

Designing Adaptive Argumentation Learning Systems Based on Artificial Intelligence

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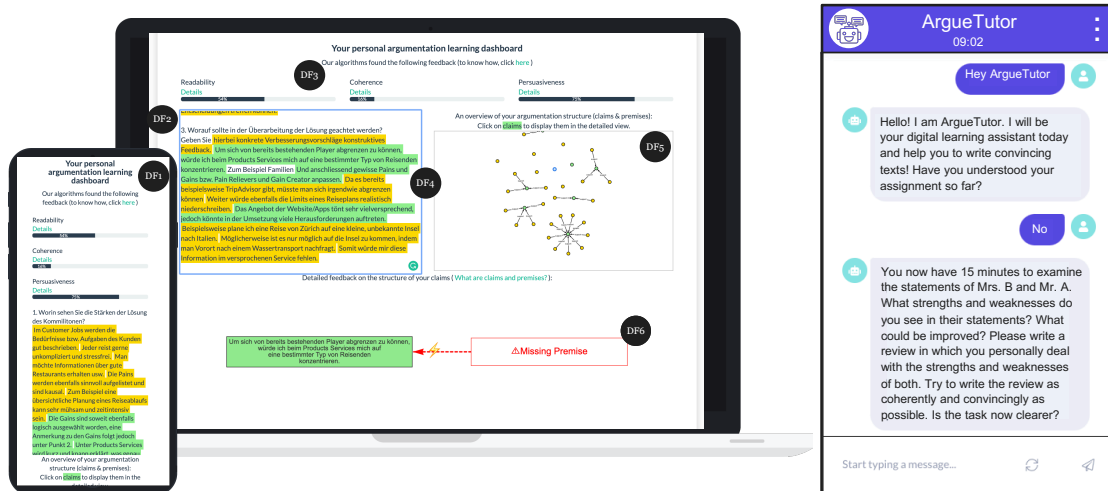


Figure 1: *Left:* A user is receiving adaptive argumentation writing support by our system *AL* while conducting a peer-review exercise in a large-scale lecture scenario. *Right:* A user is receiving adaptive argumentation tutoring with intelligent feedback and theory input by our conversational learning tutor *ArgueTutor*.

Abstract:

Argumentation skills are an omnipresent foundation of our daily communication and thinking. However, the learning of argumentation skills is limited due to the lack of individual learning conditions for students. Within this dissertation, I aim to explore the potential of adaptive argumentation skill learning based on Artificial Intelligence (AI) by designing, implementing, and evaluating new technology-enhanced pedagogical concepts to actively support students in developing the ability to argue in a structured, logical, and reflective way. I develop new student-centered pedagogical scenarios with empirically evaluated design principles, linguistic corpora, ML algorithms, and innovative learning tools based on an adaptive writing support system and a pedagogical conversational agent. My results indicate that adaptive learning tools based on ML algorithms and user-centered design patterns help students to develop better argumentation writing skills. Thereby, I contribute to research by bridging the boundaries of argumentation learning and argumentation mining and by examining pedagogical scenarios for adaptive argumentation learning from a user-centered perspective.

Keywords and Phrases: Argumentation Learning, Adaptive Skill Learning, Argumentation Mining, Pedagogical Conversational Agents

1 CONTEXT AND MOTIVATION

In today's world, most information is readily available, and solely reproducing information is losing attention. This results in a shift of job profiles towards interdisciplinary, ambiguous, and creative tasks [3]. Educational institutions need to evolve in their curricula when it comes to the composition of skills and knowledge conveyed [35]. Especially teaching higher-order thinking skills to students, such as critical thinking, collaboration, or problem-solving, has gained in importance [8]. This has also been recognized by the Organization for Economic Co-operation and Development (OECD), which included these skills as a major element of their Learning Framework 2030 [21]. One subclass represents the skill of arguing in a structured, reflective, and well-formed way [36]. Argumentation is not only an essential part of our daily communication and thinking but also contributes significantly to the competencies of communication, collaboration, and problem-solving [18]. Starting with studies from Aristotle, the ability to form convincing arguments is recognized as the foundation for persuading an audience of novel ideas and plays a major role in strategic decision-making and analyzing different standpoints, especially in regard to managing digitally enabled organizations. To develop skills such as argumentation, it is of great importance for the individual student to receive continuous feedback throughout their learning journey, also called formative feedback [2,13]. Thus, institutions, such as universities, are facing the challenge of providing individual learning conditions, since every student would need a personal tutor to have an optimal learning environment to learn how to argue [38]. However, this is unsurprisingly hindered due to traditional large-scale lectures or due to the growing field of distance learning scenarios such as massive open online courses (MOOCs, [29]). One possible solution to this dilemma is using adaptive argumentation learning tools that provide individual feedback on the argumentation of students' texts, e.g., through adaptive writing support systems or pedagogical conversational agents. These intelligent tutoring systems (ITS) often imitate meaningful, individual instructor–learner interactions (e.g., [16]) and have been successfully used in adaptively supporting learners to conduct a task by mimicking the gold standard of human tutors (e.g., [43,46,49]). By using such systems, students would be able to learn autonomously and independently of the instructor, time, and place [33,42].

More specifically, a promising way to support students to learn structured argumentation and enable teachers to convey it to classes of large sizes and independent from location might be the usage of adaptive technology-based applications in a pedagogical scenario for a student's learning journey. Therefore, recent advances in Artificial Intelligence (AI) such as argumentation mining (AM) seem to be a promising approach, since Natural Language Processing (NLP) and Machine Learning (ML) offer a scalable analysis approach to identify and classify the argumentation in texts, e.g., to access individual levels of argumentation [39,41]. This has been applied to various other types of texts, such as court statements [20], newspaper articles [4,7] or user-generated content [12]. Researchers, especially from the fields of educational technology, have designed tools to support the active teaching of argumentation to students with input masks or representational guidelines to enhance students' learning of argumentation (e.g., [11,22,24]). However, literature falls short of providing an approach with principles and proof on how to design and embed an adaptive argumentation learning tool in a pedagogical scenario to help students learn how to argue with intelligent formative feedback provided by an algorithm based on NLP and ML.

2 KEY RELATED WORK

Researchers have designed and evaluated several tools based on input masks and representational guidelines to support the active writing process of high school students. This has been investigated across a variety of fields, including law [24], science [22,34], and conversational argumentation [11]. However, literature related to research on adaptive argumentation learning is scarce [42]. Adaptive support approaches for argumentation learning (e.g., [17,24,30,32]) describe a rather new field of argumentation learning supported by technology-enhanced systems. The aim is to provide pedagogical feedback to a learner’s actions and solutions, hints, and recommendations to encourage and guide future activities in the writing processes or automated evaluation to indicate whether an argument is syntactically and semantically correct. However, the combination of NLP, ITS, and pedagogically evaluated formative feedback in a student’s learner journey is hardly investigated, due to its high complexity. As Scheuer (2015), p. 126 identifies, “*rigorous empirical research with respect to adaptation strategies is almost absent; a broad and solid theoretical underpinning, or theory of adaptation for collaborative and argumentative learning is still lacking*”. There is a clear lack of design knowledge and empirical studies for pedagogical scenarios for adaptive argumentation learning (e.g., [28,33,42]). Besides, conversational agents (CA) offer new forms of providing individual guidance and feedback to students [27,50,51], for instance, when completing a task to write persuasive texts, through a natural conversation interface combined with AM technology. However, in “*literature exists no approach with principles, design knowledge, and evaluation on how to design and embed an adaptive dialog-based argumentation tutoring system in a pedagogical scenario to help students to learn how to argue*” [16,43,48].

3 RESEARCH QUESTIONS AND METHODOLOGY

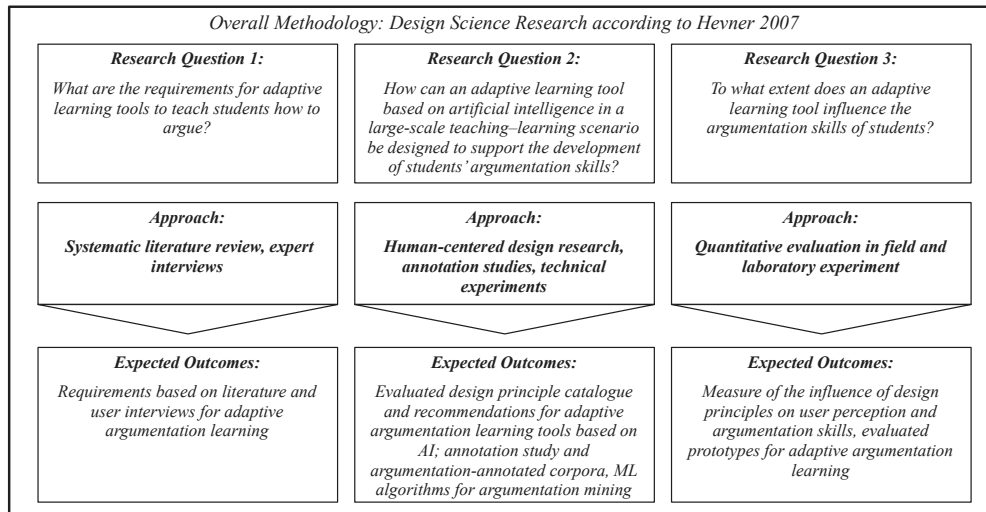


Figure 2: Research questions and methodology

This dissertation is guided by a design-oriented research (DSR) approach [14]. I decided to follow this approach in order to use a scientific method to solve a set of practical problems that researchers and practitioners experience in their own practice and to contribute to the existing body of knowledge by designing and evaluating new research artifacts. Based on the described research gaps in the related work section, I aim to contribute to adaptive argumentation learning by answering the following research questions (RQ) (illustrated in Figure 2):

RQ1: *What are the requirements for adaptive learning tools to teach students how to argue?*

RQ2: *How can an adaptive learning tool based on artificial intelligence in a large-scale teaching–learning scenario be designed to support the development of students’ argumentation skills?*

RQ3: *To what extent does an adaptive learning tool influence the argumentation skills of students?*

I intend to iteratively design and evaluate IT-learning artifacts on the baseline of existing theory (cognitive dissonance based on [9]) informing the artifact design [15]. I believe cognitive dissonance theory could explain why formative feedback on a student’s argumentation will motivate the student to learn how to argue [9]. Dissonance can be an initial trigger for a student’s learning process and thus the construing of new knowledge structures [23] through critical reflection, also reflected in the literature on transformation learning (e.g., [19]) or self-regulation theory [1]. However, the right portion of cognitive dissonance is very important for the motivation to solve it. According to Festinger, individuals might not be motivated enough to resolve it if the dissonance is too obvious, whereas a high level of dissonance might lead to frustration. Therefore, I believe that the right level of feedback to a student skill, such as argumentation skills, could lead to cognitive dissonance and thus to motivation to change the behavior, belief, or knowledge to learn how to argue.

4 RESULTS AND CONTRIBUTION TO DATE

Up to now, I was able to conduct several research steps that contribute to my three questions. For example, I investigated user and theory requirements for adaptive argumentation learning tools [42–44] for RQ1 and RQ2 and argumentation-annotated corpora [41], transfer learning algorithms for argumentation mining [39], and the effects of an adaptive argumentation learning tool on students’ ability to write persuasive business model peer reviews [40,43] for RQ3. The preliminary results of my findings are embedded in two iteratively developed learning tools (see Figure 1). First, I developed *AL* (short for Argumentation Learning), an *adaptive writing support system* that helps students to improve their argumentation skills in peer-feedback scenarios [40]. Second, I developed *ArgueTutor* (short for Argumentation Tutoring), an *adaptive dialog-based tutoring system* that provides students with adaptive and instant feedback, theoretical input, and step-by-step guidance during their writing process [43]. I will provide a brief overview of preliminary results regarding the specific RQ1. However, I would encourage the interested reader to find further details in the corresponding papers (e.g., [39–43]).

Preliminary results regarding RQ1: I followed two different development approaches: 1) a rigorous theory-motivated approach, where I systematically searched literature in the field of educational technology and HCI (following [3,6,47]) to carefully derive requirements and principles for the design of adaptive argumentation learning tools; and 2), a user-centred design approach, where I conducted a series of 42 semi-structured interviews (following [5,10]) with students from my university to derive user stories.

Preliminary results regarding RQ2: The results from RQ1 served as theory and user requirements for the design of adaptive argumentation learning systems. Hence, I derived different design principles for a) the design of an adaptive writing support system and b) the design of a dialog-based tutoring system, since both artifact types differ fundamentally in the user interaction (dialog-based vs. static interaction). Based on the initial findings, I tested the design principles as a design hypothesis according to the build–measure–learn paradigm of [25]. With several low-fidelity prototypes (e.g., [45]), I further learned about the interaction of the different

learning systems and the way students want to learn and improve their argumentation skills (more information in [40]).

From a technical perspective on designing an adaptive argumentation learning tool, it is crucial to develop an algorithm that is able to provide individual and adaptive feedback based on the argumentation level of students. Since no suitable corpora were available, I created a new dataset for argumentation skill learning. Therefore, 1) I derived an annotation scheme for a new data domain for AM based on argumentation theory (and previous work on annotation schemes for persuasive student essays (e.g., [31])), 2) presented an annotation study based on 50 persuasive peer reviews and three annotators to show that the annotation of student peer reviews is reliably possible, and 3) created a final and freely available corpus of 1,000 student peer reviews collected in our lecture about business innovation in German [41]. The corpus now serves as a reliable database for the training of ML algorithms for the design of adaptive argumentation learning systems in German.

Preliminary results regarding RQ3: Based on my design principles, the tested prototypes, the corpus development, and trained models, I designed two instantiations of an adaptive argumentation learning tool in different pedagogical scenarios. First, I built *AL*, an adaptive learning support system for argumentation skills [41], and evaluated it against a proven argumentation tool in a laboratory experiment with 54 students [40]. I found that students using *AL* wrote more convincing texts with better formal quality of argumentation and better subjective persuasiveness compared to the ones using the traditional approach. Second, I built *ArgueTutor*, an adaptive dialog-based tutoring system that provides students with adaptive and instant feedback, theoretical input, and step-by-step guidance during their writing process [43]. I evaluated *ArgueTutor* in a laboratory experiment with 55 students and found that *ArgueTutor* helps students to write formally more convincing texts compared to a static argumentation learning tool (the design and evaluation of *ArgueTutor* is currently under review at CHI 2021).

5 EXPECTED NEXT STEPS

For future work, I aim to further refine *AL* and *ArgueTutor* to evaluate to what extent an adaptive argumentation writing support system and an adaptive argumentation tutoring system can influence students' argumentation skills (**RQ3**). Therefore, I plan to conduct two further studies (*study 1* and *study 2*):

Study 1: I aim to compare *AL* and *ArgueTutor* in a laboratory experiment. My objective is to contribute to research with empirical results on the effects of a static writing support tool vs. a dialog-based tutoring tool on students' formal and informal argumentation skills as well as on effects on their perception. Therefore, I will conduct a laboratory experiment with three groups to evaluate the impact of *AL* and *ArgueTutor* on the development of students' argumentation quality. I will rely on one control group (participants will not receive any learning tool) and two treatment groups. Participants in treatment group 1 use *AL* for conducting a persuasive writing exercise, whereas participants in treatment group 2 will conduct the exact same exercise using *ArgueTutor*. I will carefully ensure that I only manipulate the interaction type (static vs. conversational). Both tools will be trained with the same feedback algorithm in the back end. Finally, I aim to measure the formal and informal argumentation level of the text from the participants and compare their perception of the learning process regarding motivation, cognitive dissonance, and technology acceptance using key constructs (e.g., [37]).

Study 2: Next, I want to embed both tools in a large-scale lecture scenario to evaluate the long-term effect of an adaptive argumentation learning tool on students' meta-argumentation skills. This can be achieved with a longitudinal study in a real-world learning setting. Therefore, particularly for analyzing the long-term effect of using *ArgueTutor* and *AL*, I aim to implement both artifacts into our existing learning management system [26] and measure long-term effects on the usability and the acceptance of skill learning during the complete three-month life cycle of a lecture. I want to investigate the hypothesis that adaptive argumentation learning tools influence the long-term meta-argumentation skills of students. At the end of the study, I want to contribute to research with two evaluated learning tools that can be used in a learning–teaching scenario where students do a certain writing exercise and receive adaptive argumentation writing support or tutoring in the writing process.

6 CONCLUSION AND EXPECTED CONTRIBUTION

In this dissertation project, I aim to design, build, and evaluate two new forms of adaptive argumentation learning tools (*AL* and *ArgueTutor*) that provide students with feedback on the argumentation structure of a text independent of an instructor, time, and place by leveraging the recent advances of AM algorithms.

Besides the software artifact as a situated implementation of an adaptive argumentation learning tool, I will contribute design knowledge to the scientific knowledge base. The resulting design knowledge is not only valid for my specific case but can also be transferred to further use cases in adaptive argumentation learning. For instance, it is easily possible to apply the concept of *AL* in courses that deal with other content than business models or other languages. For this purpose, only the back-end algorithm needs to be adapted to the other scenario. Multiple corpora and AM models exist in literature that can be easily embedded in *AL*, e.g., for English student essays [33] or English law cases [20]. The design principles of form and function and the overall system design do not need to be adapted for those use cases. Furthermore, it is also possible to transfer the design knowledge to pedagogical scenarios that target the training of other metacognition skills. For instance, if the learning of general feedback skills or empathy skills of students is aimed to be trained, a similar adaptive writing support system can be used. However, in this case, the system design might need to be revised partially, e.g., the graph visualization or the argumentation dashboard need to be adapted.

Moreover, research in argumentation learning and AM has made great strides in the last decade. In both research streams, we now know a lot about the mechanisms, the potential benefits, and shortcomings. However, both research fields have not yet crossed their boundaries to provide a comprehensive and multidisciplinary connection between argumentation learning for students and AM technology. I bridge these boundaries by examining a pedagogical scenario for adaptive argumentation learning from both perspectives, human–computer interaction and computational linguistics. Therefore, I contribute not only new rich argumentation annotation schemes, an argumentation corpus, and novel ML models but also insights into the overall embedding and design of adaptive argumentation learning tools and the potential of dialog-based argumentation learning. These insights will provide a new perspective on AI-based adaptive argumentation and more general metacognition skill learning, which has been neglected so far in existing research.

All in all, my research offers design knowledge to further improve educational feedback applications based on intelligent algorithms. With further advances in NLP and ML, I hope my work will attract researchers to design more intelligent tutoring systems for other learning scenarios or metacognition skills and thus contribute to the OECD Learning framework 2030 towards a metacognition-skill-based education.

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