TRAINING SKILL AND WILL OF ARGUMENTATIVE THINKING

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Summary

Argumentation can be a fruitful and helpful endeavor to gain knowledge, to develop deep understanding of complex matters, and to come to well-grounded conclusions, particularly, but not only when it comes to the field of science (e.g., Kuhn, 2005; Kuhn, 2010; Quinn, Schweingruber, & Keller, 2012). For instance, scientific argumentation and evaluation are both core competences of biology education (Baxmann et al., 2009). The crucial nature of these competences is underscored by the fact that learners often encounter conflicting scientific positions, especially in the domain of ecology. These conflicting positions (e.g., global warming does vs. does not lead to forest dieback) originate from the great complexity and limited predictability of ecosystems. Thus, one of the goals of biology education is to qualify learners so that they sophisticatedly process such conflicting positions to develop deep understanding and well-grounded conclusions, or put in another way: to qualify them for scientific argumentation. This not only applies to interpersonal discourse, but also to the intrapersonal process of argumentative thinking, such as supporting theories with evidence or evaluating arguments (Kuhn, 2001). Therefore, learners that are confronted with conflicting scientific positions should engage in argumentative thinking and evaluate the strength of arguments and the quality of evidence on which the conflicting scientific positions are built.

Argumentative thinking, however, is no spontaneous process; indeed, it has two central prerequisites. Learners require the "competence to apply" (Kuhn, 2001, p. 4) argumentative strategies such as supporting theories with evidence, rebutting counterarguments, or evaluating arguments. This "competence" is simply referred to as "skill" (cf. McCombs & Marzano, 1990). However, the skill of argumentative thinking is necessary but not sufficient to engage in argumentative thinking. Learners also require the "disposition to apply" (Kuhn, 2001, p. 4) these strategies. This second prerequisite is shortly labeled "will" (cf. McCombs & Marzano, 1990) and has two crucial components (Kuhn, 2001; Kuhn & Park, 2005): a) Evaluativist epistemological understanding forms the rational base for regarding argumentative thinking as being reasonable. b) Intellectual values reflect the extent to which people regard argumentation as being worthwhile. As the will to engage in argumentative thinking means regarding argumentative thinking as a reasonable and worthwhile endeavor, it could be assumed to be a supportive base for the skill of argumentative thinking.

In order to qualify learners for argumentative thinking, it seems crucial to foster both their required skill and will of argumentative thinking. For instance, Kuhn (2005) gave students the opportunity to improve both their skill and will of argumentative thinking in interactive sessions. In spite of its effectiveness, this indirect intervention took eight weeks, though. As time is a precious and scarce resource in schools, there is a need to develop and test appropriate short-term and more direct instructional approaches. The goal of this work was to meet this challenge by developing and testing short-term training interventions to foster skill and will of argumentative thinking. In recognition of biology education's emphasis of argumentation and evaluation, these interventions should center the processing of conflicting scientific positions regarding sustainable development in the domain of ecology.

Chapter 1 features the general theoretical background of this dissertation, which is based on the following cornerstones: the conceptual background of the skill and the will of argumentative thinking, biology education's concern of scientific argumentation and evaluation, and the instructional background of short-term training interventions. Section 1.1 first introduces an argumentative model as a theoretical framework together with argumentative elements and their functions as the central *skill-principles*. Then, section 1.2 introduces the framework for the will of argumentative thinking, which is based on two components: evaluativist epistemological understanding and intellectual values. The characteristics and consequences of these two components form the central *will-principles*. Section 1.3 highlights the special importance of argumentative thinking for biology education and places special emphasis on the instructional concern for appropriate measures to foster argumentative thinking. As the last cornerstone of the general theoretical background, section 1.4 provides instructional considerations for training interventions to foster skill and will of argumentative thinking. It sets up the theoretical and empirical background for this dissertation's three training interventions to be packages of the following components: learning goals and theoretical introduction that focus on the central skill- and will-principles, video examples that model these principles, self-explanation prompts that encourage learners to self-explain the videos' underlying principles, and a self-regulated argumentation phase that affords argumentative thinking on a new topic. Against the general theoretical background, section 1.5 provides an overview of the dissertation's three main theses, all of which refer to effectively training skill and will of argumentative thinking. Specifically, Thesis 1 addressed the

claim that a short-term skill-training intervention fosters the skill of argumentative thinking when processing conflicting scientific positions in the domain of ecology. Furthermore, Thesis 2 assumed that a short-term will-training intervention fosters the will to engage in argumentative thinking when processing conflicting scientific positions in the domain of ecology. Finally, Thesis 3 claimed that a short-term combined-training intervention on both skill and will fosters facets of both skill and will of argumentative thinking as well as argumentative thinking itself when processing conflicting scientific positions in the domain of ecology. Moreover, this dissertation intended to contribute to theoretical and practical considerations with reference to foster different facets of the skill and the will of argumentative thinking.

Chapter 2 presents an overview of the three experimental studies that were conducted within the scope of this dissertation in order to investigate Theses 1 – 3. Section 2.1 outlines the components of all three short-term training interventions that were tested in the three studies. Specifically, three computer-based training interventions were developed that aimed at a learning time of about one hour: a *skill-training intervention* to foster the skill of argumentative thinking, a *will-training intervention* to foster the will to engage in argumentative thinking, and a *combined-training intervention* to foster both skill and will of argumentative thinking. All three training interventions consisted of five components that were implemented against theoretical and empirical backgrounds: learning goals, theoretical introduction, video-examples, self-explanations prompts, and a self-regulated argumentation phase. Furthermore, in recognition of the central importance of argumentative thinking for biology education, the domain of the training interventions was ecology. More precisely, the interventions focused on three topics of sustainable development. Next, section 2.2 describes the central dependent variables in this dissertation. These include the two skill-facets: declarative knowledge (i.e., declarative knowledge about the skill-principles) and procedural knowledge (about how to generate argumentative elements). This section also describes the three will-facets: epistemic orientation (indicating one's orientation toward the evaluativist level of epistemological understanding), intellectual values (reflecting the extent on which one values intellectual engagement), and epistemic knowledge (i.e., declarative knowledge about will-principles). Further dependent variables were argument quality (as an indicator of argumentative thinking) and self-explanation quality referring to the skill- and will-principles.

The training interventions were tested in three experimental studies. Participants in all three studies were German high school students in the final grade levels. Study 1 (*Manuscript A,* summary in section 2.3) experimentally tested the skill-training intervention (Hefter et al., 2014) with 84 participants ($N = 84$; 53 female, 31 male; $M_{age} = 17.76$; $SD_{age} = 0.93$). The main results of Study 1 showed that the skill-training intervention fostered declarative knowledge (for at least one week) and procedural knowledge about argumentation, as well as argument quality. Furthermore, the intervention fostered self-explanation quality referring to skill-principles, which mediated the effect on declarative knowledge about argumentation after one week.

Study 2 (*Manuscript B,* summary in section 2.4) experimentally tested the will-training intervention (Hefter et al., 2015a) with 66 participants ($N = 66$; 35 female, 31 male; $M_{age} = 18.21$; $SD_{age} = 0.90$). The main results showed that this intervention had positive effects on epistemic orientation (for at least one week), on intellectual values (after one week), and on epistemic knowledge (for at least one week). Furthermore, the intervention fostered self-explanation quality referring to will-principles, which mediated the effect on epistemic knowledge. The effect on intellectual values after one week was mediated by epistemic orientation.

Finally, Study 3 (*Manuscript C,* summary in section 2.5) replicated most of the findings of Study 1 and 2. Study 3 also tested a combined-training intervention on both skill and will (Hefter et al., 2015b). It was an experiment conducted with 147 participants ($N = 147$; 80 female, 66 male, 1 unknown; $M_{age} = 17.36$; $SD_{age} = 0.89$). The combined-training intervention successfully fostered facets of skill and will of argumentative thinking (i.e., declarative knowledge about argumentation, intellectual values, and epistemic knowledge; all effects were stable after one week) as well as argument quality. The positive effect of the combined-training intervention on argument quality was mediated by self-explanation quality (referring to both skill- and will-principles).

Ultimately, *Chapter 3* discusses the results of the three studies within a bigger picture in order to draw cross-experimental conclusions. Specifically, the main results of this dissertation reveal (see section 3.1) that: (a) A short-term skill-training intervention fosters the skill of argumentative thinking when processing conflicting scientific positions in the domain of ecology (Thesis 1). This thesis was supported by findings of Study 1 and Study 3, emphasizing the effectiveness of the skill-training intervention to foster skill-facets. (b) A short-term will-training intervention fosters the will to engage

in argumentative thinking when processing conflicting scientific positions in the domain of ecology (Thesis 2). Both the findings of Study 2 and Study 3 supported this thesis and underlined the effectiveness of the will-training intervention on will-facets. (c) A short-term combined-training intervention on skill and will fosters facets of both skill and will of argumentative thinking as well as argumentative thinking when processing conflicting scientific positions in the domain of ecology (Thesis 3). This thesis was supported by Study 3.

Furthermore, based on the results of Studies 1 – 3, section 3.2 provides the following theoretical implications. First, self-explaining the video examples' underlying central skill- and will-principles turned out to be an important learning process during the training interventions because it mediated the enduring effects on knowledge about these principles. Furthermore, both the self-explanation quality referring to skill-principles and the self-explanation quality referring to will-principles mediated the combined-training intervention's effect on argument quality. Second, due to the will-training and combined-training interventions' effect on epistemic orientation and intellectual values, these will-facets can be considered malleable by instructional approaches. Third, the will can be seen as a feasible base for the skill of argumentative thinking. From a more practical point of view, section 3.3 provides the following instructional implications: First, it is recommended to foster self-explanation quality through a combination of learning goals, a theoretical introduction, and corresponding self-explanation prompts (all three referring to the targeted central principles). Second, fostering both the skill and the will of argumentative thinking—particularly the will before the skill—should help learners to achieve high argument quality. Third, for an enduring effect on procedural knowledge, the short-term skill-training intervention should be enhanced (e.g., by implementing more video examples and argumentation phases).

Finally, section 3.4 discusses limitations of this research and provides guidelines for future research; these include the focus on the domain of ecology, testing the training interventions as whole packages, possible limitations of this dissertation's frameworks for the skill and the will of argumentative thinking, and the interventions' short-term character. Section 3.5 concludes this dissertation by pointing out the potential of short-term training interventions for fostering skill and will of argumentative thinking, the importance of self-explanations of central principles during the interventions, and the advantage of addressing the will before the skill or argumentative thinking.

1 How to Foster Skill and Will of Argumentative Thinking?

In this dissertation, argumentative thinking is considered an intrapersonal process of applying argumentative strategies such as evaluating arguments or rebutting counter-arguments (Kuhn, 2001). The term intrapersonal refers to argumentative thinking that takes place in an individual's mind and stands in contrast to interpersonal argumentation, which is a form of discussion with others. Argumentative thinking can, for instance, help one come to a well-grounded conclusion when facing conflicting scientific positions (cf. Kuhn, 2005; Kuhn & Park, 2005). Apparently, applying argumentative strategies requires a skill such as knowing how to actually evaluate arguments or rebutting counterarguments. For a detailed picture of this skill of argumentative thinking, see section 1.1, which introduces an argumentative model as a theoretical framework. Argumentative elements and their functions are described as the central skill-principles. Having the necessary skill, however, is not sufficient to perform argumentative thinking unless one considers it a reasonable and worthwhile endeavor. In this dissertation, seeing argumentative thinking as being reasonable and worthwhile is regarded as the will to engage in argumentative thinking. For more details on this, section 1.2 introduces a framework and the central will-principles. The will to engage in argumentative thinking might be supportive in learning how to perform argumentative thinking. However, simply having the will to engage in argumentative thinking is not enough to perform it. In a nutshell, engaging in argumentative thinking requires both the skill and the will of argumentative thinking. Neither the skill alone, nor the will alone is sufficient to apply argumentative strategies. If, however, a learner has acquired both the skill and the will of argumentative thinking, engaging in argumentative thinking can be useful to gain knowledge, to develop deep understanding, and to come to a well-grounded conclusion when faced with conflicting scientific positions. These benefits are of special importance, for instance in biology education, particularly when it addresses the domain of ecology, as section 1.3 explains. Thus, it would be desirable to meet the challenge of developing and analyzing appropriate instructional methods to foster both central prerequisites of argumentative thinking, namely skill and will. Against the theoretical and empirical background described in section 1.4, this dissertation focuses on exploring the potential of short-term training interventions to foster both skill and will of argumentative thinking.

1.1 The Skill of Argumentative Thinking—Framework and Principles

In this dissertation, a modification of Kuhn's (1991, 2005) argumentation model serves as a framework for addressing the skill of argumentative thinking. This framework describes the following six argumentative elements as well as their functions.

The first element is the *theory*, which refers to an initial claim or statement. An example in the domain of ecology is that global warming leads to forest dieback.

The given theory should be supported by arguments. One certain type of argument is *genuine evidence*, the second element of this framework. Genuine evidence, such as empirical findings, can help to clarify the theory's truth. Therefore, genuine evidence implies a strong argument that supports the theory. For instance, data about the reproduction rates of tree-damaging parasites that benefit from an increasing temperature (Bentz et al., 2010) could serve as genuine evidence. Delivering such empirical findings that an increase in temperature increases the population of parasites that damage trees is a strong argument for the theory that global warming leads to forest dieback. In contrast to genuine evidence, pseudoevidence only consists of explanations, further descriptions of the initial theory (Kuhn, 2001) or examples from one's own life experience. Thus, pseudoevidence, such as personal impressions of damaged trees, does not contribute to the clarification of the truth of a theory such as that global warming leads to forest dieback. Hence, pseudoevidence does not imply a strong argument and thus is not seen as an argumentative element of this framework.

The third element is the *alternative theory*, which is usually opposing the given theory. It can originate from either one's own mind or external sources and is also supported by some evidence. Referring to the introductory example, the alternative theory that global warming does not lead to forest dieback opposes the theory that global warming does lead to forest dieback.

The fourth element, the *counterargument*, affords shifting perspective and answers the question "What would someone who disagrees with my own position say?" A person who disagrees with the theory that global warming leads to forest dieback could cite empirical findings on growth conditions of different tree species (e.g., Ellenberg, 2009). These findings hint that an increase in the average temperature might have hardly any effect on growth conditions of deciduous trees, as those trees would still prosper

in warmer regions. Considering these findings might lead somebody to think that global warming does not lead to forest dieback.

The fifth element, the counterargument's *rebuttal*, strengthens one's own position. The aforementioned counterargument might indeed be built on genuine evidence, namely empirical findings. However, it could be rebutted by emphasizing that it is not relevant to the whole theory, but only aspects of it. Specifically, it only refers to growth conditions of deciduous trees, whereas it neglects the growth conditions of the widespread conifers, which indeed are sensitive to an increase in temperature. Thus, this counterargument does not so much apply to global warming and forests, but rather certain parts of forests, namely deciduous trees. This evident lack of relevance to the theory could be a possible target for the rebuttal.

Finally, the sixth element, the *synthesis*, refers to a careful evaluation of the strength of all given arguments and counterarguments in order to come to a well-grounded conclusion. Kuhn's (1991) original model would suggest a refutation of the alternative theory for the final element. This dissertation's framework rather uses a synthesis so as to place a stronger focus on evaluating arguments. This might also provide a fertile ground for evaluativist epistemological understanding, which in short means regarding evaluations as reasonable (see full description in section 1.2). The synthesis should evaluate whether all given arguments and counterarguments are built on genuine evidence rather than pseudoevidence and whether the given evidence is relevant to the whole theory rather than to single aspects or prerequisites thereof. As a result, the synthesis might still be viewed as a refutation of the alternative theory. However, it might also state that one position—perhaps under certain conditions—could be more right than the other or that further evidence or research is required. With respect to the simplified example about global warming and forest dieback, a synthesis that has considered the given arguments and counterarguments might conclude that different tree species react differently to an increase in temperature. Even though this might hardly affect deciduous trees, a careful evaluation reveals that there is reason to assume that conifers would die back. Moreover, further evidence that refers to additional factors and aspects such as time or parasite populations should also be addressed.

In fine, the skill of argumentative thinking can shortly be described as the "competence to apply" (Kuhn, 2001) argumentative strategies such as evaluating arguments, supporting theories with evidence, or rebutting counterarguments. Furthermore, the

central principles of the skill of argumentative thinking (simply labeled *skill-principles*) can be derived from the six previously described elements of the argumentation model and their functions. An example for such a skill-principle is that genuine evidence—such as empirical findings—supports the given theory by contributing to the clarification of its truth.

1.2 The Will of Argumentative Thinking—Framework and Principles

As previously mentioned, the skill of applying argumentative strategies by itself is not sufficient for actually engaging in argumentative thinking. The "disposition to apply" (Kuhn, 2001) these strategies by considering argumentative thinking to be both reasonable and worthwhile is also required. This prerequisite received the short label *will* (cf. McCombs & Marzano, 1990). As outlined by Kuhn and Park (2005), the will to engage in argumentative thinking builds on two components: *evaluativist epistemological understanding* and *intellectual values*.

The first component, evaluativist epistemological understanding, refers to personal epistemology (Barzilai & Zohar, 2014). Personal epistemology describes an individual's thinking about the nature of knowledge and knowing (Hofer & Pintrich, 1997) and can be studied and conceived against the background of different and even partly contradicting scientific approaches. Examples for these approaches include the resource approach (e.g., Louca, Elby, Hammer, & Kagey, 2004) or dimensional models (e.g., Ferguson & Braten, 2013; Hofer & Pintrich, 1997). This dissertation is built on the developmental approach of Kuhn and colleagues (Kuhn, 2005; Kuhn, Cheney, & Weinstock, 2000; Kuhn & Park, 2005) and uses it as the theoretical background and framework for addressing the will to engage in argumentative thinking.

According to Kuhn and Park (2005), there are three levels of epistemological understanding for individuals between school age and adulthood. These are the absolutist level, the multiplist level, and the evaluativist level, which is the highest of the three. At the first level—the absolutist level—of epistemological understanding, positions such as that global warming leads to forest dieback are seen in black or white terms (i.e., as being either correct or incorrect facts). Thus, argumentative thinking is deemed unnecessary. At the second level—the multiplist level—of epistemological understanding, positions are seen as freely chosen opinions. Without believing in the "dis-

criminability" (Kuhn & Park, 2005, p. 113) of conflicting positions such as whether global warming leads to forest dieback, argumentative thinking is considered irrelevant. It is not until individuals have reached the third level—the evaluativist level—of epistemological understanding, that they see some positions as being more justified than others based on the evaluation of arguments and evidence. Thus, the *evaluativist level of epistemological understanding* provides the rational base on which one can come to regard argumentative thinking as a reasonable tool to develop deep understanding and well-grounded conclusions (Kuhn & Park, 2005). The importance of reaching this level for engaging in argumentative thinking is supported for example by studies of Mason and Boscolo (2004) and Mason and Scirica (2006). In both studies, the authors used controversial topics in the domain of ecology. Mason and Boscolo (2004) confronted students with conflicting positions about the topic of genetically modified food. They found that epistemological understanding facilitated the students' argumentative processes such as reasoning and evaluating conflicting positions. Furthermore, Mason and Scirica (2006) introduced students to the topics of global warming and genetically modified food. The authors found that the students with evaluativist epistemological understanding produced higher quality arguments. In sum, evaluativist epistemological understanding means regarding argumentative thinking as a reasonable endeavor and can be considered a central component of the will to engage in argumentative thinking.

However, considering argumentative thinking to be reasonable may not be enough to engage in such intellectual engagement unless it is also regarded as being intrinsically worthwhile. Hence, Kuhn and colleagues (Kuhn, 2009; Kuhn & Park, 2005) propose a further component in addition to evaluativist epistemological understanding: *intellectual values*. These represent the value one places on intellectual engagement such as argumentative thinking. The evaluativist level of epistemological understanding already regards argumentative thinking as reasonable and thus implies the possibility of developing deep understanding and well-grounded conclusions through argumentative thinking. In contrast, intellectual values go even one step further and actually imply the *desirability* of developing deep understanding and well-grounded conclusions through argumentative thinking. Hence, intellectual values are considered to be based on an evaluativist level of epistemological understanding (Kuhn & Park, 2005). This is because on the lower levels of epistemological understanding (i.e., absolutist and multi-

plist level) argumentative thinking is not seen as a reasonable, but as an unnecessary or irrelevant endeavor. Thus, the absolutist and multiplist level lack the rational base for intellectual values, whereas the evaluativist level provides this base.

In short, individuals who have acquired the will to engage in argumentative thinking have reached the evaluativist level of epistemological understanding and developed intellectual values. Thus, they consider argumentative thinking to be a reasonable and worthwhile tool to gain deep understanding and well-grounded conclusions. In other words, the will of argumentative thinking allots argumentative thinking certain utilitarian benefits or advantages, namely being a tool to gain deep understanding and well-grounded conclusions. From a more motivational perspective, this could be considered as providing argumentative thinking with utility value (e.g., Eccles & Wigfield, 2002). Hence, when learners realize that argumentative thinking has utility value, they might be more motivated to acquire the skill of argumentative thinking. This consideration might become adjuvant when developing instructional measures, because it adumbrates a possible reason for first fostering the will to engage in argumentative thinking (i.e., establishing utility value) before fostering the skill of argumentative thinking. Furthermore, it should be considered that—according to Kuhn and colleagues (Kuhn, 2009; Kuhn & Park, 2005)—evaluativist epistemological understanding and intellectual values develop (if at all) over many years between childhood and adulthood. Therefore, the will to engage in argumentative thinking could be seen as more dispositional and less malleable, thus scaling up the instructional challenge of fostering it. Hence, in order to meet this challenge, developing effective interventions such as well-designed training interventions becomes desirable.

Finally, against the background of this framework, the characteristics and consequences of each level of epistemological understanding and of intellectual values form the central principles of the will to engage in argumentative thinking (simply labeled *will-principles*). An example of such a will-principle is that the evaluativist level of epistemological understanding means not seeing conflicting scientific positions as correct/incorrect facts or freely chosen opinions, but as evaluable positions built on arguments. Thus, an individual on the evaluativist level of epistemological understanding considers argumentative thinking as a reasonable tool to develop deep understanding and well-grounded conclusions about conflicting scientific positions, both of which play a major role in, for example, biology education.

1.3 Argumentative Thinking in Biology Education

Engaging in argumentative thinking—given both skill and will to do so are assured—can help to gain knowledge and to develop deep understanding of a topic as well as well-grounded conclusions (e.g., Kuhn, 2005; Quinn et al., 2012). Biology education is a good example of where this is of special importance—in particular in the domain of ecology. The reason for this special importance lies in the nature of biology (no pun intended). Biology can be regarded as the science about living systems (Harms, Mayer, Hammann, Bayrhuber, & Ulrich, 2004). Living creatures (including trees) are enormously complex living systems of molecules, cells, and organs (Reece et al., 2011). To make matters even more complex (and at the same time even more fascinating), living systems such as certain trees are part of greater systems such as populations, communities, and whole ecosystems (Townsend, Begon, & Harper, 2008). These ecosystems are very complex because of their high number of factors, interactions and dependency on (initial) conditions (Rieß & Mischo, 2008). For example, a typical European forest can be regarded as an ecosystem that features various interacting populations of flora and fauna that are dependent on climatic conditions (among many other factors). Due to this high level of complexity, ecosystems often exhibit stochastic behavior (Schurz, 2006), which lowers the degree of predictability of their processes. An example for such processes is a temperature increase due to global warming and its possible consequences on the ecosystem forest. Does, for instance, global warming lead to forest dieback? There is no trivial answer to this question. It is not sufficient to describe the relation between temperature and tree population by using a simple linear relation model with only two factors (one factor such as temperature increases while another factor such as tree population decreases). There are many factors and conditions (e.g., tree species, location, humidity) that influence the relationship between temperature and tree population (e.g., Ellenberg, 2009). Furthermore, there are many interactions with other populations such as the population of tree-damaging parasites (e.g., Bentz et al., 2010). Moreover, these parasites' reproduction cycles are also influenced by many factors; for instance, tree parasites populations tend to be augmented by increasing temperatures. In short, ecosystems' complexity can be immense.

Qualifying students to deal and work with such complex ecosystems is a major concern of biology education. Two goals of biology education in particular makes this

concern apparent: One goal is to foster systems thinking (Baxmann et al., 2009). This refers, inter alia, to the following processes: considering the interdependence between a system's elements, considering time dynamics, developing an appropriate model of a system, and making prognoses (Ossimitz, 2000; Riess & Mischo, 2010). Recent didactical research is concerned with developing and analyzing appropriate approaches to foster systems thinking. For instance, Riess and Mischo (2010) analyzed teaching methods to foster systems thinking of sixth-grade students. They found that a combination of special lessons and a computer-simulated scenario on the topic "ecosystem forest" promoted conceptual understanding of systems thinking.

In spite of these results, understanding systems thinking is not enough for processing ecosystems' complexity. Thus, biology education has another important goal that this dissertation seizes in particular: the goal to qualify students to actively participate in social communication, discussion, and decision-making about ecosystems (Baxmann et al., 2009). This goal recently gained even more importance, as the United Nations declared the years 2005 till 2014 the "Decade of Education for Sustainable Development" (Wals, 2012). Education for sustainable development is part of the interdisciplinary goals of biology education (Harms et al., 2004). Sustainable development refers to discussions and solutions about (but not limited to) interactions between humanity and ecosystems. Issues in the field of sustainable development include the consequences of genetic engineering or of resettling disappeared species such as the lynx. The "Decade of Education for Sustainable Development" (Wals, 2012) emphasized the importance of qualifying students to initiate, create and discuss processes of sustainable development. In short, they are required to participate in discussions about sustainable development (Künzli & Bertschy, 2008). This is however easier said than done: As previously stated, due to their complexity and limited predictability, ecosystems cannot be fully analyzed. This might lead to fragile knowledge or even conflicting scientific positions. These can in particular be found when it comes to topics of sustainable development. Revisiting the previous example about global warming and forest dieback, there is the position that global warming leads to forest dieback. In order to support this position, one could refer to data about temperature-sensitive reproduction of tree-damaging parasites (e.g., Bentz et al., 2010). These data indicate rather negative consequences of global warming on the forests because an increase in the average temperature would lead to an increase in the reproduction of parasites that in turn causes in-

creasing damage to trees. On the other hand, one could also support the position that global warming does not lead to forest dieback. Thereto, empirical findings could be cited that show the growth conditions of different tree species (e.g., Ellenberg, 2009). These findings hint that a rise in temperature might hardly affect the growth conditions of deciduous trees because they still prosper when it is warmer. Apparently, both exemplary positions can be backed up with evidence.

Given such conflicting positions that refer to a complex ecosystem, how might students follow the previous recommendations and participate in social communication, discussion and decision-making (Baxmann et al., 2009)? Prior to that, how might they develop a deep understanding of the topic and arrive at a well-grounded conclusion? Scientific argumentation and evaluation might help. In short, students should be qualified to support claims with scientific evidence and to evaluate different scientific positions such as whether a systems' complexity has been sufficiently considered and/or whether these positions are based on empirical evidence rather than personal impressions or mere descriptions. In sum, in addition to fostering systems thinking (which is not in the focus of this dissertation), biology education has to foster its learners' scientific argumentation and evaluation. Indeed, scientific argumentation and evaluation are both core competences of biology education, particularly in higher grades (Baxmann et al., 2009; Harms et al., 2004).

Against this background, developing appropriate instructional methods to foster argumentative thinking has the potential to contribute to biology education's goal to foster scientific argumentation and evaluation. This dissertation provides such a contribution by developing and analyzing short-term training interventions on skill and will of argumentative thinking while processing conflicting scientific positions in the domain of ecology.

1.4 Training Interventions to Foster Skill and Will of Argumentative Thinking

Argumentative thinking is of major importance—especially in biology education with respect to the domain of ecology—because it can help learners when processing conflicting scientific positions: Argumentative thinking can serve as a tool to gain deep

understanding and well-grounded conclusions (Kuhn & Park, 2005). Thus, developing and analyzing appropriate instructional methods to foster both central prerequisites of argumentative thinking, namely skill and will, is an instructional challenge.

Most of the few existing instructional approaches to foster skill and will of argumentative thinking follow principles of indirect instruction (e.g., Valanides & Angeli, 2005). For instance, Kuhn (2005) used practice methods and had students engage in interactive sessions to foster their argumentative processes. The students had certain goals to reach, for instance to learn that "some reasons are better than others" (Kuhn, 2005, p. 153) or "opposing reasons can be countered" (Kuhn, 2005, p. 153). In order to achieve this, the students cycled through different activities and, depending on the activity, were required to work individually, in pairs, and in groups with coaching to prepare for the "showdown" (Kuhn, 2005, p. 158). In this showdown, student teams represented conflicting views and discussed their arguments. Additionally, adults who interacted with the students were supposed to serve indirectly as "role models" along the way and to thereby contribute to the students' valuation of intellectual engagement. In short, Kuhn's (2005) intervention offered students the opportunity to improve both the skill and the will of argumentative thinking. This could be considered an indirect intervention because little instructional guidance was given, examples or problem solutions were hardly presented, and central principles of argumentation were not made explicit either. Although Kuhn's (2005) intervention has shown promising results in terms of fostering students' argumentation processes, it is a rather time consuming process, for it required 16 sessions of 90 minutes over a span of eight weeks. As time is a precious and scarce resource in schools, there is a clear need for developing more direct and short-term, yet effective instructional methods to foster skill and will of argumentative thinking.

This dissertation is an attempt to address this by contemplating short-term training interventions on both skill and will of argumentative thinking. Generally, training interventions are defined as structured and temporary interventions aimed at developing or increasing various types of knowledge and competences (Fries & Souvignier, 2009). They are frequently used as effective means in instructional settings to achieve various learning goals, for instance fostering reading comprehension (Gersten, Fuchs, Williams, & Baker, 2001), generic fostering of self-explanations (Busch, Renkl, &

Schworm, 2008), fostering self-explanation and reading strategies (McNamara, 2004), or fostering focused processing of explanations (Berthold & Renkl, 2010).

How to build training interventions that are short-term, yet effective? A reasonable approach on which to build appropriate training interventions is example-based learning, which is considered to be a prototype form of direct instruction (Kirschner, Sweller, & Clark, 2006; Lee & Anderson, 2013). Instructional approaches based on example-based learning have the potential to be both time-efficient (e.g., Kirschner et al., 2006) and effective for learning various procedures (e.g., Renkl, 2011). This effectiveness can be explained against the background of the cognitive load theory (e.g., Sweller, 2005), which recognizes the limited capacity of the learners' working memory. Confronting learners with an unfamiliar problem—especially learners with little or no prior knowledge about this problem—bears the risk of cognitive overload (Sweller, Van Merrienboer, & Paas, 1998). For instance, giving learners the task to process conflicting scientific positions and develop well-grounded conclusions might overstrain them, because they have not yet acquired argumentative strategies such as evaluating arguments. Thus, without an appropriate solutions strategy (in this case argumentative strategies to process the conflicting positions), learners would get cognitively absorbed in their search for a solution. In the end, learners might be unable to deeply understand the principles that are relevant to the solution process (Renkl, 2014). They are highly unlikely to find a satisfactory solution and might even acquire misconceptions or incomplete knowledge instead (Kirschner et al., 2006). In contrast, providing examples that model the core problem-solving principles would allow learners to devote their cognitive resources to understanding the necessary solution process (Renkl, 2014). For instance, the intervention by Schworm and Renkl (2007), which effectively fostered argumentation skills, consisted of video examples that showed two people discussing the topics of stem cell research and gender differences in learning. Note that, unlike worked examples for algorithmic domains such as mathematics, these video examples on argumentation skills showed no discrete algorithmic solution (Schworm & Renkl, 2007). Rather, they exemplified a problem solution for processing conflicting positions by modeling argumentative strategies, which followed Kuhn's (1991) argumentation model. Hence, learners had to actually process "two content levels" (Schworm & Renkl, 2007, p. 286). One level represented the argumentative strategies, which were in the main focus of learning. The other level was the concrete the-

matic exemplifications of these strategies in the given topics of the dialogues. Exemplifying argumentative strategies to solve the problem of given conflicting positions should help learners devote their attention to these argumentative strategies. Ideally, learners would then deeply understand these argumentative strategies and acquire the knowledge necessary to apply them to other situations.

Realistically however, providing examples is seldom sufficient without ensuring that learners deeply process them as well. This is due to the fact that learners often just cursorily go over the given examples. Although they acknowledge the information, they do not automatically develop a deep understanding of the examples' underlying principles (e.g., Renkl, 1997, 2011). As a corrective for this, self-explanation in generally considered to be a learning strategy that can be applied in various domains and contexts and has the potential to effectively help learners to deeply process and benefit from examples (Roy & Chi, 2005). Self-explaining the principles that underlie the examples is a crucial process on the way to a deep understanding of these principles (e.g., Renkl, 1997). In other words, learners should explain the principles that are the rationale of the examples' solution to themselves (Renkl, 2014). For learners to engage in such principle-based self-explaining, example-based learning has to be facilitated by self-explanation prompts or a previous training for self-explanation (Renkl, 2011). For instance, an example-based approach for fostering argumentation tested by Lao and Kuhn (2002) had not considered these important aspects to foster self-explanation and thus showed to be hardly effective. In contrast, self-explanation prompts were a central element of the effective example-based intervention on argumentation skills by Schworm and Renkl (2007). Their self-explanation prompts were questions that guided the learners' attention toward the examples' central principles as they should recognize and justify argumentative elements and their function. Thereby, these prompts fostered the learners' self-explanation of the central argumentative principles. Indeed, the implementation of these self-explanation prompts was essential for the intervention's effect on argumentation skills, as an experimental condition without these prompts proved to be relatively ineffective. Recent research provides even more evidence for the benefits of complementing examples with self-explanation prompts (e.g., Berthold, Eysink, & Renkl, 2009; Berthold & Renkl, 2009; Crippen & Earl, 2007; Hilbert, Renkl, Kessler, & Reiss, 2008; Wong, Lawson, & Keeves, 2002). Against this background, the following approach appears to be a reasonable core for an effective training inter-

vention on skill and will of argumentative thinking: combining *video examples* that model central principles of skill and will of argumentative thinking with *self-explanation prompts* that ask learners to self-explain these underlying principles.

However, there are more aspects to consider while developing effective training interventions that focus on example-based learning. First, a presentation of learning goals is also important. Making the corresponding learning goals explicit to the learners might support them in self-explaining the examples' underlying principles (Renkl, 2011). Furthermore, reviews of effective strategy instruction (Friedrich & Mandl, 1997; Harris, Alexander, & Graham, 2008) also hint at the importance of presenting learning goals. For example, Harris et al. (2008) suggested a metacognitively rich strategy instruction for maintaining and transferring learned strategies. Presenting learning goals could be considered to be a type of such an instruction (Berthold & Renkl, 2010). Second, the initial phase of example-based learning is crucial because it is here that learners "acquire basic declarative knowledge about a domain" (Renkl, 2014, p. 15). Thus, one should consider integrating a theoretical introduction on the targeted principles in example-based training interventions. This introduction should provide information about the upcoming video examples' underlying principles, which learners are supposed to self-explain. Recent research supports this consideration, as there are a few studies on effective training interventions that also presented their learning goals as well as theoretical introductions. For instance, the effective training interventions by Berthold and Renkl (2010), which fostered focused processing of explanations, instructed learners to read about the intervention's learning goals before providing them a theoretical introduction on the upcoming content. The successful generic self-explanation training intervention by Busch et al. (2008) also featured a presentation of the intervention's learning goals and provided general introductory theoretical information about self-explanations. Against this background, it seems reasonable that—before presenting video examples and self-explanation prompts—an effective training intervention on skill and will of argumentative thinking should show leaners the respective *learning goals*. This should be followed by a *theoretical introduction* that provides some initial explanatory input about the central principles of skill and will of argumentative thinking.

Finally, interventions should also encourage learners to practice the acquired strategies (van Hout-Wolters, Simons, & Volet, 2000). Similarly, Harris et al. (2008) suggest

that strategies instruction “demands self-regulated use of the academic strategies that have been developed” (p. 92). In other words, there should be a transition from the previous act of self-explaining video examples to independently solving a problem. This is also recommended by Renkl and Atkinson (2003); they argue that the cognitive demands of applying principles to solve a problem should have ideally decreased due to the knowledge acquired by previously self-explaining the former examples. With respect to argumentative thinking, when leaners then actively practice argumentative strategies without any support, they cannot just follow an available example. Rather, they should solve a given problem that is they have to process conflicting scientific positions and develop their own position. To solve this problem meaningfully, learners should have already acquired a basis (Renkl, 2014) through the previous studying and self-explaining of central principles underlying the video examples. Then, a self-regulated argumentation phase should build on this basis and afford learners the opportunity to finally apply, practice, and thus further consolidate argumentative strategies.

All in all, the previous theoretical and empirical considerations view effective training interventions on skill and will of argumentative thinking as packages that are comprised of a total five components that are learning goals, a theoretical introduction, video examples, self-explanation prompts, and a self-regulated argumentation phase. To explore the potential of such newly developed training interventions, it would be sensible to test them in experimental studies.

1.5 Research Theses

As previously discussed, there is a need to overcome the instructional challenge of developing short-term, yet effective, interventions to foster skill and will of argumentative thinking. Emphasizing this challenge in particular, argumentative thinking is of major importance in biology education when addressing the domain of ecology. For short-term, yet effective methods, it seemed feasible to rely on training interventions that focus on example-based learning. In order to foster skill and will of argumentative thinking, training interventions should address the central principles of skill and will of argumentative thinking, which are explained in the sections 1.1 and 1.2: the argumentative elements and their function (i.e., the skill-principles) and the characteristics and consequences of each level of epistemological understanding and of intellectual values

(i.e., the will-principles). As justified in section 1.4, these training interventions should be packages that are comprised of the following components: a presentation of *learning goals* and a *theoretical introduction* that refer to the targeted principles, *video examples* that model these principles, *self-explanation prompts* to encourage learners to self-explain these principles, and finally a *self-regulated argumentation phase* that affords applying argumentative strategies without any support. Given this background, the following questions arise for empirical testing: Does such a training intervention that focuses on skill-principles foster facets of the skill of argumentative thinking? Similarly, when a training intervention's components focus on will-principles, does it foster facets of the will to engage in argumentative thinking? Does a training intervention that focuses on both the skill- and the will-principles foster skill- and will-facets of argumentative thinking? Finally, and reflecting the fact that argumentative thinking requires both the skill and the will to do so, does such a training intervention foster argumentative thinking as well? These questions reflect the overall research goal that this dissertation addressed with three experimental studies: To explore the potential of short-term training interventions on fostering skill- and will-facets as well as argumentative thinking when processing conflicting scientific positions in the domain of ecology. At the same time, the three studies were intended to further contribute to these theoretical considerations: Does self-explaining the video examples' principles play such a crucial role during the training interventions, as suggested in section 1.4? Is the will to engage in argumentative thinking really more dispositional and thus less malleable as previously mentioned in section 1.2, or can potentially high effective instructional measures still enhance will-facets? Might the will to engage in argumentative thinking be a feasible base for the skill to perform it, as suggested in section 1.2? From a more practical point of view, the ultimate goal of this dissertation was to provide instructional implications to guide the design of short-term training interventions to foster skill and will of argumentative thinking.

To address these issues, three computer-based training interventions were developed: a skill-training intervention to foster the skill of argumentative thinking, a will-training intervention to foster the will to engage in argumentative thinking, and a combined-training intervention to foster both the skill and the will of argumentative thinking. Skill and will of argumentative thinking were conceived against the respective frameworks described in sections 1.1 and 1.2. Each of the three training interventions

was developed against the instructional background of training interventions discussed in section 1.4 and thus featured the following components: learning goals, theoretical introduction, video examples, self-explanations prompts, and a self-regulated argumentation phase. Furthermore, to reflect the major importance of argumentative thinking in biology education when addressing the domain of ecology, each of the training intervention featured the domain of ecology and referred to topics of sustainable development. As mentioned before, scientific argumentation and evaluation are core competencies of the curriculum of biology education, especially in the final grade levels of German high schools (Harms et al., 2004). Thus, the participants for the training interventions were German high school students in the final grade levels. One particular benefit for those soon-to-be high school graduates is that fostering skill and will of argumentative thinking could also contribute to their growing role as responsible citizens after leaving school (Kuhn, 2005).

The three training interventions were tested in three experimental studies presented in three *Manuscripts A – C*. The goal of Study 1 (see *Manuscript A*) was to test the skill-training intervention, whereas the goal of Study 2 (see *Manuscript B*) was to test the will-training intervention. Finally, in Study 3 (see *Manuscript C*) the goals were to replicate findings of the previous studies and to test the combined-training training intervention. Overall, the following three theses (Theses 1 – 3) are in the focus of this dissertation, and they address the potential of short-term training interventions to foster skill and will of argumentative thinking.

- Thesis 1: A short-term skill-training intervention fosters the skill of argumentative thinking when processing conflicting scientific positions in the domain of ecology.
- Thesis 2: A short-term will-training intervention fosters the will to engage in argumentative thinking when processing conflicting scientific positions in the domain of ecology.
- Thesis 3: A short-term combined-training intervention on skill and will fosters facets of both skill and will of argumentative thinking as well as argumentative thinking when processing conflicting scientific positions in the domain of ecology.

Study 1 investigated Thesis 1 and Study 2 investigated Thesis 2. Finally, Study 3 once again tested Thesis 1 and Thesis 2, and it investigated Thesis 3.

2 Experimental Studies in this Dissertation

This dissertation covers three experimental studies that explored the potential of short-term training interventions on fostering skill and will of argumentative thinking. *Manuscripts A – C* reported on each of the three studies in detail. Study 1 (Hefter et al., 2014) tested effects of a skill-training intervention on the skill of argumentative thinking. Study 2 (Hefter et al., 2015a) tested effects of a will-training intervention on the will to engage in argumentative thinking. Finally, Study 3 (Hefter et al., 2015b) replicated findings of Study 1 and 2 and furthermore tested a combined-training intervention on both skill and will of argumentative thinking.

2.1 Overview of the Training Interventions

Three different training interventions were developed and tested within the scope of the three studies in this dissertation: a *skill-training intervention* to foster the skill of argumentative thinking, a *will-training intervention* to foster the will to engage in argumentative thinking, and a *combined-training intervention* to foster both skill and will of argumentative thinking. The domain of all three training interventions was ecology (referring to topics of sustainable development), thereby reflecting the importance of argumentative thinking for biology education (see section 1.3). Each intervention (described in detail in the respective manuscripts) took the form of a computer-based learning environment that aimed at a learning time of about one hour. Furthermore, each of the three training interventions was developed against the previously discussed instructional background about training interventions (see section 1.4). Thus, all the interventions featured the components that section 1.4 justified earlier: *learning goals*, *theoretical introduction*, *video examples*, *self-explanation prompts*, and *self-regulated argumentation phase*. Table 1 presents an overview of the training intervention's components and their targeted principles.

Table 1. The Training Interventions' Components and Their Targeted Principles

Component	Skill-training	Will-training	Combined-training		No-training
			Skill-will-version	Will-skill-version	
Learning goals and theoretical introduction I	Skill	Will	Skill	Will	E-learning
Video example I	Skill	Will	Skill	Will	Skill/Will
Self-explanation prompts	Skill	Will	Skill	Will	Ecology
Learning goals and theoretical introduction II	—	—	Will	Skill	—
Video example II	Skill	Will	Will	Skill	Will/Skill
Self-explanation prompts	Skill	Will	Will	Skill	Ecology
Self-regulated argumentation phase	Identical for all conditions				

Specifically, the learning goals and the theoretical introduction of the skill-training intervention referred to the skill-principles (i.e., argumentative elements and their functions; see section 1.1). Likewise, the learning goals and the theoretical introduction of the will-training intervention referred to the will-principles (i.e., characteristics and consequences of each level of epistemological understanding and intellectual values; see section 1.2). The combined-training intervention featured *both* of these presentations of learning goals and theoretical introductions about the skill-principles and about the will-principles.

Furthermore, each training intervention featured two video examples that showed genuine conflicting positions in the domain of ecology. The first video example referred to the topic of biodiversity. Biodiversity, at its simplest, means species richness and refers to the number of different species in a given area, such as a certain forest (Townsend et al., 2008). The video example on this topic featured the conflicting scientific positions, whether resettling the lynx in local forests does or does not lead to negative ecological consequences. The second video example referred to the topic of global warming and featured the conflicting scientific positions, whether global warming does

or does not lead to forest dieback. In the skill-training intervention, both video examples showed two people who modeled the skill-principles. During each of the video examples, four self-explanation prompts encouraged the participants to self-explain the underlying skill-principles (i.e., argumentative elements and their functions). Similarly, in the will-training intervention both video examples modeled the will-principles. They were also supplemented with four self-explanation prompts that encouraged the participants to self-explain the video's will-principles (i.e., characteristics and consequences of each level of epistemological understanding and intellectual values). While developing the combined-training intervention, the priorities were to keep the learning time still short (not much longer than one hour). Moreover, overstraining the participants should be avoided. Thus, the number of video examples remained two, and the focus of the video examples and the respective self-explanation prompts was either on the skill- or the will-principles at one time. Hence, the combined-training intervention consisted of only *one* video example on each the skill and the will of argumentative thinking, unlike the skill-training and will-training intervention that used *two* video examples. Furthermore, actually two versions of the combined-training intervention were developed: The skill-will-version featured the components that addressed the skill-principles (i.e., learning goals, theoretical introduction, and video example with prompts) before the components that addressed the will-principles (i.e., learning goals, theoretical introduction, and video example with prompts). The will-skill-version was composed vice versa (see Table 1). This allowed for testing the assumption that fostering the skill of argumentative thinking should benefit from first providing argumentative thinking with utility value by fostering the will of argumentative thinking (see section 1.2).

Each training intervention also featured a self-regulated argumentation phase about the topic of genetic engineering. This phase afforded the participants the opportunity to generate their own position on whether the cultivation of genetically modified plants leads or does not lead to negative ecological consequences. A short video, which did not include any modeling or discussion, provided the necessary content information for the participants to generate their own position without any support.

Furthermore, a no-training intervention was developed as a learning environment for the control groups of each of the three studies. This no-training intervention did indeed feature the identical video examples on skill and will, respectively (as outlined in Table 1, Column 6) as well as a self-regulated argumentation phase identical to the

training interventions. However, learning goals and theoretical introduction were about e-learning and the self-explanation prompts referred to the exemplifying content of the videos (i.e., ecology). Thus, the no-training intervention did not address any skill- or will-principles.

2.2 Overview of the Dependent Variables

Manuscripts A – C describe the dependent variables of all three studies in detail. Nevertheless, Table 2 provides the reader with a neat overview of these variables, all of which are briefly discussed in the remainder of this section. It also plays a supportive role in cross-experimental discussion, which is presented later in *Chapter 3*.

Table 2. Central Dependent Variables in the Three Studies

Type	Label	Study 1	Study 2	Study 3
Skill-facets	Declarative knowledge	X	—	X
	Procedural knowledge	X[1]	—	X
Will-facets	Epistemic orientation	—	X	X
	Intellectual values	—	X	X
	Epistemic knowledge	—	X[2]	X
Argumentative thinking	Argument quality	X	—	X
Self-explanation quality of skill-principles		X	—	X
Self-explanation quality of will-principles		—	X	X

Note. X: assessed, —: not assessed.

[1]Procedural knowledge was labeled generative knowledge in *Manuscript A*.

[2]Epistemic knowledge was labeled conceptual knowledge in *Manuscript B*.

2.2.1 Facets of the skill of argumentative thinking—declarative and procedural knowledge

The two facets of the skill of argumentative thinking (simply labeled *skill-facets*) refer to the framework and principles introduced in section 1.1. They were central de-

pendent variables in Study 1 and Study 3, which tested the skill-training intervention and the combined-training intervention. Effects of the will-training intervention on skill-facets were not tested because of the lack of a reasoned hypothesis to assume such effects; no analyses were conducted unless they were explicitly based on proper hypotheses (as recommended for example by Rosenthal & Rosnow, 1985). Moreover, Study 2 did not address skill-facets because it solely focused on testing effects of the will-training intervention on the will to engage in argumentative thinking.

Within the scope of this dissertation, the first skill-facet is *declarative knowledge.* Declarative knowledge is defined as knowledge that can be reported or described (Anderson, 1993). It can relate to rather single facts but also to more complex knowledge about concepts and principles (Renkl, 2009). In this dissertation, declarative knowledge represents reportable knowledge about the skill-principles that form the six previously described elements of the argumentation model and their functions (see section 1.1).

The second skill-facet within the scope of this dissertation is *procedural knowledge* about how to perform argumentative thinking. Procedural knowledge is defined as knowledge that is manifested in people's performance and "must be compiled from declarative knowledge through practice" (Anderson, 1993, p. 22). It should be noted that in this dissertation the self-regulated argumentation phase is considered to be a type of practice opportunity (see section 1.4). Moreover, the label procedural knowledge is not used in *Manuscript A* because its study (i.e., Study 1) actually assessed two different kinds of procedural knowledge. They referred to different aspects of the argumentation model and were labeled *evaluative knowledge* and *generative knowledge*. Evaluative knowledge focuses on how to evaluate arguments. It refers to knowing how to choose the stronger of two given arguments by evaluating and differentiating between genuine evidence and pseudoevidence. Generative knowledge focuses on knowing about how to generate all six elements of the argumentation model. Unlike Study 1, Study 3 only assessed generative knowledge as procedural knowledge because of the high number of variables assessed in Study 3. When having to decide between assessing either evaluative or generative knowledge, generative knowledge seems to be more appropriate to represent procedural knowledge. This is due to the fact that generative knowledge entails generating all six argumentative elements, whereas evaluative knowledge involves just one argumentative element (i.e., genuine evidence).

Thus, this dissertation focuses on generative knowledge as a representation of procedural knowledge. Consequently, the label *procedural knowledge* refers to generative knowledge throughout the whole dissertation.

2.2.2 Facets of the will of argumentative thinking—epistemic orientation, intellectual values, and epistemic knowledge

The facets of the will of argumentative thinking (simply labelled *will-facets*) refer to the framework and principles outlined in section 1.2. Will-Facets were central dependent variables in Study 2 and Study 3 to analyze effects of the will-training intervention and the combined-training intervention. Note that effects of the skill-training intervention on will-facets were not tested because there were no reasoned hypotheses to assume such effects. Furthermore, will-facets were not addressed in Study 1 because it only focused on the skill-facets.

The first will-facet is *epistemic orientation* and is based on the framework of epistemological understanding as outlined in section 1.2. Epistemic orientation represents a tendency to move away from rather absolutist beliefs toward more evaluativist beliefs. Absolutist beliefs are beliefs an individual on the absolutist level of epistemological understanding—according to Kuhn and Park (2005)—would hold, such as that scientific statements are either clearly true or false. In contrast, evaluativist beliefs are beliefs an individual on the evaluativist level of epistemological understanding would hold. An example would be that even uncertain knowledge (e.g., when scientific positions contradict each other) can be evaluated. In short, epistemic orientation indicates the extent to which one considers argumentative thinking to be reasonable.

Besides epistemic orientation, the second will-facet is *intellectual values*; these serve as a measure for the extent to which an individual values intellectual engagement such as argumentative thinking. Finally, the last will-facet within the scope of this dissertation is *epistemic knowledge*. This dissertation uses the name epistemic knowledge as a distinctive (and unmistakable) label for declarative knowledge about will-principles, because the label “declarative knowledge” already refers to the skill-facet that is declarative knowledge about skill-principles. As section 1.2 explains, will-principles are characteristics and consequences of each level of epistemological under-

standing and of intellectual values. Note that due to the review processes for the manuscripts, epistemic knowledge is labeled conceptual knowledge in *Manuscript B.*

2.2.3 Argumentative thinking—argument quality

Each of the three training interventions featured a self-regulated argumentation phase that afforded the participants an opportunity to process two conflicting scientific positions without any support. The participants' task was to generate their own position. The participants' positions were rated for argument quality against the background of the previously described modified argumentation model (see section 1.1). For instance, high argument quality refers to when participants have generated their own position using all components of the argumentation model: theory, genuine evidence, alternative theory, counterargument, rebuttal, and synthesis. This process of independently developing one's own position entailed applying argumentative strategies such as supporting a theory, evaluating evidence, and developing a well-grounded conclusion. In other words, the act of generating one's own position actually meant engaging in argumentative thinking. The participants could not rely on extraneous input or help because no such was given. Furthermore, they could not rely on simply reciting the previous video examples from memory, because the self-regulated argumentation phase referred to a new topic. Hence, the generation of their own position could be considered a kind of output of argumentative thinking, suggesting that argument quality might serve as an indicator of argumentative thinking.

Argument quality was assessed as a dependent variable in Study 1 and Study 3 to analyze effects of the skill-training intervention (Study 1 and Study 3) and the combined-training intervention (Study 3). Note that this dissertation's rationale is that a decent level of argument quality—as an indicator of argumentative thinking—requires both skill and will of argumentative thinking. The three studies in this dissertation contribute to this rationale step by step, first focusing exclusively on fostering the skill (Study 1), then exclusively on fostering the will (Study 2), and finally on fostering both the skill and the will (Study 3) of argumentative thinking. Therefore, argument quality was not framed as requiring both skill and will of argumentative thinking until *Manuscript C* (about Study 3) and this synopsis. More precisely, in *Manuscript A* about Study 1, argument quality was simply framed as a component of argumentation skills. This was due to the fact, that Study 1 did not address the will to engage in argumenta-

tive thinking, but focused exclusively on the skill of argumentative thinking. Furthermore, argument quality was not assessed in Study 2. Rather, Study 2 used a simplification of the variable argument quality: *Application of evaluativist knowledge.* This was not a detailed rating for argument quality, but a dichotomous check to see, whether the participants had considered that there was more than one position, and that one of these could be better or more right than the other. This could be regarded as a precursor of argumentative thinking. The reason for this modification in Study 2 was the fact that the argumentation model (on which the rating of argument quality was based) was not addressed in the will-training intervention. The will-training intervention did not focus on training the skill to use strategies such as comprehensively evaluating arguments or rebutting counterarguments.

2.2.4 Self-explanation quality that refers to the central skill- and will-principles

In each training intervention, the participants were prompted eight times to type in self-explanations referring to the video examples. In the control condition, these prompts focused on the ecological content, whereas the prompts in the training conditions focused on the respective principles that were modeled in the video examples (see also Table 1 in section 2.1). As a measure for learning processes, the quality of the participants' self-explanations was rated. This rating referred to the quality, how the participants self-explained the principles that were trained in the respective training intervention. Thus, when testing the skill-training intervention in Study 1, self-explanation quality referred to the skill-principles (see section 1.1). Likewise, when testing the will-training intervention in Study 2, self-explanation quality referred to the will-principles (see section 1.2). Finally, testing the skill-training, the will-training, and the combined-training intervention on skill and will in Study 3 necessitated assessing two kinds of self-explanation quality: one referring to the skill-principles and another one to the will-principles.

2.3 Summary of Study 1: Developing and Testing a Skill-Training Intervention

The goal of Study 1 was to develop and test a short-term computer-based training intervention on the skill of argumentative thinking. This skill-training intervention was tested against a no-training intervention (i.e., control group design) in an experimental study with 84 German high school students (N = 84; 53 female, 31 male; M_{age} = 17.76; SD_{age} = 0.93).

In short, the results of Study 1 showed that the skill-training intervention successfully fostered the skill-facets that are declarative and procedural knowledge about argumentation. Furthermore, the skill-training intervention had a positive effect on argument quality. The positive effect on declarative knowledge was stable one week after the training. However, in contrast to the stable effect on declarative knowledge, the training intervention's effect on procedural knowledge had vanished when it was tested again one week after the training. This finding implies that the short-term skill-training intervention's effect on procedural knowledge was not strong enough to be preserved over a longer period of time. The skill-training intervention also fostered self-explanation quality that referred to the skill-principles. This self-explanation quality, in turn, mediated the training intervention's effect on declarative knowledge one week after the training.

In sum, the results of Study 1 show that the skill-training intervention is an effective instructional measure when starting to foster the skill of argumentative thinking. However, the skill-training intervention did not focus on the will to engage in argumentative thinking; this was addressed in Study 2.

2.4 Summary of Study 2: Developing and Testing a Will-Training Intervention

The goal of Study 2 was to develop and test a short-term computer-based training intervention on the will to engage in argumentative thinking. This will-training intervention was tested against a no-training intervention (i.e., control group design) in an experimental study with 66 German high school students (N = 66; 35 female, 31 male; M_{age} = 18.21; SD_{age} = 0.90).

In short, the findings of Study 2 showed that the will-training intervention successfully fostered epistemic orientation, the application of evaluativist knowledge, and epistemic knowledge. Furthermore, one week after the training intervention, there were still positive effects on epistemic orientation and on epistemic knowledge as well as a positive effect on intellectual values. The will-training intervention also fostered self-explanation quality that referred to the will-principles. This self-explanation quality, in turn, mediated the training intervention's effect on epistemic knowledge both immediately and one week after the training. These effects indicate the crucial role of self-explanations for learning processes during the training intervention. Moreover, the effect on intellectual values after one week was mediated by epistemic orientation.

Overall, the will-training intervention can be regarded as an effective instructional method when starting to enhance the will to engage in argumentative thinking. However, the will-training intervention did not address the skill of argumentative thinking. Hence, Study 2 did not assess skill-facets or argument quality. Thus, the will-training intervention might be insufficient instructional help for learners to actually perform strategies such as evaluating arguments or rebutting counterarguments when learners do not have such strategies in their skill repertoire. Finally, Study 3 addressed both the skill and the will of argumentative thinking.

2.5 Summary of Study 3: Replicating Findings of Study 1 and 2 and Developing and Testing a Combined-Training Intervention

In Study 3, two goals were addressed. The first goal was to replicate the findings on the effectiveness of the previous skill-training intervention (Study 1) and of the previous will-training intervention (Study 2). Conducting replication studies is recently particularly emphasized (e.g., Yong, 2012) and doing so would strengthen the findings of the first two studies. Thus, the original skill-training intervention (Study 1) and the original will-training intervention (Study 2) were tested against a control condition (i.e., no-training intervention). The second goal was to develop and to test a short-term training intervention on both the skill and the will of argumentative thinking. This combined-training intervention was developed while building on the materials of the previous skill-training intervention (Study 1) and the previous will-training intervention

(Study 2). As described in section 2.1, it contained components of both previous interventions.

Study 3 was an experimental study with 147 German high school students (N = 147; 80 female, 66 male, 1 unknown; M_{age} = 17.36; SD_{age} = 0.89). Five conditions were compared: (a) skill-training intervention, (b) will-training intervention, (c) combined-training intervention, (d) combined-training intervention with reversed sequence of skill- and will-components, and (e) no-training intervention (control condition). In short, the results of Study 3 showed a replication of previous findings on the effectiveness of both the skill-training and the will-training interventions. Again, the skill-training intervention fostered declarative knowledge for at least one week as well as procedural knowledge. Furthermore, the will-training intervention fostered two will-facets, namely intellectual values and epistemic knowledge, for at least one week. However, there was no effect on epistemic orientation. A closer look (see *Manuscript C*) indicates unexpectedly high values of epistemic orientation of the control group as a possible reason for this lack of effect on epistemic orientation. It might have been a coincidence or a consequence of the only moderate reliability of the scale for epistemic orientation (Cronbach's $\alpha_{Posttest\ (Study\ 3)}$ = .62).

Moreover, the combined-training intervention fostered skill- as well as will-facets. This is remarkable because, unlike the skill-training and the will-training interventions, the combined-training intervention consisted of only one video example on each the skill and the will of argumentative thinking. Despite this, it fostered declarative knowledge, intellectual values, and epistemic knowledge. These positive effects were stable for at least one week. However, the combined-training intervention did not foster procedural knowledge. This finding was no surprise because even the skill-training intervention, which featured two video examples on skill, reached its limits with respect to fostering procedural knowledge, as its effect on procedural knowledge vanished after one week. Moreover, the combined-training intervention achieved no effect on epistemic orientation. The sections 3.1.2 and 3.1.3 further act on this matter when they address the respective theses.

Study 3 also showed positive effects on argument quality. Not only did both the skill-training and the will-training intervention foster argument quality, but—as expected—the combined-training intervention as well. Furthermore, Study 3 provided further insight into fostering argument quality, which served as an indicator for argu-

mentative thinking. First, the will-skill-version of the combined-training intervention, which addressed the will-principles before the skill-principles, was superior at fostering argument quality when compared to the other training interventions. Second, both types of self-explanation quality (i.e., referring to both the skill- and will-principles) mediated the combined-training intervention's effect on argument quality.

In sum, Study 3 replicated findings on the effectiveness of the skill-training intervention (Study 1) and of the will-training intervention (Study 2). Furthermore, the results of Study 3 show that the combined-training intervention (the will-skill-version in particular) is an effective and promising short-term method to foster both the skill and the will of argumentative thinking and argumentative thinking itself.

3 General Discussion

As this dissertation's central contributions, section 3.1 supports its three main theses, which address the potential of short-term training interventions to effectively foster skill and will of argumentative thinking. Section 3.2 deals with the theoretical implications of this dissertation's findings, which shed light on self-explaining central principles as a crucial learning process, the malleability of will-facets, and the will as a feasible base for the skill of argumentative thinking. Furthermore, section 3.3 presents practical instructional implications for designing training interventions to achieve higher self-explanation quality, higher argument quality, and enduring effects on procedural knowledge about argumentation. Following a critical discussion of the limitations of this research as well as lines for future research, a conclusion wraps up this dissertation.

3.1 The Potential of Short-Term Training Interventions

This dissertation's overarching goal was to experimentally investigate the potential of short-term training interventions to foster two central prerequisites of argumentative thinking: skill and will. As this dissertation's central contributions, this section discusses the main results below by examining the following three theses (see section 1.5).

3.1.1 Thesis 1: A short-term skill-training intervention fosters the skill of argumentative thinking when processing conflicting scientific positions in the domain of ecology.

To examine this thesis, the present dissertation features two experimental studies. First, Study 1 tested the effects of a short-term skill-training intervention (see section 2.1). The results of Study 1, which are summarized in section 2.3, showed that this skill-training intervention successfully fostered not only self-explanation quality of skill-principles and argument quality, but also declarative knowledge and procedural knowledge. The positive effect on declarative knowledge was found to be stable one week after the training. In addition to this enduring positive effect, another important aspect emphasizes the skill-training intervention's effectiveness: The control group received the exact same video examples as well as an identical self-regulated argumen-

tation phase as the training group. Thus, the control group could be considered rather "strong", underlining the training intervention's effects. All these results provide support for Thesis 1.

Moreover, one of the goals in Study 3 was to replicate the findings of Study 1. As previously summarized in section 2.5, the results of Study 3 did indeed replicate findings of Study 1: Once again, the skill-training intervention fostered declarative knowledge (for at least one week), procedural knowledge, and argument quality.

In summary, these findings of both Study 1 and Study 3 provide cross-experimental and thus strong support for Thesis 1: The two skill-facets (i.e., declarative and procedural knowledge about argumentation) can effectively be fostered through a short-term skill-training intervention. However, in both Study 1 and Study 3 the skill-training intervention reached its limits with respect to fostering procedural knowledge as the effect on procedural knowledge had vanished after one week. This finding implies that the intervention's effect was not strong enough to be preserved over an extended period of time. From a theoretical perspective on different knowledge types, there is a plausible explanation for these limited effects on procedural knowledge: As mentioned earlier, when introducing the skill-facets in section 2.2.1, declarative knowledge can be seen as reportable knowledge about facts, concepts, and principles (Anderson, 1993; Renkl, 2009). In contrast, procedural knowledge rather manifests itself in people's performance and has to be compiled from declarative knowledge (Anderson, 1993). In line with the ACT-R theory (Anderson, 1983, 1993), it could further be argued that procedural knowledge about generating arguments is built on available declarative knowledge about the structure of these arguments. In other words, it might be easier and faster for learners to construct declarative knowledge rather than procedural knowledge about argumentation. Thus, the skill-training intervention appears a rather insufficient measure for constructing enduring procedural knowledge. This raises the question, how the training intervention might be modified to ensure enduring effects on procedural knowledge. Suggestions for modifications might include increasing the number of video examples and providing more than one self-regulated argumentation phase; section 3.3.3 provides a more detailed explanation.

3.1.2 Thesis 2: A short-term will-training intervention fosters the will to engage in argumentative thinking when processing conflicting scientific positions in the domain of ecology.

Two experimental studies examined Thesis 2: First, Study 2 tested the effects of a short-term will-training intervention (see section 2.1). The results of Study 2, which are summarized in section 2.4, showed that the will-training intervention successfully fostered epistemic orientation, intellectual values (after one week), and epistemic knowledge. Furthermore, the positive effects on epistemic orientation and on epistemic knowledge could still be observed after one week. Just as it was the case in Study 1 when testing the skill-training intervention, the control group received the exact same video examples as well as an identical self-regulated argumentation phase as the training group. Bearing this "strong" control group in mind, the positive findings further emphasize the effectiveness of the will-training intervention, especially because they could still be found after one week. Thus, Thesis 2 is supported.

Additionally, in order to provide more support for Thesis 2, one goal of Study 3 was to replicate findings of Study 2. As previously summarized in section 2.5, the results of Study 3 did indeed replicate some important findings of Study 2. In Study 3, the will-training intervention fostered intellectual values and epistemic knowledge. Both effects could still be found one week after the experiment. However, there was no effect on epistemic orientation. A closer look (see discussion in *Manuscript C*) indicates that this might be caused by the control group's unexpectedly high measures of epistemic orientation in Study 3, which were higher than the control group's measures of epistemic orientation in Study 2. This might be due to the only moderate reliability of the epistemic orientation scale (see section 2.5). Nevertheless, both the findings of Study 2 and Study 3 together provide cross-experimental and thus strong support for Thesis 2.

Moreover, as previously mentioned in section 1.2, Kuhn and colleagues (Kuhn, 2009; Kuhn & Park, 2005) argue that evaluativist epistemological understanding and intellectual values develop over many years between childhood and adulthood. However, the support of Thesis 2 (specifically: the will-training intervention's positive effect on the will to engage in argumentative thinking), puts this consideration in a differ-

ent light because it shows the possibility of actually training will-facets. The derived theoretical implications are discussed in section 3.2.2.

3.1.3 Thesis 3: A short-term combined-training intervention on skill and will fosters facets of both skill and will of argumentative thinking as well as argumentative thinking when processing conflicting scientific positions in the domain of ecology.

To examine this thesis, Study 3 tested the effects of a short-term combined-training intervention on skill and will of argumentative thinking that was based on the previous skill-training and will-training interventions. The results of Study 3, which are summarized in section 2.5, showed that the combined-training intervention fostered not only declarative knowledge (a skill-facet), but also intellectual values (a will-facet), and epistemic knowledge (also a will-facet) as well. These effects could still be found one week after the experiment. Furthermore, the combined-training intervention fostered argument quality. As mentioned previously, argument quality served as an indicator for argumentative thinking. Thus, all these findings provide support for Thesis 3: The combined-training intervention did indeed foster facets of both skill and will of argumentative thinking as well as argumentative thinking. Even against the background of the previously shown effectiveness of the skill-training and the will-training interventions, these results are not trivial. This is due to the fact that the combined-training intervention was not just a consecutive combination of the skill-training and the will-training interventions. Rather, it consisted of only one video example on each the skill and the will of argumentative thinking, unlike the skill-training and will-training intervention that used two video examples (see section 2.1). Even so, the combined-training intervention provided an additional benefit to the participants compared to the previous skill-training or will-training intervention: It fostered facets of *both* the skill and the will of argumentative thinking as well as argumentative thinking (i.e., argument quality) itself.

However, not all of the results were positive for the combined-training intervention, for it did not foster all the previously introduced skill-facets and will-facets, as there was no effect on procedural knowledge and no effect on epistemic orientation. The lack of effect on procedural knowledge seems to be in line with a general limitation of short-

term training interventions, as the skill-training intervention was only capable of showing an immediate but not enduring effect on procedural knowledge (see section 3.1.1). Thus, section 3.3.3 discusses practical implications for fostering procedural knowledge. The lack of effect on epistemic orientation, however, seems to be due to the control group's unexpectedly high measures of epistemic orientation, which was already mentioned in section 3.1.2 when addressing Thesis 2. All in all, in supporting Thesis 3, the findings underline the potential of short-term training interventions on fostering skill and will of argumentative thinking.

3.2 Theoretical Implications

From a theoretical perspective, the three studies of this dissertation pursued the overarching goal to shed light on theoretical assumptions on which the training interventions were developed: the importance of self-explaining the central skill- and will-principles as a crucial learning process during the interventions, the malleability of will-facets, and finally the will as a feasible base for the skill of argumentative thinking. Overall, the results of all three studies together suggest the following theoretical implications.

3.2.1 Self-explaining central principles as an important learning process during the training interventions

First, self-explanation quality that referred to the skill-principles mediated the skill-training intervention's effect on declarative knowledge one week after the training (Study 1). Hence, the extent to which the participants successfully self-explained the skill-principles underlying the video examples (i.e., the argumentative elements and their functions) influenced the knowledge about argumentative elements and their functions one week later. Second, in Study 2, self-explanation quality that referred to the will-principles mediated the will-training intervention's effect on epistemic knowledge both immediately and one week after the training. In other words, the extent to which the participants successfully self-explained the will-principles underlying the video examples (i.e., the characteristics and consequences of each level of epistemological understanding and of intellectual values) influenced their knowledge about these prin-

ciples—not only immediately but also one week after the training intervention. In a nutshell, this mediation effect pattern in both Study 1 and Study 2 emphasizes the importance of self-explanations for intervention effects that go *beyond* immediate performances. Apparently, the self-explaining of central principles facilitates enduring knowledge about these principles that can be retrieved one week later. This could be considered an important contribution to the literature because previous research (e.g., Berthold et al., 2009; Berthold & Renkl, 2009) has mostly focused on the mediating influence of self-explaining on immediate performances.

Moreover, the findings of Study 3 place even more emphasis on the importance of self-explanations during the training intervention. Both the self-explanation quality of skill-principles and the self-explanation quality of will-principles mediated the combined-training intervention's effect on argument quality. Thus, self-explaining both the skill- and will-principles influenced the participants' actual performance of argumentative thinking. This could also be considered an important contribution the literature, because it does not show the mediating influence of self-explaining on knowledge like previous research does (e.g., Berthold et al., 2009; Berthold & Renkl, 2009), but on actually performing argumentative thinking. Again, the participants had performed argumentative thinking while generating their own position on conflicting scientific positions about a new topic without any support. Besides the knowledge or skill to do that, it also required the will to engage in argumentative thinking.

In summary, self-explanations played a crucial role during the training interventions. Self-explanation quality that referred to central principles mediated important effects of the training interventions that go beyond immediate performances and also beyond effects on knowledge. Section 3.3.1 revisits the importance of self-explaining from a more practical point of view.

3.2.2 Will-facets as malleable by instructional approaches

Both the findings of Study 2 and Study 3 contribute the following aspects that might emphasize the malleability of will-facets. First, the training interventions on the will to engage in argumentative thinking used in this dissertation showed positive effects on will-facets. To be more precise, the will-training intervention fostered epistemic orientation, intellectual values, and epistemic knowledge in Study 2. In Study 3, the will-training intervention and the combined-training intervention fostered intel-

lectual values and epistemic knowledge. These results reveal that will-facets such as epistemic orientation (at least in Study 2) and intellectual values might be seen as less dispositional constructs as suggested by notions of Kuhn and colleagues (Kuhn, 2009; Kuhn et al., 2000; Kuhn & Park, 2005). As section 1.2 describes, according to Kuhn and colleagues, evaluativist epistemological understanding is a belief system developed over many years between childhood and adulthood, and intellectual values are considered to be founded on evaluativist epistemological understanding. However, the present results show that the will-facets epistemic orientation (indicating a tendency to move away from rather absolutist beliefs toward more evaluativist beliefs) and intellectual values might be considered malleable by effective instructional approaches such as the training interventions in this dissertation.

As a side note, there was no reason to assume that the third will-facet of this dissertation, epistemic knowledge, has some sort of dispositional character. Epistemic knowledge was introduced as declarative knowledge about will-principles (see section 2.2.2). Generally, declarative knowledge is not of dispositional character; it is acquirable knowledge about facts, concepts, and principles (Anderson, 1993; Renkl, 2009). For instance, declarative knowledge about skill-principles had already been successfully and enduringly fostered by the skill-training intervention in Study 1, suggesting a similar positive effect on epistemic knowledge (i.e., declarative knowledge about will-principles) by the will-training intervention in Study 2.

This dissertation also reveals more insights with respect to the malleability of intellectual values. First, the findings in Study 2 revealed that epistemic orientation assessed immediately after the experiment mediated the will-training intervention's effect on intellectual values one week after the training. This mediation implies that intellectual values (one week after the training) had been fostered indirectly through the fostering of epistemic orientation. As mentioned earlier, this epistemic orientation means a tendency toward beliefs that an individual on the evaluativist level of epistemological understanding holds (see section 1.2). Conclusively, these results underline the suggestion by Kuhn and Park (2005) that intellectual values are based on the evaluativist level of epistemological understanding. Second, regarding the development of intellectual values, there was a delayed increase of intellectual values after one week. In Study 2, the will-training intervention's positive effect on intellectual values did not appear until one week after the intervention. In Study 3, the positive effect on intellectual values did

indeed show already immediately after the intervention but still even increased (descriptively) after one week. This suggests that the training interventions may have served as an initial impulse to value intellectual engagement. This initial impulse may have been supported by intellectual activities at school during the week between the intervention and the delayed posttest, hence resulting in a delayed effect on intellectual values. This suggestion seems consistent with Kuhn and Park's (2005) notion that intellectual values are "embedded in cultural meaning systems" (p. 155). In summary, all the will-facets proposed within this dissertation appear to be malleable by short-term training interventions, highlighting especially the effects on epistemic orientation and intellectual values.

3.2.3 The will as a feasible base for the skill of argumentative thinking

The main theoretical rational for this dissertation—following Kuhn (2001)—was that both the skill and the will are central prerequisites for argumentative thinking (see *Chapter 1*). Thus, it is legitimate to ask, which of these two prerequisites should be addressed first? For Kuhn and colleagues (Kuhn, 2005; Kuhn & Udell, 2003; Lao & Kuhn, 2002), this question might not be of great relevance, as they would likely propose long-term indirect instructional measures to foster argumentative processes. As mentioned in section 1.4, Kuhn's (2005) interactive and argumentative discourses featured tasks such as peer-discussion, recognizing different qualities of reasons, or preparing for a final confrontation. These discourses could be considered as indirectly fostering both the skill and the will of argumentative thinking simultaneously. When it comes to more direct and short-instructional measures though, training both the skill-principles and the will-principles simultaneously might overstrain the learners. When developing short-term training interventions that focus on either the skill-principles or the will-principles at one time, the inevitable question arises: Should one address the will before the skill or vice versa? For considerations about this question, the literature offers the following aspects: Kuhn and colleagues would regard evaluativist epistemological understanding (i.e., the fundamental will-component, see section 1.2) as "a crucial underpinning" (Kuhn, 2010, p. 13), a "supporting structure" (Kuhn, 2001, p. 7), and "an essential foundation" (Kuhn & Park, 2005, p. 114) of (the skill of) argumentative thinking. Does this imply that the will to engage in argumentative thinking should be fostered first? There is a sound reason to assume just that: The will to engage in ar-

gumentative thinking means nothing less than considering argumentative thinking as a reasonable and worthwhile tool to gain deep understanding and well-grounded conclusions—particularly when facing conflicting scientific positions (see section 1.2). As a result, argumentative thinking has perceivable benefits or utility value (e.g., Eccles & Wigfield, 2002), which can motivate leaners to acquire the skill of argumentative thinking. Whereas they might not strive to acquire this skill for its own sake, they might strive to acquire it because of its utility value that is being a helpful tool for processing conflicting scientific positions.

The findings of Study 3 shed some light on these theoretical considerations because Study 3 featured comparisons between the interventions' effects on argument quality. Even though all three training interventions fostered argument quality, the will-skill-version of the combined-training intervention showed to be superior compared to the other training interventions in terms of fostering argument quality. In other words, training the will before the skill of argumentative thinking turned out to be this dissertation's most effective preparation regarding argument quality and thus regarding the learners' actual performance of argumentative thinking. Admittedly, some sort of recency effect (cf. Murdock Jr, 1962) may have had some influence on this finding. It is possible that during the argumentation phase, participants who received the will-skill-version might have remembered the skill-principles better than participants who received the skill-will-version might have. This might be due to the fact that the will-skill-version addressed the skill-principles at the end of the intervention immediately before the argumentation phase, whereas the skill-will-version addressed the skill-principles at the beginning of the intervention (see Table 1 in section 2.1). Thus, at the beginning of the argumentation phase, participants who received the will-skill-version might have had an advantage of an easier availability of skill-principles in their memory. However, the argumentation phase afforded the participants to generate their own position on a new topic that featured conflicting scientific positions. This task required actual argumentative thinking. In contrast, the studies about the recency effect typically referred to a simple free recall of items (cf. Howard & Kahana, 1999). Argumentative thinking, however, goes way beyond such a free recall of items, thus curtailing expectations of a recency effect affecting argumentative thinking. In conclusion, albeit the need for further empirical evidence, the advantage of the will-skill-version for fostering argumentative thinking contributes to the theoretical assumption that the will

to engage in argumentative thinking might be considered to be a feasible base for the skill of argumentative thinking.

3.3 Practical Implications

The training interventions in this dissertation fostered skill-facets and will-facets. Furthermore, they fostered argument quality referring to the output that comes from performing argumentative thinking. The training interventions also fostered self-explanation quality that referred to the central skill- and will-principles. From a more practical point of view, the goal of this dissertation was to provide instructional implications for training skill and will of argumentative thinking. The following three instructional suggestions can be derived from this research against the background of the results of all three studies. They could serve as practical implications to guide the design of short-term training interventions to foster skill and will of argumentative thinking.

3.3.1 Foster self-explanation quality that refers to central skill- and will-principles

As section 3.2.1 emphasized, it is important to ensure a high self-explanation quality that refers to the central skill- and will-principles, because it was a crucial factor for learning processes during the training interventions. It mediated important effects that go beyond immediate performances (i.e., effects on declarative knowledge and epistemic knowledge after one week) and beyond effects on knowledge (i.e., effects on argument quality). How could this fostering of self-explanation quality be achieved concretely? A combination of learning goals, a theoretical introduction, and corresponding self-explanation prompts (all three referring to the targeted central principles) appears to be an effective way to foster self-explanation quality that refers to the central principles. This notion is not only in line with the guidelines in recent literature (e.g., Renkl, 2011, 2014), but also cross-experimentally (and thus strongly) supported by the three studies in this dissertation. After all, both the control groups and the training groups received identical video examples, thus ruling these out as a difference maker. However, only the training groups received the learning goals, the theoretical introduction, and the self-explanation prompts that exclusively referred to the central skill-/will-principles. By contrast, the control groups' learning goals, theoretical introduction, and

self-explanation prompts referred to e-learning and ecological content and neglected any principles of the skill and/or the will of argumentative thinking.

3.3.2 Foster both skill and will of argumentative thinking

When the goal is to foster argumentative thinking, learners should receive a training intervention on both the skill and the will of argumentative thinking. More specifically, such a training intervention should address the will before the skill. This implication is based on the following cross-experimental step-by-step considerations about the findings of all three studies and refers to the actual performance of argumentative thinking: First of all, the skill-training intervention fostered argument quality (see Study 1), which served as an indicator of argumentative thinking (see section 2.2.3). However, the skill-training intervention did not focus on the will to engage in argumentative thinking, because its goal was to exclusively foster the skill of argumentative thinking. Hence, the skill-training intervention addressed only one (i.e., the skill) of two (i.e., the skill and the will) prerequisites of argumentative thinking. Thus, with respect to argumentative thinking, there should be room for improvement, especially when learners with little will to engage in argumentative thinking are involved. In other words, when the goal is actually to foster argumentative thinking (and not exclusively the skill to do so) the skill-training intervention should not be the practical method of choice. The same applies for the will-training intervention. It exclusively focused on fostering the will to engage in argumentative thinking irrespective of the participants' skill to do so. It was successful in fostering the application of evaluativist knowledge (Study 2), which can be seen as a precursor of argumentative thinking (see section 2.2.3). However, this will-training intervention is not recommended when the goal is to foster argumentative thinking because it did not address the necessary skill of argumentative thinking. The question arises what is the method of choice for fostering argumentative thinking? Against the background of all three studies in this dissertation, it is the combined-training intervention, particularly the will-skill-version. Study 3 identified the will-skill-version of the combined-training intervention—which addressed the skill after the will—as being superior at fostering argument quality when compared to the other training interventions. In a nutshell, to train argumentative thinking, it is recommended to foster both the skill and the will of argumentative thinking; in terms of order, the will before the skill for best results. As a practical implication, use the will-

skill-version of the combined-training intervention if learners should engage in argumentative thinking and generate their own position on conflicting scientific positions.

3.3.3 Enhance the skill-training intervention for an enduring effect on procedural knowledge

When the goal is to foster learners' procedural knowledge about argumentation, the skill-training intervention should receive some enhancements. As section 3.1.1 presents, the skill-training intervention reached its limits: Although it did indeed foster procedural knowledge immediately after the training intervention (Study 1 and Study 3), this effect was not strong enough and thus failed to show one week later in both studies. Furthermore, the combined-training intervention did not foster procedural knowledge at all (see section 2.5). This particular result was no surprise, given the modest nature of the combined-training intervention, which featured only one video example on skill. As the skill-training intervention featured two video examples on skill, it follows that one video example might not be enough to foster procedural knowledge. Therefore, from a practical point of view, an *immediate* effect on procedural knowledge requires a skill-training intervention that features at least two video examples on skill. However, as the results of Study 1 and Study 3 show, for an *enduring* effect on procedural knowledge, a short-term skill-training intervention—even with two video examples—is insufficient. As mentioned earlier with respect to the ACT-R theory and different knowledge types (Anderson, 1983, 1993), it might take more time and effort to acquire procedural knowledge than declarative knowledge. This is due to the fact that procedural knowledge needs to be compiled from declarative knowledge (Anderson, 1993). Now from a more practical point of view, the question arises, what modification of the skill-training intervention might foster procedural knowledge for more enduring effects?

Future studies should test a training intervention with an increased number of video examples on the skill of argumentative thinking. Study 3 showed, that one video example on skill (in the combined-training intervention) was not sufficient to produce an effect on procedural knowledge. Furthermore, Study 1 and Study 3 showed that two video examples on skill were indeed sufficient for an immediate, but in fact insufficient for an enduring effect. Even more video examples might induce an enduring effect on

procedural knowledge. Moreover, given the fact that procedural knowledge is defined as knowledge that is manifested in people's performance (Anderson, 1993), the argumentation phase might play a crucial role in fostering procedural knowledge. This is due to the fact that procedural knowledge refers to knowledge about generating argumentative elements and the argumentation phase in fact afforded generating argumentative elements for one's own position. In other words, this phase afforded practicing just the performance that the procedural knowledge variable refers to. Thus, a further modification of the skill-training intervention to improve its effectiveness on procedural knowledge might involve implementing two or more self-regulated argumentation phases. This would afford learners more occasions to practice generating their own position on conflicting scientific positions of new topics, which is likely to induce an enduring effect on procedural knowledge.

3.4 Limitations and Guidelines for Future Research

How far can the findings of this research be generalized? Despite the promising results of the three studies in this dissertation, some limitations and open questions need to be addressed.

3.4.1 The domain of ecology

The decision to use the domain of ecology for the training interventions in this dissertation reflects the major importance that biology education places on scientific argumentation and evaluation in this domain (see section 1.3). Furthermore, the training interventions featured three different topics in this domain (i.e., biodiversity, global warming, and genetic engineering). Each of these topics provided genuine conflicting scientific positions that can be supported with evidence. However, with respect to the domain, the generalizability of the findings is restricted. Although the self-regulated argumentation phase afforded a type of transfer in that the participants had to generate their own position on a new topic that was not addressed in the video examples (i.e., genetic engineering), the topic was still related to the domain of ecology. Thus, future studies should analyze training interventions that feature conflicting scientific positions in other domains to assure that the present findings are generally applicable.

3.4.2 Testing the training interventions as whole packages

Another aspect that could be regarded as a limitation of (possible expectations in) this research is the focus on the training interventions as a whole. In fact, the clear goal of this research was to develop and test short-term training interventions as effective interventions as a whole. This goal was reached and three experimental studies demonstrated the effectiveness of this dissertation's three training interventions. However, a detailed analysis of which of the training interventions' components (i.e., learning goals, theoretical introduction, video examples, self-explanation prompts, and self-regulated argumentation phase) caused which effect, was not one of the goals of this research. Rather, each training intervention was developed as a package of components and tested as a whole—a frequently used approach in previous research on training interventions (e.g., Berthold & Renkl, 2010; Busch et al., 2008; McNamara, 2004). Nevertheless, referring to effects of the present training interventions' components, the following aspects can be offered:

Mediation analyses revealed that self-explanation quality that referred to the central skill- and will-principles had a major positive influence on the training interventions' effects on knowledge about these principles after one week and on argument quality (see also section 3.2.1). In addition to the mediation analyses, theoretical and logical considerations can provide further conclusions about the components' effects. For instance, section 3.3.1 suggests a combination of learning goals, theoretical introduction, and self-explanation prompts (all referring to central principles) as an effective way to foster self-explanation quality that refers to these principles. Moreover, the skill-training intervention's argumentation phase might play a crucial role in fostering procedural knowledge, as section 3.3.3 explains.

However, it cannot precisely be stated which component and the extent to which it was responsible for the effects—for instance on procedural knowledge. Nevertheless, as analyzing the effects of different instructional components was not the goal of this research, it should be addressed in future studies.

3.4.3 The framework for the skill of argumentative thinking

Another point worth discussing, which also offers guidelines for future research, refers to the framework for addressing the skill of argumentative thinking in the training

interventions. This framework was based on a modification of Kuhn's (1991, 2005) argumentation model and featured six argumentative elements and their functions (see section 1.1). Admittedly, the interventions' presentation of these elements and their functions in the theoretical introduction as well as in the video examples might be considered as being rather basic or even simplistic. The learning material referred to basal characteristics that high school students should be able to grasp in about an hour. For instance, the interventions portrayed genuine evidence as contributing to the clarification of the theory's truth. More importantly, they presented empirical findings as genuine evidence and contrasted this to pseudoevidence such as explanations or further descriptions of the initial theory. However, none of the interventions addressed aspects such as the quality and significance of genuine evidence, the difference between causality and correlation, or generalization issues. Furthermore, when it came to the argumentative elements rebuttal and synthesis, the difference between sufficiency and necessity, or typical fallacies were not part of any intervention. Thus, these features might be added to future training interventions to provide a more in-depth and more challenging view on argumentative elements and their functions. Of course, learning time and the learners' background should be adequately considered and the effects of such extended training interventions should be experimentally investigated.

3.4.4 The framework for the will of argumentative thinking

Another possible limitation of this research refers to the framework for the will of argumentative thinking. As discussed in section 1.2, the will-components of the training interventions as well as the instruments to measure will-facets were developed on the basis of Kuhn and colleagues' developmental approach of epistemological understanding (Kuhn, 2005; Kuhn et al., 2000; Kuhn & Park, 2005). The following aspect should be taken into consideration: This developmental approach of epistemological understanding by Kuhn and colleagues is not the only approach to study and analyze personal epistemology (Barzilai & Zohar, 2014); there are various and even partly contradicting scientific approaches in current research, such as the resource approach as outlined by Louca et al. (2004) or dimensional models (e.g., Ferguson & Braten, 2013; Hofer & Pintrich, 1997). This dissertation's exclusive focus on one particular approach (i.e., the developmental approach by Kuhn and colleagues) might also be considered as strength with respect to theoretical and practical clarity and consistency. Nevertheless,

the training interventions in this dissertation might not be the preferred instructional methods for theoretical perspectives that, for instance, seek to activate developed epistemological resources in the sense of Louca et al. (2004). This is because the training interventions did not focus on activating epistemological resources, but rather on a first impulse to help learners reach the evaluativist level of epistemological understanding. If activating developed epistemological resources in the sense of the resource approach (e.g., Louca et al., 2004) is the instructional goal of choice, it will be recommendable to develop and analyze appropriate interventions in future studies.

3.4.5 The training interventions' short-term character

As a final limitation, the short-term character of the training interventions' might be taken into consideration. Indeed, the goal of this research was to develop and analyze short-term training interventions to foster skill and will of argumentative thinking. Therefore, the short amount of learning time (about an hour) of these interventions should be emphasized. Nonetheless, the short-term training interventions proved to be a promising first step, an initial impulse. The next step would be building on the promising results of this research and developing longer and more in-depth interventions. For instance, the number of video examples and self-regulated argumentation phases in the interventions could be increased. Furthermore, as suggested in section 3.4.3, the framework for the skill of argumentative thinking could be enhanced. Finally, it seems feasible to suggest bringing these further developed interventions into the classroom with some sort of blended learning for a number of lessons—for example in biology lessons in order to reflect core competences of biology education, namely scientific argumentation and evaluation (Baxmann et al., 2009). Combining further developed training interventions to foster skill and will of argumentative thinking with class activities and exercises might be a fruitful support for reaching central goals of education: to qualify leaners to successfully engage in scientific argumentation, and to enable them to contribute to society in their growing role as responsible citizens when leaving school (Kuhn, 2005).

3.5 Conclusion

Very briefly, this dissertation revealed three important and concise implications for instruction and research on training skill and will of argumentative thinking:

(a) *Use short-term training interventions for first promising effects on skill and will of argumentative thinking*. Featuring a learning time of only about an hour, these short-term training interventions proved to be capable of fostering skill-facets, will-facets, and argument quality (i.e., argumentative thinking). These findings underline the high potential of short-term training interventions when starting to foster skill and will of argumentative thinking. Building on this fertile ground, further (long-term) interventions and/or blended-learning approaches to further facilitate argumentative thinking might follow.

(b) *Ensure self-explanation quality that refers to the training interventions' central principles.* Self-explanation quality that refers to central skill- and will-principles was identified as a mediator for enduring effects on declarative knowledge about both the central skill- and the will-principles. It also mediated the effect on argumentative thinking (i.e., argument quality). Thus, self-explaining the video examples' underlying skill- and will-principles is a crucial learning process during the training interventions and its fostering is of great importance. To ensure this, a corresponding combination of learning goals, theoretical introduction, and self-explanation prompts (that all refer to the central principles) is an essential part of effective training interventions.

(c) *Train the will and then the skill of argumentative thinking.* Building on Kuhn (2001), this dissertation's main rationale was that argumentative thinking requires both the skill and the will to do so. Hence, considering argumentative thinking a reasonable and worthwhile endeavor (i.e., having the will) is not sufficient to successfully engage in argumentative thinking without having any skill to perform it. However, as Study 3 revealed, considering argumentative thinking to be reasonable and worthwhile might serve as fruitful base and facilitate the acquisition of the skill to perform it.

The author hopes that this research will contribute to a better understanding of fostering skill and will of argumentative thinking and the potential of short-term training interventions. Furthermore, he is hopeful that this research will stimulate further investigation and development of approaches to foster argumentative thinking as well as of applications of training interventions.

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