasibility of the attributes considered, minimizing variance within the group and maximizing variance between groups (Bailey 1994). The model of empirically sound types of construction (Kluge 2000) is used in the analysis to maintain methodical flexibility while achieving a systematic and transparent process of typology development. The model describes four steps in the construction type (Figure 1). The first three steps can be repeated several times to evaluate can (combinations) attributes.Fig. 1Model empirically sound type designs (Kluge 2000)So, in this study, the corresponding dimensions of the analysis will be determined (step 1), grouped, and researched in terms of empirical patterns (step 2) and meaningful relationships (step 3) in modeling processes to identify different types that can be characterized as a modeling strategy (step 4). Specifically, the following four research questions will be discussed, according to which each question relates to one step of the model of empirically sound-type designs (Figure 1): 1) 1) What attributes are appropriate for the development of empirically sound typologies of pre-service science modeling strategies for teachers (p. 1, step 1)? 2) To what extent are the modelling processes of pre-service teachers can be properly grouped based on the selected selected and the consideration of criteria to minimize intragroup heterogeneity and maximize heterogeneity between groups (p. Figure 1, step 2)? 3) To what extent can meaningful cases be found between the identified groups and between the identified groups (p. Figure 1, step 3)? 4) What types of modeling strategies can be obtained from the type building process (cf. Fig. 1, step 4)? The context of this study is the first stage of teaching science teachers in Germany, which takes place at the university. In this first phase, science teachers will be asked to develop the basic professional knowledge and competencies they need as science teachers (Neumann et al. 2017), including knowledge and competencies related to research and reasoning in science (KMK 2019). In Germany, pre-service teachers usually study two subjects (i.e. two future subjects) as part of a bachelor's degree (six semesters) and a subsequent master's program (four semesters) before leaving university and entering the second stage of pedagogical education (internship). Existing empirical studies show a significant positive development in the competence of German teachers of pre-service sciences in the field of scientific reasoning during the course of training (e.g. Hartmann et al. 2015; Kruger, etc. 2020). Students in later semesters are therefore expected to have advanced competencies related to investigation and reasoning in science. Installation For the induction of scientific reasoning processes was used the installation of the black box (Lederman and Abd-El-Khalick 2002). The black box approach is established in scientific research to study the processes of scientific thinking and modeling (Khan and Krell 2019; Lederman and Abd el-Khalik 2002; Passmore and Liberty 2012). In such approaches, the black box is a natural phenomenon that is being studied, and the study of the black box is a process of scientific discovery. Black box approaches have been shown to be suitable for modeling processes, with models being used as epistemic tools for black box detection (Krell et al. 2019; Passmore and Liberty 2012). In this study, the black box approach was preferably chosen instead of a genuine and content-rich scientific problem in order to reduce the impact of prior knowledge on the modelling processes of pre-service science teachers. However, it is recognized that this may be one of the limitations of the study, as some authors emphasize the importance of content knowledge for scientific modelling (e.g. Ruppert et al. 2019). This article used a black box of water. It can be explored by filling the black box with water (entry), which then leads to measurable water outlets (see Krell et al. 2019 for a detailed description of the black box). Participation in the activities of black is voluntary and is not related to any university courses or compulsory parts of the curriculum. Researchers and participants had no formal relationship with each other. Other. participant was briefly represented in the study and signed an informed consent. To learn more about scientific reasoning processes, all participants were asked to think aloud at the same time (Leighton and Gierl 2007), who practiced with three short questions. After these preparations, the participants were bequeathed to a room equipped with three video cameras, a black box, pre-filled glasses of water and a board. The researcher briefly explained the basic functionality of the black box using a prepared script and gave the following task: Draw a model inside the black box. Participants were informed that there were no time limits (the average duration of the event for all participants was 1 hour and 11 minutes). The first author stayed in the room during the simulation process to prevent any technical errors and, if necessary, remind participants to think out loud at the same time; otherwise he did not intervene. For this study, sample data from 32 participants were collected and analyzed. Academic progress of participants ranged from the first (i.e. undergraduate) to the tenth semester (i.e. the master's degree). Participants were between the ages of 17 and 39 (the average age was 25). Theoretical sampling was used to further maximize the heterogeneity of participants and increase the likelihood of observing different strategies. Teachers of pre-service science were selected on the basis of two criteria. The first criterion was the achievement of pre-service science teachers in an established multi-choice testing tool, which was previously developed to assess the competencies of scientific reasoning and includes tasks related to research and scientific modelling (Kr'ger et al. 2020). The second criterion was the achievement of pre-service science teachers in the so-called I-S-T 2000R instrument (Liepmann et al. 2007). This paper-pencil tool assesses overall cognitive abilities. It also includes spatial transformation tasks, which are said to be one of the capabilities required for modeling (Nersessian 2002). Both criteria were evaluated before participants were invited to the black box activity, and only those pre-service science teachers, distinguished by one standard deviation from the average test population scores on both tests, were invited to participate. Data From AnalysisThe video participants were transcribed verbatim, including all verbalization, and behavioral aspects are considered important for analysis (they included making or observing an exit, walking on a board, or cleaning a board). The videos and related transcripts were analyzed by the first author and another tariff (trained by the student assistant) in accordance with the quality content-analytical approach (Schreier 2012). To improve the comparability of the results and improve the workflow, the transcripts were Watch the video at the same time. The modeling process for each participant was divided into separate activities of scientific modeling. That's why. The basis of 19 different modeling activities (table 1, i.e. a category system) was used, which was developed in the previous study (Khan and Krell 2019; Krell et al. 2019) and integrates the frameworks used to describe analog reasoning processes (Brown and Clement 1989) and scientific reasoning through models (Giere et al. 2006). This structure also allows each activity to be made concession to one of the three phases of the study modeling, model development or forecasting. Although this previously developed category system includes all modeling activities that have been identified in the entire sample of the previous study (Khan and Krell 2019; Krell et al. 2019), this study further uses this system of categories to find patterns and determine the types of modeling strategies of individual pre-practice teachers based on the sequence of these models. In addition, it should be noted that analogies (Code 6) can be activated throughout the process in which participants can evaluate their ideas and mental models orally; however, the methodical approach in this study requires an externalized model in the form of a drawing. Table 1 Category System with 19 activity simulations (Krell et al. 2019) Table 2 illustrates how the transcripts were divided into separate activities for brief transcript excerpts. This passage covers minutes 24 to 30 of the 66-minute modeling process of one respondent. Thus, the exposure begins in the middle of the modeling process, after the initial phase of the study and development of the original model. Table 2 Excerpt from a transcript of one participant, exemplary showing how the transcripts were divided into separate activities to ensure the reliability of the analysis (intra-party agreement), each video and corresponding transcript were encoded twice by the first author. To ensure the inter-personality of the analysis (international agreement), the video and transcripts were then re-encoded by a qualified student's assistant, followed by discussion and elimination of any disagreements that might arise. Cohen's Kappa offers acceptable for high agreements (table 3). Disagreements were discussed and resolved between both tariffs. The activity sequences identified were then used for further analysis related to the phases of the empirically sound type design model (Figure 1). Thus, the relevant approaches to data analysis are infuriated in the sections below. Table 3 Of Kappa Cohen's calculations: the following, the findings are presented in accordance with research questions that relate to the steps of the model of empirically sound type designs. There will be two cycles focused on the occurrence of activities (cycle 1) and inter-activities (cycle 2) respectively. Cycle 1, Step 1: Activity Emergence appropriate measurement of analysis based on the studies described above, phenomena (Klahr and Dunbar 1988; Schauble et al. 1991a) were identified as the first relevant aspect of the analysis. In the first cycle of typology, the sequence of activities conducted by the participants was visualized as code strings (see, for example, Figure 2), which is a common practice in scientific studies of education (e.g., Luke and zacharia 2015).Fig. 2Codelines Angelina (above) and Jonathan (bottom). Activities are displayed in chronological order, which corresponds to the size of each data point, which corresponds to the time tinged for each action. Dotted lines point to the purpose of activities for three phases of research, model development and forecasting. While both participants are engaged in exploration and modeling, Angelina mainly focuses on exploration activities, with activity to develop models at the end. In contrast, Jonathan often switches between exploration and model development. However, as Angelina and Jonathan do not conduct any events predictionCycle 1, Step 2: Grouping cases and analyzing empirical patterns based on the occurrence of activities based on visual evaluation of these codes, it is easy to distinguish three groups of participants: (1) One participant conducted only intelligence activities and did not make a model at all. (2) Seventeen participants conducted exploration and development activities, but received no projections from their models (p. Figure 2). (3) Fourteen participants conducted exploration, model development and forecasting activities. Since members of their group can be directly identified as activities occur, no further interpretation is required, indicating a sufficient degree of heterogeneity between the groups. Comparisons of the sequence of participants in the same group, however, indicate a fairly low degree of homogeneity within the group, as participants show significant differences in the proportion of activities and in their consistent manner. For example, Angelina shows a long sequence of intelligence activities by developing a model at the very end (Figure 2 from above), while Jonathan shows the activity of designing the model throughout, alternating with the activities of intelligence (Figure 2 from below). Consequently, further differentiation of groups seems to be needed, and no further analysis of meaningful relationships and types of construction on the basis of activity has been carried out (p. Figure 1; step 3). Cycle 2, Step 1: Transitions between activities as an appropriate analytical measurementIn relation to quantitative analysis, such as clustering, will only take into account the number and time during which activities were conducted, transitions between individual modelling activities have been selected as appropriate attributes, taking into account activities in the second cycle of typology development (Sins, etc. 2005). To visualize Code lines depicting the sequence of activities performed by each participant have been converted into state transition schedules (Andrienko and Andrienko 2018). These state transition graphs show all nineteen identified activities as nodes that are connected by the directional edges of different weights, taking into account the number of transitions between these nodes. In addition, two nodes for the start and end are appended. All state transition graphs are automatically laid out in Gefi (Bastian et al. 2009) using force-directed algorithm of ForceAtlas2 (Jacomy et al. 2014). Cycle 2, step 2: Grouping cases and analyzing empirical patterns based on transitions between activitiesIn the result of graphs were then grouped by two tariffs in the first visual analysis. Six groups (table 4) could be identified, which further distinguish the three original groups from the first phase. Participants engaged in simulation activities as follows: (1) Intelligence only (n No. 1) (2a) Exploration and development with a focus on development (n No. 1) (2b) Intelligence and development with a focus on exploration (n No. 11) (2c) Intelligence and development, Balanced (n No. 5) (3a) Study, development and drawing of projections from the model once (n No 9) (3b) Study, development and repeated drawing of predictions from the model (n No. 5) Table 4 Examples of state transition graphs for each identified group Differences results between results between In addition, when discussing the grouping process, both rhythms considered size, complexity (number of nodes and edges), uniformity of edges and weight of the edge when analyzing state transition graphs. that further differentiates typology, improving homogeneity within the group. Cycle 2, Step 3: Analysis of meaningful relationships and type of construction based on transitions between activities For the evaluation of visual evaluation, various quantitative graph metrics (Cr. Andrienko and Andrienko 2018) were considered, representing the complexity of attributes and homogeneity. Lower-complexity state transition graphs show a larger number of communities because activities that are not party-related and therefore not related to the rest of the schedule are counted as one community (Bastian et al. 2009). To imagine the complexity, the number of communities was inverted by subtraction with 14 (maximum number of communities-1). To quantify homogeneity, the reciprocal central role of the graph was chosen based on the sum of three centrality indicators (central proximity, central degree and central degree) to account for structural emissions (Ronqui and Travieso 2015). Averages each group in terms of complexity and homogeneity corresponded to the visual assessment (table 5). Table 5 Averages of calculated complexity and homogeneity metrics for each group in groups (3a) and (3b) show higher difficulty scores than other groups because they conduct a wider range of different actions as they use their models to predict black box behavior. Group participants (2c) and (3b) show higher scores for homogeneity compared to groups (2a), (2b) and (3a), as they tend to hold different activities more equally. Single participants in groups (1) and (2a) show an estimate of complexity 0, as they conduct only a few different activities, resulting in the largest number of different communities that have been used to compensate for all calculations. Along with individual participants' estimates, you can see certain areas that support the visual grouping and which are in line with expectations (Figure 3).Fig. 3Star is a story illustrating calculated metrics of each participant's state transition chart combined with the averages of his or her respective group (table 4)However, the two participants (Sabrina and James) showed statistically higher homogeneity compared to their assigned groups. Step 3). Both participants invested less time in the black box study compared to their respective groups: while Sabrina and James engaged in black box activities for about half an hour, the other participants in the groups (3a) and (3b) invested an hour more on average. A shorter investigation time results in less repetitive actions and a higher homogeneity score than other participants. Modeling is regarded as a central practice of scientific reasoning (e.g. Clement 2000; Gilbert 2004) and stands out in educational documents as the primary scientific practice (e.g. NGSS Lead States 2013). However, research on scientific modelling does not have extensively detailed studies of modeling processes (Nicolaou and Constantinou 2014). The study was thus aimed at contributing to filling this gap in educational research by developing typology strategies for modeling teachers. This typology has the potential to inform and guide further research, as well as develop interventions to promote competencies in the field of scientific modelling. The proposed typology is based on the homogeneity and complexity of modeling processes (Figure 3) and includes the following strategies: (1) study only; (2a) exploration and development with a focus on development; (2b) intelligence and development with a focus on exploration; (2c) exploration and development, balanced; (3a) reconnaissance, development and drawing of forecasts from the model once; and (3b) intelligence, development and drawing forecasts from repeatedly (table 4). Comparison of the types of modeling strategies developed with the strategies identified in the Research of scientific reasoning processes, many parallels can be made, pointing out that at least the strategies of modeling and experimental evaluation are very similar: Participants of type (2b), who conduct research activities and develop models with a focus on exploration, show similarities with participants Schauble et al. (1991a), who use an engineering model of scientific research in experiments. Participants are investigating; in this case, reconnaissance of the black box until a certain effect is achieved, such as a repetitive pattern. Participants then complete the modeling process by following the original task by drawing their black box model. In contrast, participants in type (2a) and (2c) perform model development activities more often, expressing behavior similar to what was previously described as model fitting (Sins et al. 2005). In addition, unlike previous empirical studies, it shows that understanding the predictive use of models is challenging for most sample groups (Krell and Kruger 2016; Passmore et al. 2014), half of the cases we have observed can be classified as type (3a) or (3b) and included in the simulation processes. However, even participants of type (3b), who repeatedly drew predictions from their model, finished the modeling process when they found a possible solution. Participants did not further evaluate the developed models by attempting to falsify the model or systematically testing alternative hypotheses, although this is suggested in other studies as important for scientific modeling (Grosslight et al. 1991; Luke and zacharia 2015). Methodologically, the identification of certain activities of scientific reasoning, in this case modeling, has built the basis for further analysis of scientific and logical processes. On the basis of the emergence of activities and transitions between them, the typology of modeling strategies has been successfully developed. The emergence of activities is not in itself considered to be a sufficient attribute, as the resulting groups do not show a sufficiently homogeneous degree within the group. In addition, considering the sequence of actions in the form of their transitions, typology has been further improved, improving homogeneity within the group while maintaining heterogeneity between groups (Bailey 1994). Visualizing each participant's modeling processes in different forms that emphasize selected attributes, i.e. code lines and state transition graphs, allows for a quick, visual grouping process that has helped reduce the complexity of rich data sets, and improve their comparability. The grouping of several tariffs allowed to assess the inter-stratat agreement and the blurs in the process of grouping and related decisions. This led to the identification of more abstract attributes, such as the complexity and homogeneity of state transition graphs, that could and it supports visual evaluation. Several typology development cycles were needed, which in this study were conducted iteratively in accordance with the model of empirically sound type designs (Kluge 2000). This model was useful in assessing and refining typology, as well as avoiding errors in assigning a particular type to a separate case, as the model supported the systematic selection and evaluation of attributes and the resulting team. We also argue that a clear description of the various stages of empirical construction of types significantly enhances transparency, as the choice of attributes and processes of grouping has rarely been determined in other studies. As for the practical effects, we know that the black box parameter and sample size can limit the overallization of the results. In addition, the participants' mental models (cf. Johnson-Laird 1983) were not considered in the analysis, as the current study focused on externalized models. Further research is needed that uses the methods described in other contexts and contexts to reproduce the proposed typology. Consequently, at this stage, integrating these findings into learning environments and developing activities to promote scientific modelling competencies continue to be out of reach. However, under the current findings that expand the Krell et al. (2019) category system, individual modeling processes for pre-service teachers can be quickly assigned to one of the proposed types, highlighting the differences between pre-service science teachers and reducing the complexity of analysis. Determining the type of modeling strategy that a preservice science teacher uses in a particular setting, it can give potential leverage points at the individual level and can be used to guide this science teacher to understand and use models as epistemtic tools for scientific reasoning. Therefore, the proposed typology of modelling strategies could guide further research and development of the theory (Cf. Clare and Dunbar 1988) and potentially contribute to the development of specific educational activities (cf. Schauble et al. 1991a, b; Klahr et al. 1993; Clare and Nigam 2004). One example might be progression in learning, similar to Schauble et al. (1991a, b), in which the proposed typology can be used as levels of progression of learning, which are encouraged by modeling tasks with increasing complexity. In this case, setting up a black box can be considered quite difficult, as participants are less likely to use their knowledge, and the black box is opaque and dynamic (Betsch et al. 2011). Our sample will be expanded, and possible improvements in group homogeneity and heterogeneity between groups will be further investigated. In addition, in order to automate the appointment process other statistics to calculate differences between sequence sequences considered and possibly integrated into typology as additional dimensions, including z-evaluations (cf. Sins et al. 2005) and Yule's (Cf. Lamse et al 2020). To get an idea of how successful a particular type of modeling strategy is, we plan to investigate the relationship between the type of participant modeling strategy and the quality of the participant modeling product (i.e. the final model or model throughout the process), as it is assumed that specific strategies will be used by less successful participants (Schauble et al. 1991a; Sins, etc. 2005). Finally, built types will be characterized, including all the rated background variables and the quality of the models developed. We hope that this will help to develop an understanding of how the model of teachers of pre-service science and what factors influence their modeling, and thus provide valuable information for those who seek to develop pre-service competencies in the field of scientific modeling.

Aher, A., Arch, M., Sanmarte, N. (2007). Modeling as a learning process for understanding materials: an example in primary education. Science Education, 91 (3), 398-418.Google Scholar Aizpurua, A., Lizaso, I., Iturbe, I. (2018). Learning strategies and reasoning skills of university students. Revista de Psicodidactics, 23(2), 110-116. . Article Google Scientist Andrienko, N., Yu Andrienko, G. (2018). State transition graphs for semantic analysis of motion behavior. Information visualization, 17(1), 41-65. . Article by Google Scientist Beiler-Jones, D. (2002). Scientists' thoughts on scientific models. Perspectives on Science, 10 (3), 275-301. . Article by Google Scholar Bailey, K. (1994). Typology and taxonomies: introduction to classification methods (Vol. 102). Thousand Oaks, California: Sage.Backeman, R. Gottman, J.M. Monitoring interaction: Introduction to sequential analysis. Cambridge, NY: Cambridge University Press.Bastian M, Heymann S, Jacomy M (2009). Gephi: Open source software to study and manipulate networks. AAAI International Conference on Social Media Blogs, 8 (2009), 361-362.Betsch, T., Funke, J., y Plessner, H. (2011). Denken-Urteilen, Enchaden, Problemlesen. Berlin/Heidelberg: Springer Nature. Google Scholar British Columbia Department of Education (BCMOE). (2019). Received from D., and Clement, J. (1989). Overcoming misconceptions with analog reasoning: Abstract transmission vs. explanatory design of the model. Academic science, 18(4), 237-261. . Article by Google Fellow, M.P., Planinsic, G., Etkin, E. (2015). Analysis of patterns in the approaches of specialists to solving experimental problems. American Physics, 83(4), 366-374. Researcher Google Chinn, C. A., Malhotra, B. A. (2002). Epistemologically authentic query in schools: a theoretical basis for evaluating the tasks of the study. Science education, 86 (2), 175-218. . Article by Google Scientist Clement, J. (2000). Model learning as a key area of research in the field of scientific education. International Journal of Scientific Education, 22 (9), 1041-1053.Article Google Scientist Clement, J. (2008). Creative model of construction among scientists and students: the role of images, analogy and mental modeling. Springer Science - Business Media.Clement, J., Rhea-Ramirez, M.A. (2008). The model is based on teaching and learning in science (model based on teaching and learning in science). Dordrecht: Springer. Researcher Google Fischer, F., Kollar, I., Ufer, S. Sodian, B., Guzmann, H., Pecrun, R, et al(2014). Scientific reasoning and reasoning: Advancing the interdisciplinary research agenda in education. Front-line learning studies, 2(3), 28-45. Researcher at Google Gere, R.N. (1999). Science without laws. Chicago, Illinois: University of Chicago Press.Giere, R.N., Bickle, J., and Mauldin, R. (2006). Understanding scientific reasoning (5th place). Belmont: Thomson Wadsworth. Google Scientist Gilbert, J. (2004). Models and modeling: Ways to a more authentic scientific education. International Journal of Scientific and Mathematical Education, 2(2), 115-130. . Article by Google Scientist Gilbert, J., and Osborne, R. J. (1980). Using models in teaching science and science. European Journal of Scientific Education, 2 (13), 3-13. . Article Google Scholar Grosslight, L., Unger, C., Jay, E., S Smith, C. L. (1991). Understanding models and using them in science: Concepts of middle and high school students and experts. Research Journal in teaching science, 28 (9), 799-822.Article by Google Scientist Hammann, M., Fan, T.H., th Bayrhuber, H. (2008). Experimentieren als Probleml'sen: Lasst sich das SDDS- Modell nutzen, um unterschiedliche Dimensionen beim Experimentieren zu messen? Experiments as a Problem Solution: Can the SDDS model be used to measure different measurements of experiments? In M. Prenzele, I. Gogoline, H.-H. Kruger (ed.), Compotenzient: Seitschrift Fur Erzihuungssenshaft (p. 33-49). Wisbaden: VS Verlag Fur Sozialvissenshaften. Researcher Google Hartmann, S., Ubmeier zu Belsen, A., Kruger, D., Pant, H.A. (2015). Scientific reasoning in higher education: building and assessing the criterion of validity of the assessment of the competencies of teachers of pre-service sciences. Seihriff Fuhr-Psychology, 223 (1), 47-53. W. S. (2004). New Model for Research: Is the Scientific Method Dead? Teaching science in college, 33 (7), 29-33. Google Scholar Hodson, D. (2014). Science Study, Science Study, Science: Different Goals different teaching methods. Training. Scientific Journal Of Education, 36, 2534-2553. . Article Google Scholar Jacomy, M., Venturini, T., Heymann, S., S. and Bastian, M. (2014). ForceAtlas2, a continuous graphics layout algorithm for convenient network visualization, designed for Gephi software. PLoS One, 9(6), e98679. Google Scholar Johnson-Laird article, P. (1983). Mental models: To the cognitive science of language, output and consciousness. Cambridge: Cambridge U.P. Google Scholar Justi, R., and Gilbert, J. K. (2003). Teachers' views on the nature of models. International Journal of Scientific Education, 25, 1369-1386.Article by Google Scholar Khan, S., th Krell, M. (2019). Scientific competence reasoning: Case of preservice of pedagogical education. Canadian Journal of Science, Mathematics and Technology Education. (19), 446–464. Received from ., Osborne, J. (2017). Styles of scientific reasoning: a cultural justification for scientific education? Science Education, 101 (1), 8-31. . Google Scholar Klahr article, D. (2002). Study of science: Cognition and development of discovery processes. Cambridge, Massachusetts: MIT Press. Clare, D., Dunbar, K. (1988). Double search for space during scientific reasoning. Cognitive Science, 12(1), 1-48.Article Google Scientist Clare, D., Nigam, M. (2004). Equivalence of learning pathways in early scientific instructions: the effects of direct learning and learning discovery. Psychological Science, 15 (10), 661-667. . Article Google Scholar Klahr, D., Fay, A. L., and Dunbar, K. (1993). Heuristia for Scientific Experiments: Research of Development. Cognitive Psychology, 25 (1), 111-146.Article By Google Scholar Kluge, S. (2000). The construction of types and typologies in qualitative social studies is empirically justified. Forum, Qualitative Social Research / Forum, Qualitative Sozialforschung, 1 (1). nbn:de:0114-fqs0001145.KMK. (2005). Bildungsstandards ym Fah Biologists Fuhr den Mittleren Schulabschlus Biological Educational Standards for Mittler Shulabschlus (5th place). Munich and Neuvid: Volters Kluver. Google KMK Researcher. (2019). Lendermeinsame inhaltliche Anforderungen f'r die Fachwissenschaften und Fachdidaktiken in der Lehrerbildung General Federal requirements regarding scientific disciplines and scientific education in teacher training programs. Berlin: Secretariat der KultusminstererenzCoslowski, B. (2013). Scientific reasoning: Explanation, confirmation bias and scientific practice. In G.J. Feiste and M. E. Gorman (ed.), Handbook on the Psychology of Science (p. 151-192). New York, NY: Springer.Krell, M. (2018). Schwierigkeitserzeugende Aufgabenmerkmale bei Multiple-Choice-Aufgaben zur Experimentierkompetenz im Biologieunterricht: Eine Replikationsstudie. Seitschrift Fuhr Didaktic Der Naturvissenshaften, 24 years old. M., Kruger, D. (2016). Testing Models: A key aspect of promoting modeling and modeling in biology lessons? 50(2), 160-173. M., Ubmeier-zu-Belsen, A., Kruger, D. (2014a). Context-specificity in students' understanding of models and modeling: E-book Proceedings of the conference ESERA 2013: Scientific and educational research for scientific learning and consistency in learning. Nicosia, Cyprus: European Scientific and Educational Association. Krell, M., Upmeier zu Belzen, A., th Kruger, D. (2014b). Levels of understanding of models and modeling of students in biology: global or dependent on aspects? Research in Science Education, 44(1), 109-132. M., Redman, K., Matescius, S. Kruger, D., Van Driel, J. (2018). Assessment of the competencies of science teachers prior to service in scientific reasoning. Research in science education. M., Walzer, K., Gergert, S., Kruger, D. (2019). Develop and apply a system of categories to describe the activities of science teachers prior to the start of service in the scientific simulation process. Research in Scientific Education 49 (5), 1319-1345. �ger, D., Hartmann, S., Nordmeier, W., Ufmayer zu Belsen, A. (2020). Measuring the competencies of scientific reasoning. In O. Slatkin-Troitskaya, H. Pant, M. Topper, K. Lautenbach (ed.), Student studies in German higher education (p. 261-280). Wiesbaden: Springer. Google Fellow Lamse, J., Hyamalainen, R., Koskinen,., Viri, J., Mannonen, J. (2020). Potential temporary analysis: Combining log data and consistent analysis of delays to examine the temporal differences between scaffolding and non-scaffolded group learning processes based on queries. Computers and Education, 143, 103674. . Google Scholar Lawson article, A. E. (2004). Nature and the development of scientific reasoning: a synthetic view. International Journal of Scientific and Mathematical Education, 2 (3), 307-338.Article by Google Scientist Lederman, N.G., Abd el-Khalik, F. (2002). Avoiding the de-nature of science: An activity that promotes understanding of the nature of science. In W. F. M. (ed.), Nature of Science in The Education of Science (Vol. 5). Dordrecht: Science and Technology Library of Education: Springer. Google Researcher Lehrer, R., Schaeuble, L.A. (2015). The development of scientific thinking. Children's Psychology and DevelopmentAldion, 2 (7), 671-714. Google Researcher Leighton, J., y Gierl, M. (2007). Cognitive Diagnostic Assessment of Education: Theory and Applications. Cambridge: Cambridge University Press. Researcher Google Liepmann, D., Baudousel, A., Brocke, B., Amthauer, R. (2007). Intelligenz-Struktur-Test 2000 R: IST 2000 R (2-й прим. Гёттинген: Хогрефе. Научный сотрудник Google Лука, Л. Т., К.К. (2012). Simulations based on learning in Education: Cognitive, metacognitive, social, material and epistemological contribution. Educational review, 64(4), 471-492. . Article by Google Scholar Louca, L. T., and zacharia, K.K. (2015). Learning through modeling in K-6 scientific education. Scientific Educational and Technology Journal, 24(2), 192-215. . Article Google Scholar Mathesius, S., Hartmann, S., Upmeier zu Belzen, A., and Kruger, D. (2016). Scientific reasoning as an aspect of preschool education teachers biology: Assess competences with a paper-pencil test. In T. Tal and A. Yarden (Eds.), Future Research biology education (p. 93-110). Israel: Haifa. Researcher Google Morris, B.J., Crocker, S., Masnik, AM, zimmerman, K. (2012). The emergence of scientific reasoning. In H. Kloos, B. J. Morris, y BJ Amaral (Eds.), Current topics in children's learning and cognition. It's an integral. N. (1992). What do scientists think? Capture the dynamics of conceptual changes in science. In R. N. Giere and H. Feigl (Eds.), Cognitive Models of Science (Vol. 15, p. 3-45). Minneapolis, MN: University of Minnesota Press.Nersessian, North (2002). Cognitive basis of model reasoning in science. V. Carruthers, S. Stiche, M. Segale (ed.), cognitive-based science (p. 133-153). New York: Cambridge University Press. Google researcher Neumann, K., Hurtig, H., Harms, USA, Parchmann, I. (2017). Trained science teachers in Germany. In J. E. Pedersen, T. Isozaki, Hirano T. (Eds.), Model Science Teacher Training Program: International Comparison of What Works. Charlotte, North Carolina: Information Age.Neumann, K., Shaker, H., th Onisen, H. (2019). Evaluating complex models of student resources and behavior on a large scale. Annals of the American Academy of Political and Social Sciences, 683(1), 233-249. . Article Google Scientist NGSS lead states. (2013). Scientific standards of the new generation: For states, states. Washington, D.C.: National Academy Press. Google researcher Nicolau, C. T., Yu Constantinou, C. P. (2014). Assessment of modeling competence: systematic review and synthesis of empirical studies. Review of Educational Studies, 13, 52-73. . Article Google Scholar Osborne, J. (2013). The challenge of the 21st century for scientific education: Assessing scientific reasoning. Thinking Skills and Creativity, 10, 265-279.Article by Google Scientist Passmore, C. M., y Liberty, J. (2012). Exploring the possibilities for reasoning in model classes. International Journal of Scientific Education, 34 (10), 1535-1554.Passmore, C., Stewart, J., and Cartier, J. (2009). Model based on research and school science: Creating connections. School of Science and Mathematics, 109 (7), 394-402.Article By Google Scholar Passmore, C., Gouvea, J. S., and Giere, R. Models in science and learning Focusing scientific practice on the sense. In M. R. Matthews (Ed.), International Handbook on Research in History, Philosophy and Teaching of Natural Sciences (p. 1171-1202). Dordrecht: Springer. Google Researcher Rasmussen, J. (1981). Models of mental strategies in the plant diagnosis process. In J. Rasmussen and W. B. R (Eds.), Human Detection and System Failure Diagnosis, NATO Conference Series (Vol. 15, p. 241-258). Boston: Springer. Google Scholar Reiff, R., Harwood, W. S., and Phillipson, T. (2002) Scientific Method based on research concepts by research scientists. In Proceedings of the Annual International Conference of the Association for the Education of Teachers in Science, Charlotte, North Carolina: Association for the Education of Teachers in Science.Rennebeck, S., Bernholt, S., and Ropol, M. (2016). Finding the same place is a literary overview of empirical research in the field of research. Research in Scientific Education, 52 (2), 161-197. . Article by Google Scholar Ronqui, J. R. F., and Travieso, G. (2015). Analysis of complex networks using correlations in centrality measurements. Journal of Statistical Mechanics: Theory and Experiment, 2015 (5), P05030. Article by Google Scholar Ruppert, J., Duncan, R.G., and Chinn, C. A. (2019). The common role of domain-specific knowledge in student modeling. Research in Science Education, 49, 921-948. L., Glaser, R., Ragavan, K., Rainer, M. (1991a). Causal models and strategies of experiments in scientific reasoning. Journal of Educational Sciences, 1(2), 201-238. . Article Google Scholar Schauble, L., Klopfer, L. E., and Raghavan, K. (1991b). The transition of students from an engineering model to a scientific model of experimentation. Scientific Journal, 28 (9), 859-882.Article by Google Scholar Schreier, M. (2012). High-quality content analysis in practice. London: Sage Publications. Researcher Google Schwartz, C. V., Passmore, C., and Reiser, BJ (Eds.). (2017). Helping students understand the world through next-generation science and engineering practices. Arlington: NSTA Press. Google Scholar Sins, P. H., Savelsbergh, E. R., and Van Joolingen, W. R. (2005). Complex process of scientific modeling: analysis of the reasoning of beginners in computer modeling. International Journal of Scientific Education, 27 (14), 1695-1721.Article by Google Scientist van Driel, J. H., and Verloop, N. (1999). Teachers' knowledge of models and modeling in science. International Journal of Scientific Education, 21, 1141-1153. . Google Scholar VCAA article Victorian Curriculum and Evaluation Office. (2016). Victorian curriculum: F-10. Melbourne, VIC. Received from M., Thompson, J., and Braaten, M. (2008). How novice science teachers are appropriate discourses around model request for use in classrooms. Cognition and instruction, 26 (3), 310-378. . Article by Google Scholar, C. (2005). The development of scientific reasoning skills. Development Review, 20(1), 99-149.Article Google Scholar Download linksPopered access funding provided by Projekt DEAL. We thank Jonna Kirchhoff and Mike Barnebeck, who have made significant contributions to the quality of the data analysis, and the German Research Foundation (DFG) for funding the TypMoL project (Project 327507949). Any opinions, conclusions, conclusions or recommendations expressed in this article are the views of the authors and do not necessarily reflect the views of DFG. Dfg. understanding scientific reasoning giere. understanding scientific reasoning giere pdf