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Development and Design of Technology-Based Feedback Using Design-Based Research

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Abstract Constructive feedback plays a critical role in educational processes, with empirical evidence highlighting its substantial influence on student development and learning outcomes. It enables learners to recognise both their strengths and areas for improvement, facilitates the formulation of future learning strategies, and fosters motivation for continued progress. The emergence of computer-based feedback systems addresses the challenge of delivering timely, continuous feedback without overburdening educators. These systems can be tailored to the needs of individual students, offering significant potential for optimising the learning experience. The project adressed in this article explores the development of technology-based feedback for virtual experimentation in geography using a design-based research approach, with a particular focus on the first step: the initial formulation of design principles based on literature and interviews. Regarding feedback timing, it is determined that learners will receive immediate feedback during task execution, allowing for real-time revisions, while delayed feedback is provided at the end of the experimentation process to guide future scientific endeavours. The feedback mechanism is expected to offer promising opportunities to enhance learning outcomes by promoting scientific literacy and competency development in geography education.

Keywords technology-based feedback, design-based research, geography education, design principles, virtual experimentation

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Development and Design of Technology-Based Feedback Using Design-Based Research

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1.0 Introduction

Constructive feedback is a key driver of learning success. It fosters students' individual development, sharpens their understanding of strengths and weaknesses, and guides subsequent learning processes, thereby enhancing overall performance (Bangert-Drowns, Kulik, Kulik, & Morgan, 1991; Hao et al., 2021; Hattie & Timperley, 2007; Hey-Cunningham, Ward, & Miller, 2021; Mertens, Finn, & Lindner, 2022). Despite these clear benefits, teachers face significant challenges when providing feedback. Time constraints and the large number of students in classrooms make it nearly impossible to regularly deliver detailed and individualised feedback to each student (Schmidt, Fiene, & Siegmund, 2024). As a result, many students receive only limited or imprecise feedback (Steingrübl & Budke, 2024; Voerman, Meijer, Korthagen, & Simons, 2012), which reduces its instructional value. This underutilisation of feedback contributes to it being one of the most challenging and unsatisfactory aspects of education (Boud & Molloy, 2013). Technological advances, particularly in artificial intelligence (AI), offer new ways to address this gap. AI-powered systems, such as chatbots, can provide immediate, individualised, and in some cases more detailed feedback than human instructors (Dai et al., 2023; Kasneci et al., 2023; Wedenig, Franz, Kaminski, Holzhausen, & Peters, 2023). Yet, their limitations are equally evident: AI feedback is often criticised for lacking contextual sensitivity, nuanced understanding, and authenticity (Hao et al., 2021; Zhang, Gao, Suraworachet, Nazaretsky, & Cukurova, 2025). A promising solution lies in a technology-based model that combines the scalability and efficiency of technology with the contextual awareness, emotional intelligence, and motivational impact of human feedback (Sherafati, Largani, & Amini, 2020). Such an approach can merge the strengths of both worlds to create feedback processes that are not only efficient but also pedagogically meaningful.

Within this context, the present dissertation study aims to develop and validate design principles for a technology-based feedback mechanism in geography education through the design-based research (DBR) approach. The feedback mechanism will be embedded within a virtual geography laboratory available to students from Year 7 and above. Within this virtual environment, students will be able to conduct experiments focused on understanding the regional impacts of climate change (Schmidt et al., 2024). This article presents the initial development and operationalisation of the design principles prior to iterative design cycles. The article begins with a review of the existing research on feedback, focusing specifically on three models that form the empirical foundation for the derived design principles. Following the description of the methodological approach, the subject-specific elaboration on feedback timing is presented as a case study, in which the underlying rationale is discussed and the limitations of the proposed design principles are examined.

2.0 Relevance of feedback for educational processes

The development of feedback models has been a crucial area of research in educational psychology. Ramaprasad (1983) provided a seminal definition of feedback as "information about the gap between the actual level and the reference level of a system parameter which is used to alter the gap in some way" (p. 4). While Ramaprasad's definition was rooted in management, behavioural, and social psychology literature and did not explicitly address educational contexts, subsequent scholars including Sadler (1989) extended this definition to the realm of education. To date, countless feedback models have been developed that focus on different levels of feedback (Bangert-Drowns et al., 1991; Butler & Winne, 1995; Carless & Boud, 2018; Hattie & Timperley, 2007; Kulhavy & Stock, 1989; Lipnevich, Berg, & Smith, 2016). These diverse perspectives and conceptualisations contribute to a comprehensive understanding of feedback models in education, underscoring their multifaceted nature and their critical role in supporting student learning and development. By examining and evaluating these diverse feedback models, educators can adapt their approaches to better meet the specific needs of their classrooms, thereby enhancing students' learning experiences. The following section provides a short overview of feedback conceptualisations, drawing on the foundational work of Kluger and DeNisi (1996), Narciss and Huth (2004), and Hattie and Timperley (2007).

Kluger and DeNisi (1996) developed the feedback intervention theory (FIT) as part of a meta-analysis which tested and partially confirmed some of its predictions. The analysis revealed mixed effects of feedback interventions, with one third negatively impacting performance. FIT was introduced to explain these varying effects. The FIT combines assumptions from various social psychological theories, such as control theory, goal setting theory, and action theory. Based on these theories, Kluger and DeNisi (1996) formulated five central assumptions: (1) Behaviour is regulated by comparisons of feedback to goals or standards. (2) Goals or standards are organised hierarchically. (3) Attention is limited and therefore only feedback-standard gaps that receive attention actively participate in behaviour regulation. (4) Attention is normally directed to a moderate level of the hierarchy. (5) Feedback interventions change the focus of attention and therefore affect behaviour (Kluger & DeNisi, 1996, p. 259). The effectiveness of feedback depends on its focus within a hierarchy of attentional levels (Kluger & DeNisi, 1996). At the lowest level, feedback addresses task-learning processes, focusing on specific task details. The middle level targets task motivation, engaging with the task itself. At the highest level, meta-task processes connect the task to broader self-related goals. Feedback should primarily focus on the middle level, as shifting attention to meta-task processes, such as normative comparisons, praise, or feedback affecting self-esteem, can diminish its positive impact on performance (Kluger & DeNisi, 1996).

Narciss and Huth (2004) introduced a feedback model designed for multimedia learning in mathematics, emphasising tutoring systems that adapt feedback to meet students' needs. The interactive tutoring feedback model is based on the cybernetic paradigm from systems theory and represents the interacting processes and factors of the two feedback loops that can explain a wide variety of feedback. Narciss (2006) presented three main components that need to be considered when developing feedback strategies: (1) characteristics of the feedback strategy, such as function, content, and presentation, (2) individual learner factors, such as goals and motivation, and (3) didactic factors, such as learning objectives and task type. The model integrates several influencing factors that determine whether and how feedback from an external source is processed effectively. One essential aspect of a feedback strategy is its timing, which significantly influences both learners' ability to process feedback and their motivation to use it for improving performance. Feedback can be classified as either immediate or delayed. In the context of computer-based assessments, 'immediate' refers to feedback provided as soon as the learner responds to an item (van der Kleij, Eggen, Timmers, & Veldkamp, 2012), allowing learners to promptly identify and correct errors, thereby fostering a strong link between action and response (Dihoff, Brosvic, & Epstein, 2003). This approach is particularly beneficial for simple tasks or at the early stages of learning, when motivation and error correction are priorities (Mullet, Butler, Verdin, von Borries, & Marsh, 2014). In contrast, delayed feedback is presented after a predetermined interval, often following a reflection period or subsequent learning activities (Dempsey & Wager, 1988). This timing encourages deeper cognitive processing and supports the development of self-regulation skills, particularly for complex tasks or in advanced learning phases. Beyond the timing of feedback, its frequency and the intervals at which it is delivered are equally critical. Research has shown that frequent and timely feedback can significantly enhance instructional quality and improve learner outcomes (Hattie, 2020). Such feedback facilitates continuous progress monitoring, allowing learners to identify discrepancies between their current and desired performance levels (Kluger & DeNisi, 1996). However, excessively frequent feedback can inhibit self-regulation and reflective thinking, while feedback delivered at extended intervals risks weakening the connection between actions and responses. Achieving an optimal balance between frequency and timing is critical for aligning feedback with learners´ cognitive capacities and ensuring its maximum benefit.

Narciss (2006) further refined feedback strategies by proposing a content-oriented classification. This framework includes three evaluative and five elaborated feedback categories. Evaluative feedback focuses on providing information about the learner's performance or results. Examples include knowledge of performance (e.g. how well a task was executed) and knowledge of results (e.g. whether the answer was correct or incorrect). This type of feedback is often concise and informs learners of their current status. In contrast, elaborative feedback goes beyond evaluation by offering detailed information to guide improvement and foster deeper understanding. Examples include knowledge on task constraints (e.g. specific limitations or rules governing the task), knowledge about mistakes (e.g. identifying and explaining errors), and knowledge on how to proceed (e.g. providing actionable steps for further progress). By addressing the underlying processes and strategies involved in learning, elaborative feedback supports the development of higher-order thinking skills and promotes self-regulation (Mertens et al., 2022).

Hattie and Timperley (2007) defined feedback as "information provided by an agent (e.g. teacher, peer, book, parent, self, experience) regarding aspects of one´s performance or understanding" (p. 81). The idea of feedback is based on the proposition that it should close the gap between the current performance and the desired goal, as Ramaprasad (1983) proposed. To maximise the effectiveness of feedback, it should answer three questions: (1) Where am I going?, (2) How am I going there?, and (3) Where to next? Feedback that addresses the question of Where to next? has the most significant impact on learning outcomes, yet it remains one of the least frequently implemented forms of feedback. Notably, when students are asked to define feedback, they often highlight feedforward as the most essential component they require (Lipnevich & Panadero, 2021). The effectiveness of feedback in narrowing the discrepancy between learners' current performance and the targeted goal depends on the level at which the feedback is given. A distinction is made between the task level (statements about the quality of task completion), the process level (strategies for task completion), the self-regulation level (monitoring and control of the learning process), and the self level. Feedback at the self level rarely leads to an improvement in performance (Hattie & Timperley, 2007). Instead, it draws attention to the self as it does not provide any specific information on particular performances. Concurrently, students are encouraged to reflect on their performance and independently identify areas for improvement (Hattie & Timperley, 2007).

While feedback concepts have been widely explored in various educational contexts, their application in geography education remains underdeveloped, presenting challenges in effectively supporting meaningful knowledge construction, skill development, and conceptual understanding. Despite its recognised importance for effective learning, feedback practices in geography education lack consistency and structure (Steingrübl & Budke, 2024). For example, pre-service teachers providing feedback on students´ argumentative texts often begin with positive reinforcement but demonstrate highly variable approaches shaped by individual preferences rather than standardised principles. Feedback can offer a promising solution by providing consistent and structured input that reduces variability and delivers constructive, targeted support for student learning. While existing frameworks, such as the interactive tutoring feedback model by Narciss and Huth (2004), have proven effective in mathematics education, feedback strategies must be adapted to the specific needs of geography education to maximise clarity, relevance, and impact. Geography education presents unique challenges, particularly in experimental learning contexts, which are less common but highly engaging for students (Hemmer & Hemmer, 2021). Feedback in this domain must extend beyond outcome evaluation to encompass the experimental process itself, fostering deeper understanding and skill refinement. This reveals the research gap: the absence of a process-oriented feedback mechanism tailored to the specific needs of experimentation in geography education. Addressing this gap is the overarching aim of this dissertation study. This paper focuses on demonstrating how the initial design principles for such a feedback mechanism can be derived from existing literature and empirical data. The paper shows this process through the example of feedback timing as one instance from the dissertation project.

3.0 Methods

The research process comprised a narrative literature review, exploratory interviews, and a structured procedure for developing and operationalising design principles. The literature review provided a contextual foundation, summarising research on feedback with particular attention to its general principles, applications in geography education and experiential learning, and its role in virtual learning environments. The main empirical component consisted of ten guided interviews with German high school teachers (three female and seven male participants) to gather insights into practical experiences and attitudes towards experiments, feedback, and virtual learning environments. Participation required prior classroom experience with experiments, limiting the sample to teachers of biology, chemistry, or geography. The interviews served as a primary data source for the initial formulation of the design principles. The interviews were conducted in German, transcribed, anonymised, and analysed using qualitative content analysis (Mayring, 2015) with the support of MAXQDA software. Key themes and patterns were identified, providing valuable insights into the practical challenges and opportunities associated with feedback in experimental and virtual settings. The findings were translated into English for this article. The integration of these empirical findings with theoretical insights follows the collaborative approach advocated in DBR, emphasising the connection between researchers and practitioners (DBRC, 2003; Euler, 2014).

A central component of the DBR approach is the formulation of well-defined design principles. These principles are understood as an overarching concept encompassing action-oriented guidelines that can be articulated at varying levels of abstraction (Euler, 2014). They constitute the conceptual foundation of the research focus (Euler, 2014; Feulner, 2020) and facilitate the transfer of findings to broader educational contexts (Feulner, Hiller, & Serwene, 2021). Within the research process, existing or theoretically derived design principles may be reviewed and refined, or new principles may be developed (Euler, 2014; Lehmann-Wermser & Konrad, 2016). The explicit formulation and systematic documentation of design principles play a crucial role in ensuring the traceability and transferability of DBR studies (Feulner et al., 2021; Hiller, 2018). For the discipline of geography, Feulner et al. (2021) proposed a three-stage operationalisation. In the first stage, overarching action guidelines were formulated, often derived directly from theory and representing either general didactic principles or discipline-specific content. In the subsequent stages, implementation principles were elaborated, followed by the specification of target group-specific details (see Fig. 1). This multi-level operationalisation ensured both the generalisability of results and the transparency of instructional development processes (Feulner et al., 2021). These design principles formed the basis for the subsequent iterative design cycles, the evaluation of which lies beyond the scope of this paper.

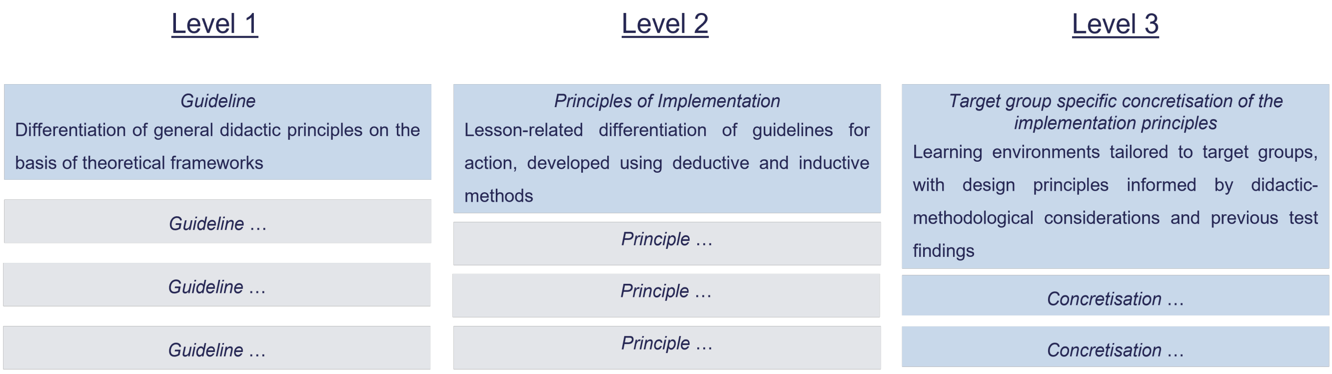

Figure 1. *Operationalisation level in deriving design principles (based on Feulner, Hiller, & Serwene, 2021, p. 9)*

4.0 Contextual embedding

The feedback mechanism was integrated into a pre-existing virtual laboratory designed to engage students in investigating the consequences of regional climate change (Schmidt et al., 2024). This laboratory was structured around thematic learning units, such as soil erosion and drought stress, providing an immersive educational experience. Students began with an introductory session in a virtual seminar room before progressing to small-group experiments within the virtual laboratory. Each student operated as a self-configured avatar, fostering interaction with peers in the virtual environment. A pedagogical agent offered step-by-step guidance and explanations throughout the process, ensuring that students remained engaged and on task. This virtual laboratory, intended for students from Year 7 and above, was explicitly aligned with the geography education standards established in Germany (DGfG, 2020).

This setup introduced specific design constraints that influenced the development of design principles. Feedback within the virtual laboratory was mediated solely by the pedagogical agent, which provided guidance and feedback to students during the experimental activities. The laboratory limited text length, so concise, focused feedback was required. While these restrictions may seem restrictive at first glance, they offered distinct advantages, as they promoted structured and clear feedback. Short, direct feedback improves readability and comprehension, which is critical in a virtual environment (Shute, 2008). Although longer feedback may address misconceptions more fully, brevity is consistent with the step-by-step instructional approach of the lab and supports effective student engagement. The specific experiment integrating the virtual feedback mechanism focused on the growth of wheat plants under varying climatic conditions. Using growth cabinets, students were able to manipulate environmental factors such as temperature, carbon dioxide concentration, and soil type to observe their effects on plant growth. Throughout the experiment, students engaged in tasks designed to deepen their understanding, such as single-choice questions prompting them to explain the observed behaviour of the parameters. Feedback delivered by the pedagogical agent guided students in reflecting on their findings and refined their experimental techniques.

5.0 Results and discussion – development of design principles for technology-based feedback

During the development stage of the design principles process, it became evident that the feedback concepts from the three previously described models provided a solid empirical foundation. All three models defined feedback as externally provided information aimed at reducing the discrepancy between the current state (actual state) and the desired state (target state). This conceptual understanding of feedback provided the foundation for structuring diverse feedback content. In this context, the content-oriented classification proposed by Narciss (2006) served as the basis.

Within the framework of the dissertation study three design principles were developed and subsequently operationalised, following the approach outlined by Feulner et al. (2021). The categorisation of the design principle ‘virtual feedback’ was based on functional, content-related, and formal aspects (Fig. 2, Level 1). The guideline “formal aspects” cover the timing, frequency, coding formats and sensory modalities of virtual feedback (Fig. 2, Level 2). The derivation of the implementation principle ‘feedback timing’ and its target group-specific concretisations (Fig. 2, Level 3) are explained and discussed individually before proceeding to the next implementation.

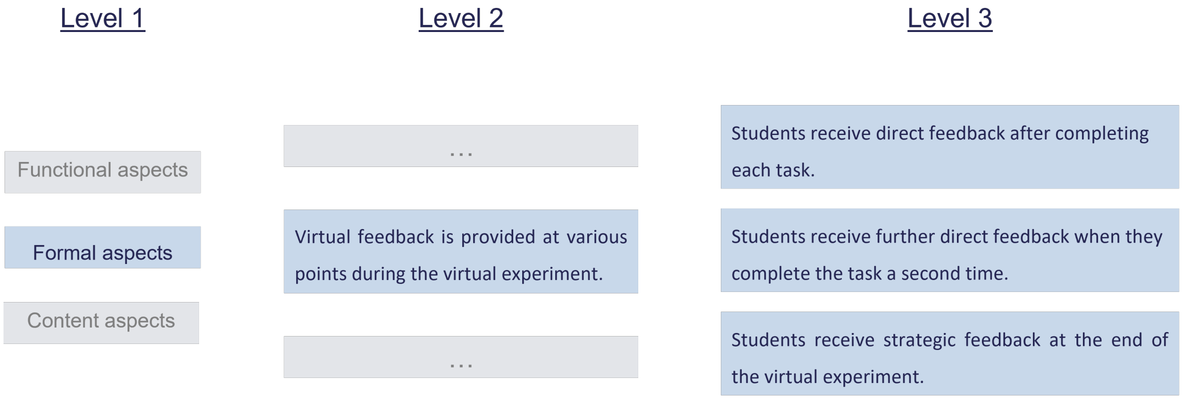

Figure 2. *Operationalisation of the guideline "formal aspects" as part of the design principle 'virtual feedback' (grey = additional aspect of interest, not further detailed; own illustration)*

Throughout the virtual experiment, virtual feedback is provided at various points (Principle 1), allowing the students to continuously monitor and adjust their performance. The principle is based on the findings of Kluger and DeNisi (1996) which suggested that providing feedback frequently (effect size of d = 0.55) can significantly enhance performance. This improvement is largely attributed to the way frequent feedback helps students gain a clear understanding of the gap between their current performance and their desired goals. Interviews with teachers (I1, I5, I7) further corroborated this approach by emphasising the importance of providing feedback at different times to address students' evolving needs throughout the learning process. Through the provision of regular feedback within the virtual laboratory, it is anticipated that students will be better equipped to identify areas requiring improvement and implement the necessary adjustments to bridge the performance gap. This ongoing feedback process not only facilitates the refinement of students' skills, but also contributes to a more effective and targeted learning experience, as evidenced by prior research on computer-based assessments (Mertens et al., 2022; Song & Keller, 2001). As part of the virtual experiment, students were prompted to answer questions at three distinct points in time. These tasks built directly on the previous experimental steps and served as formative checkpoints without disrupting the ongoing process. The feedback on students' responses combined summative evaluations with explanations of technical terms, thereby supporting both subject-specific and general learning objectives. In this way, the feedback checked whether students were beginning to draw initial conclusions from the experiment while simultaneously providing reassurance and guidance. As one teacher noted: "The students then take this as an aid, as reassurance: I can explain this to myself with the help of this support." (I6, para. 26).

At the beginning of the development process, it became evident that the timing of the feedback provision significantly influenced the learning process. Feedback can be given either immediately or with a delay. In the virtual geography laboratory, the students received immediate feedback on their responses during the experiment (Level 3, Concretisation 1). This approach helps students identify and correct misunderstandings, motivates them to acquire knowledge, and boosts their confidence and motivation (Epstein et al., 2002). In the interview, one teacher emphasised the importance of direct feedback, highlighting how it supports students in experiments and stating that this is also necessary:

> The students are not so frustrated if they get direct feedback and also get feedback if they have made a wrong step and if they get the opportunity to repeat the whole thing again. I think this feedback also has to be a bit of a companion. (I8, para. 34)

Providing immediate feedback allows students to proceed with the correct response in the experiment or attempt the question again, receiving guidance each time (Level 3, Concretisation 2). If the response remains incorrect, they are provided with the correct answer and explanations (knowledge on task constraints, knowledge about mistakes), as immediate and specific feedback in analog settings significantly enhances learning quality (Truskowski & VanderMolen, 2017). The goal is to ensure that students learn from their mistakes, and to foster skill improvement over time. To address common challenges with analog experiments, several teachers (I5, I7, I9) emphasized the necessity of consistently providing foundational reminders or "remember to" prompts and actively directing students' attention. After the experiment, students received strategic feedback in the form of guidelines for scientific work (knowledge on task constraints) (Level 3, Concretisation 3). This feedforward was designed to support students in conducting future experiments by proactively providing them with advice on scientific methodologies. The goal was to facilitate the transfer of knowledge acquired in virtual experiments to real-world settings and to stimulate interest in active experimentation within geography classes (Otto & Mönter, 2015; Schubert, 2016).

During the initial formulation of the design principles and their concretisation, it became evident that significant overlaps exist, and insights derived from the literature and interviews cannot be confined to addressing isolated topics. Instead, they must be considered in conjunction with other design principles. For instance, structuring feedback requires careful consideration of its timing (immediate versus delayed) and its focus, particularly in a virtual laboratory setting. Research suggests that feedback should primarily target task-related aspects rather than personal attributes (Baadte & Kurenbach, 2017; Bangert-Drowns et al., 1991; Hattie & Timperley, 2007; Shute, 2008). Task-focused feedback, aligned with content-specific criteria and standards, is more effective in fostering deeper learning and goal commitment compared to generic, person-related comments such as "great effort" (Hattie & Timperley, 2007) However, in the context of virtual laboratories, it may be necessary to complement task-oriented guidance with motivational elements, particularly for students who are less familiar with such environments. This need highlights how multiple considerations can overlap when establishing design principles. Defining these underlying principles is therefore a complex and multifaceted challenge that requires careful evaluation of different perspectives to enable informed decisions. Precisely delineating the context and distinguishing it from other relevant factors is crucial, as it ensures that the resulting design principles not only align with the intended objectives but are also coherent and effectively address the specific requirements of the project.

6.0 Conclusion and Outlook

The specific implementations of feedback timing in the virtual geography laboratory ensure that learners receive tailored support at multiple stages of the experimentation process. Immediate feedback during task execution addresses performance in real time, enabling learners to revise their actions and correct errors promptly. Delayed feedback provided upon completion of the laboratory process provides guidance for future scientific work, fosters deeper understanding, and facilitates the transfer of skills, particularly within the context of geography education. The iterative testing of the feedback mechanism evaluates the chosen principles for feedback timing alongside additional implementation guidelines and specifications. Insights gained through this process are used to refine the design principles continuously, enhancing their effectiveness in practical applications.

A reliable foundation for the initial development of the design principles was established by combining theoretical insights from the literature with practical perspectives derived from interviews. Predefined design principles play a pivotal role in structuring and ensuring traceability within the DBR approach. Their formulation and operationalisation provide a transparent framework to guide the iterative process and systematically evaluate its outcomes. The development of effective design principles for technology-based feedback systems involves considerable complexity due to the interplay of overlapping considerations. These interconnected elements necessitate a holistic approach that integrates individual principles into a cohesive framework. This complexity underscores the importance of continuous refinement to ensure that the feedback mechanisms not only meet immediate educational objectives but also foster engagement and competence in scientific enquiry. Developing a structured framework for design principles has therefore proven essential for maintaining transparency, adaptability, and consistency in feedback design. Despite the conceptual and technical challenges, the development of technology-based feedback offers significant opportunities to transform educational practice. Well-designed feedback has the potential to provide purposeful, efficient, and meaningful learning experiences for diverse groups of students. The integration of virtual experiments into geography lessons aligns seamlessly with the subject's problem-based teaching approach and strengthens its scientific foundations. Furthermore, by promoting scientific literacy, reflective thinking, and experimental skills, virtual laboratories empower learners to apply their knowledge effectively in both digital and real-world contexts. These systems thus promise to bridge the gap between theoretical knowledge and practical application, ultimately improving educational outcomes in the digital age.

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7.0 References

Baadte, C., & Kurenbach, F. (2017). The effects of expectancy-incongruent feedback and self-affirmation on task performance of secondary school students. European Journal of Psychology of Education, 32(1), 113–131. https://doi.org/10.1007/s10212-016-0312-y

Bangert-Drowns, R. L., Kulik, C.-L. C., Kulik, J. A., & Morgan, M. (1991). The Instructional Effect of Feedback in Test-Like Events. Review of Educational Research, 61(2), 213–238. https://doi.org/10.3102/00346543061002213

Boud, D., & Molloy, E. (2013). Rethinking models of feedback for learning: the challenge of design. Assessment & Evaluation in Higher Education, 38(6), 698–712. https://doi.org/10.1080/02602938.2012.691462

Butler, D. L., & Winne, P. H. (1995). Feedback and Self-Regulated Learning: A Theoretical Synthesis. Review of Educational Research, 65(3), 245–281. https://doi.org/10.3102/00346543065003245

Carless, D., & Boud, D. (2018). The development of student feedback literacy: enabling uptake of feedback. Assessment & Evaluation in Higher Education, 43(8), 1315–1325. https://doi.org/10.1080/02602938.2018.1463354

Dai, W., Lin, J., Jin, H., Li, T., Tsai, Y. S., Gasevic, D., & Chen, G. (2023). Can large language models provide feedback to students? A case study on ChatGPT. In N.-S. Chen, G. Rudolph, D. G. Sampson, M. Chang, R. Kuo, & A. Tlili (Eds.), Proceedings – 2023 IEEE International Conference on Advanced Learning Technologies, ICALT 2023 (pp. 323–325). https://doi.org/10.1109/ICALT58122.2023.00100

DBRC (2003). Design-Based Research: An Emerging Paradigm for Educational Inquiry. Educational Researcher, 32(1), 5–8. https://doi.org/10.3102/0013189X032001005

Dempsey, J. V., & Wager, S. U. (1988). A Taxonomy for the Timing of Feedback in Computer-Based Instruction. Educational Technology, 28(10), 20–25. Retrieved from http://www.jstor.org/stable/44427652

DGfG (2020). Bildungsstandards im Fach Geographie für den Mittleren Schulabschluss mit Aufgabenbeispielen (10., aktualisierte und überarbeitete Auflage).

Dihoff, R. E., Brosvic, G. M., & Epstein, M. L. (2003). The Role of Feedback During Academic Testing: The Delay Retention Effect Revisited. The Psychological Record, 53(4), 533–548. https://doi.org/10.1007/BF03395451

Epstein, M. L., Lazarus, A. D., Calvano, T. B., Matthews, K. A., Hendel, R. A., Epstein, B. B., & Brosvic, G. M. (2002). Immediate Feedback Assessment Technique Promotes Learning and Corrects Inaccurate first Responses. The Psychological Record, 52(2), 187–201. https://doi.org/10.1007/BF03395423

Euler, D. (2014). Design Principles als Kristallisationspunkt für Praxisgestaltung und wissenschaftliche Erkenntnisgewinnung. In D.

Euler & P. F. E. Sloane (Eds.), Zeitschrift für Berufs- und Wirtschaftspädagogik: Beiheft 27. Design-Based Research (pp. 97–112). Stuttgart: Franz Steiner.

Feulner, B. (2020). SpielRäume: eine DBR-Studie zum mobilen ortsbezogenen Lernen mit Geogames (Dissertation). Universität Augsburg.

Feulner, B., Hiller, J., & Serwene, P. (2021). Design-Based Research in der Geographiedidaktik. EDeR. Educational Design Research, 5(2). https://doi.org/10.15460/eder.5.2.1576

Hao, Q., Smith IV, D. H., Ding, L., Ko, A., Ottaway, C., Wilson, J., Greer, T. (2021). Towards understanding the effective design of automated formative feedback for programming assignments. Computer Science Education, 32(1), 105–127. https://doi.org/10.1080/08993408.2020.1860408

Hattie, J. (2020). Lernen sichtbar machen (5. unveränderte, erweiterte Auflage mit Index und Glossar). Baltmannsweiler: Schneider Verlag Hohengehren.

Hattie, J., & Timperley, H. (2007). The Power of Feedback. Review of Educational Research, 77(1), 81–112. https://doi.org/10.3102/003465430298487

Hemmer, I., & Hemmer, M. (2021). Das Interesse von Schülerinnen und Schülern an geographischen Themen, Regionen und Arbeitsweisen – ein Bundeslandvergleich zwischen Bayern und Nordrhein-Westfalen. Zeitschrift für Geographiedidaktik, 49(1), 3–24. https://doi.org/10.18452/22789

Hey-Cunningham, A. J., Ward, M.-H., & Miller, E. J. (2021). Making the most of feedback for academic writing development in postgraduate research: Pilot of a combined programme for students and supervisors. Innovations in Education and Teaching International, 58(2), 182–194. https://doi.org/10.1080/14703297.2020.1714472

Hiller, J. (2018). Akteurszentriert, problemorientiert, situiert – Design-basierte Entwicklung der Unternehmensfallstudie als Unterrichtsmethode des Geographieunterrichts. Zeitschrift für Geographiedidaktik, 46(1), 33–60. https://doi.org/10.18452/22468

Kasneci, E., Sessler, K., Küchemann, S., Bannert, M., Dementieva, D., Fischer, F., … Kasneci, G. (2023). ChatGPT for good? On opportunities and challenges of large language models for education. Learning and Individual Differences, 103, 102274. https://doi.org/10.1016/j.lindif.2023.102274

Kluger, A. N., & DeNisi, A. (1996). The effects of feedback interventions on performance: A historical review, a meta-analysis, and a preliminary feedback intervention theory. Psychological Bulletin, 119(2), 254–284. https://doi.org/10.1037/0033-2909.119.2.254

Kulhavy, R. W., & Stock, W. A. (1989). Feedback in written instruction: The place of response certitude. Educational Psychology Review, 1(4), 279–308. https://doi.org/10.1007/BF01320096

Lehmann-Wermser, A., & Konrad, U. (2016). Design-Based Research als eine der Praxis verpflichtete, theoretisch fundierte Methode der Unterrichtsforschung und -entwicklung. Methodologische Grundlagen, dargestellt am Beispiel eines Forschungsprojektes im Bandklassen-Unterricht. In J. Knigge & A. Niessen (Eds.), Musikpädagogik und Erziehungswissenschaft (pp. 265–280). Münster: Waxmann. https://doi.org/10.25656/01:15312

Lipnevich, A. A., Berg, D., & Smith, J. K. (2016). Towards a Model of Students Response to Feedback. In G. Brown & L. Harris (Eds.), Educational psychology handbook series. Handbook of Human and Social Conditions in Assessment (pp. 169–185). New York: Routledge.

Lipnevich, A. A., & Panadero, E. (2021). A Review of Feedback Models and Theories: Descriptions, Definitions, and Conclusions. Frontiers in Education, 6. https://doi.org/10.3389/feduc.2021.720195

Mayring, P. (2015). Qualitative Inhaltsanalyse: Grundlagen und Techniken (12., überarbeitete Auflage). Weinheim: Beltz.

Mertens, U., Finn, B., & Lindner, M. A. (2022). Effects of computer-based feedback on lower- and higher-order learning outcomes: A network meta-analysis. Journal of Educational Psychology, 114(8), 1743–1772. https://doi.org/10.1037/edu0000764

Mullet, H. G., Butler, A. C., Verdin, B., von Borries, R., & Marsh, E. J. (2014). Delaying feedback promotes transfer of knowledge despite student preferences to receive feedback immediately. Journal of Applied Research in Memory and Cognition, 3(3), 222–229. https://doi.org/10.1016/j.jarmac.2014.05.001

Narciss, S. (2006). Informatives tutorielles Feedback: Entwicklungs- und Evaluationsprinzipien auf der Basis instruktionspsychologischer Erkenntnisse. Pädagogische Psychologie und Entwicklungspsychologie: Bd. 56. Münster, New York, München, Berlin: Waxmann.

Narciss, S., & Huth, K. (2004). How to design informative tutoring feedback for multi-media learning. Retrieved from https://api.semanticscholar.org/CorpusID:18399234

Otto, K.-H., & Mönter, L. O. (2015). Scientific Literacy im Geographieunterricht fördern. Experimentelle Lehr-/Lernformen und Modellexperimente. Geographie heute. (322), 2–7.

Ramaprasad, A. (1983). On the definition of feedback. Behavioral Science, 28(1), 4–13. https://doi.org/10.1002/bs.3830280103

Sadler, D. R. (1989). Formative assessment and the design of instructional systems. Instructional Science, 18(2), 119–144. https://doi.org/10.1007/BF00117714

Schmidt, V., Fiene, C., & Siegmund, A. (2024). Experimentelles Arbeiten im virtuellen Raum zur Vermittlung von Folgen des regionalen Klimawandels – Bedeutung und Potenziale von Feedback. In W. Becker & M. Metz (Eds.), Serious Games und Gamification in der schulischen Bildung (pp. 205–218). Wiesbaden:

Springer Fachmedien. https://doi.org/10.1007/978-3-658-44317-7_11

Schubert, J. C. (2016). Kognitiv aktivierend und eigenständig experimentieren. Schülerinnen und Schüler erforschen das Wasserhaltevermögen von Böden. Geographie aktuell & Schule, 38(219), 24–34.

Sherafati, N., Largani, F. M., & Amini, S. (2020). Exploring the effect of computer-mediated teacher feedback on the writing achievement of Iranian EFL learners: Does motivation count? Education and Information Technologies, 25(5), 4591–4613. https://doi.org/10.1007/s10639-020-10177-5

Shute, V. J. (2008). Focus on Formative Feedback. Review of Educational Research, 78(1), 153–189. https://doi.org/10.3102/0034654307313795

Song, S. H., & Keller, J. M. (2001). Effectiveness of motivationally adaptive computer-assisted instruction on the dynamic aspects of motivation. Educational Technology Research and Development, 49(2), 5–22. https://doi.org/10.1007/BF02504925

Steingrübl, S., & Budke, A. (2024). Diagnostic and Feedback Behavior of German Pre-Service Teachers Regarding Argumentative Pupils' Texts in Geography Education. Education Sciences, 14(8), 919. https://doi.org/10.3390/educsci14080919

Truskowski, S., & VanderMolen, J. (2017). Outcomes and perceptions of annotated video feedback following psychomotor skill laboratories. Journal of Computer Assisted Learning, 33(2), 97–105. https://doi.org/10.1111/jcal.12167

Van der Kleij, F. M., Eggen, T. J., Timmers, C. F., & Veldkamp, B. P. (2012). Effects of feedback in a computer-based assessment for learning. Computers & Education, 58(1), 263–272. https://doi.org/10.1016/j.compedu.2011.07.020

Voerman, L., Meijer, P. C., Korthagen, F. A., & Simons, R. J. (2012). Types and frequencies of feedback interventions in classroom interaction in secondary education. Teaching and Teacher Education, 28(8), 1107–1115. https://doi.org/10.1016/j.tate.2012.06.006

Wedenig, H. H., Franz, A., Kaminski, J. J., Holzhausen, Y., & Peters, H. (2023). KI-gestützte Kommentierung und Feedback für Test-enhanced Learning mit Multiple-Choice-Fragen im Medizinstudium. Jahrestagung der Gesellschaft für Medizinische Ausbildung (GMA). https://doi.org/10.3205/23GMA008

Zhang, A., Gao, Y., Suraworachet, W., Nazaretsky, T., & Cukurova, M. (2025). Evaluating Trust in AI, Human, and Co-produced Feedback Among Undergraduate Students. Retrieved from http://arxiv.org/pdf/2504.10961

Appendix

Template of “The students then take this as an aid, as reassurance: I can explain this to myself with the help of this support.” (I6, para. 26: Die Schüler nehmen das dann als Hilfe, als Beruhigung: Ich kann mir das mit Hilfe dieser Unterstützung selbst erklären.)

“The students are not so frustrated if they get direct feedback and also get feedback if they have made a wrong step and if they get the opportunity to repeat the whole thing again. I think this feedback also has to be a bit of a companion.” (I8, para. 34: Die Schüler sind nicht so frustriert, wenn sie ein direktes Feedback bekommen und auch ein Feedback bekommen, wenn sie einen Schritt falsch gemacht haben und wenn sie die Möglichkeit bekommen, das Ganze noch einmal zu wiederholen. Ich denke, dieses Feedback muss auch ein bisschen ein Begleiter sein.)

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