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A Proficiency Model for Design Science Research Education

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ABSTRACT

Design science research (DSR) produces knowledge via the design and evaluation of innovative solutions to real-world problems. DSR provides an improved understanding of how and why the solutions work. While DSR is being widely embraced in many research disciplines, its educational pedagogy so far remains immature with little guidance on how best to inform and train various audiences on relevant and rigorous DSR skillsets. Grounded on the authors' wide experience in designing and delivering DSR courses over the past decades, we develop a "DSR Proficiency Model" to highlight key skills required to succeed in planning, applying, and communicating DSR. We recognize the different educational environments and student backgrounds that DSR courses must accommodate and provide actionable guidance for mapping the proficiency model to academic, training, and executive audiences. Informative examples demonstrate how we have structured DSR curricula for different academic and executive education programs.

Keywords: Design science research (DSR), Educational pedagogy, Proficiency model, DSR curricula, Design science education

1. INTRODUCTION

The Design Science Research (DSR) paradigm has its roots in the sciences and engineering of the artificial (Simon, 1996). DSR seeks to enhance human knowledge with the creation of innovative and useful artifacts with an understanding of *how* and *why* the artifacts improve the human condition via rigorous design theories. Design artifacts as solutions to real-world problems incorporates the ideas, practices, technical capabilities, and products through which technologies and human behaviors embodied in system solutions can be efficiently and effectively developed, deployed, and used. Artifacts are not exempt from natural laws or behavioral theories. To the contrary, their creation relies on existing laws and theories that are applied, tested, modified, and extended through the experience, creativity, intuition, and problem-solving capabilities of the researcher. Thus, the results of DSR include both the newly designed artifact and a fuller understanding of the theories of why the artifact is an improvement to the relevant application context (Baskerville et al., 2018). This balance of scientific theory and practical utility makes DSR a uniquely valued research paradigm. Because of these characteristics, DSR contributes to solving socially relevant problems through research (vom Brocke et al., 2020), such as in the field of social and economic sustainability (Lee, 2015; Watson et al., 2010).

Design activities are central to all applied disciplines. Research in design has a long history in many fields, including architecture, engineering, education, entrepreneurship, anthropology, and the fine arts. The Information Systems (IS) field, since its beginning, has identified with a research focus on the design and use of socio-technical systems (Sarker et al., 2019). Socio-technical systems are composed of inherently mutable and adaptable hardware, software, and human interfaces. Socio-technical systems provide many unique and challenging design problems as they integrate aspects of task, technology, people, and structure (Bostrom & Heinen, 1977). Specifically, the design of socio-technical systems has been found to be challenging given the dependency on "time and space" or, more precisely, the dependency on the socio-technical application context in which the design takes place (vom Brocke et al., 2020), and these challenges call for new and creative research methods.

The current state of the scientific discourse surrounding DSR is gaining maturity. DSR methods, processes, theories, and contributions have been structured into a well-defined paradigmatic framework in the IS community (Hevner et al., 2004; Hevner & Chatterjee, 2010; vom Brocke et al., 2020b). However, widely accepted DSR educational pedagogy has been very slow to emerge. DSR courses and seminars are still underrepresented in most academic programs and training curricula despite a few recent activities. Hevner and Chatterjee

(2016) provide a reference syllabus for DSR courses and seminars that has been one of the most downloaded on the AIS (Association for Information Systems) syllabus website. Winter and vom Brocke (2021) report on their experiences teaching DSR seminars to both managerially and technically oriented PhD and MS student populations. They present an effective syllabus, teaching materials, and guidelines for teaching DSR that have been developed over 14 years and presented to over 2,000 students from 20 countries across all three geographic AIS regions. Hevner (2021) discusses the planning and presentation of a DSR doctoral seminar. Thuan and Antunes (2022) provide an overview of recent contributions to design science education in different fields, e.g., Information Systems, Software Engineering, Medical Radiation Science, Engineering, and Management) and on different levels (undergraduate, Masters, and PhD).

DSR has been intensively discussed in the IS research community; however, DSR is not limited to IS, nor is DSR education limited to IS education. While an extensive survey of the disciplinary reach of DSR is beyond the goals of this paper, to provide a compelling example, the 2022 Design Science Research in Information Systems and Technology (DESRIST) conference highlighted a theme of transdisciplinary DSR applications. Research tracks such as *Innovation and Entrepreneurship*, *Healthcare Systems and Quality of Life*, *Sustainability and Responsible Design*, and *DSR Education* received many strong submissions with authors from multiple academic disciplines (Drechsler et al., 2022). Other major conferences, such as the *International Conference on Information Systems* (ICIS) and the *Academy of Management* (AoM) offer research tracks and professional development seminars on DSR topics. For example, at the 2021, 2022, and 2023 AoM meetings, professional development workshops on DSR discussed the adoption of DSR for a wider management community (Seckler et al., 2021a, 2021b, 2022). In parallel, a sister journal of *Business Venturing*, the journal of *Business Venturing Design*, has recently begun publication (Berglund, 2021).

Our goals in this paper are to identify and define essential proficiencies that require mastery for researchers performing DSR projects. We develop a DSR Proficiency Model comprising of six essential proficiencies that allow rigorous and relevant research to be conducted. We also apply this DSR Proficiency Model to various educational environments and diverse audiences in academic and training courses. Given the increasingly widespread interest in DSR as a research paradigm contributing to real-world problem solving, we argue that DSR needs to consider the contextual background of the specific target audience along with the goals, opportunities, and constraints of the teaching environment. Actionable guidance is provided on how to map the DSR Proficiency Model to different environments and audiences. We demonstrate examples of DSR curricula design strategies for three typical DSR student audiences: PhD students, Executive Education (DBA) students, and online students. Our intention is to make DSR education more rigorous by clearly defining the essential proficiencies and skillsets to be taught and more relevant by recognizing student backgrounds and the characteristics of the educational environment. We hope that by providing guidelines and specific links to educational resources, it will become easier, more effective, and more efficient for fellow academics to plan and deliver DSR education in a variety of educational contexts.

2. A DSR PROFICIENCY MODEL

Pedagogy, as an academic discipline, is the study of how knowledge and skills are imparted in an educational context and the role of instructor/student interactions that take place during learning (Hinchliffe, 2003). An effective educational pedagogy defines a teaching strategy that takes into consideration the interests, backgrounds, contextual factors, and learning

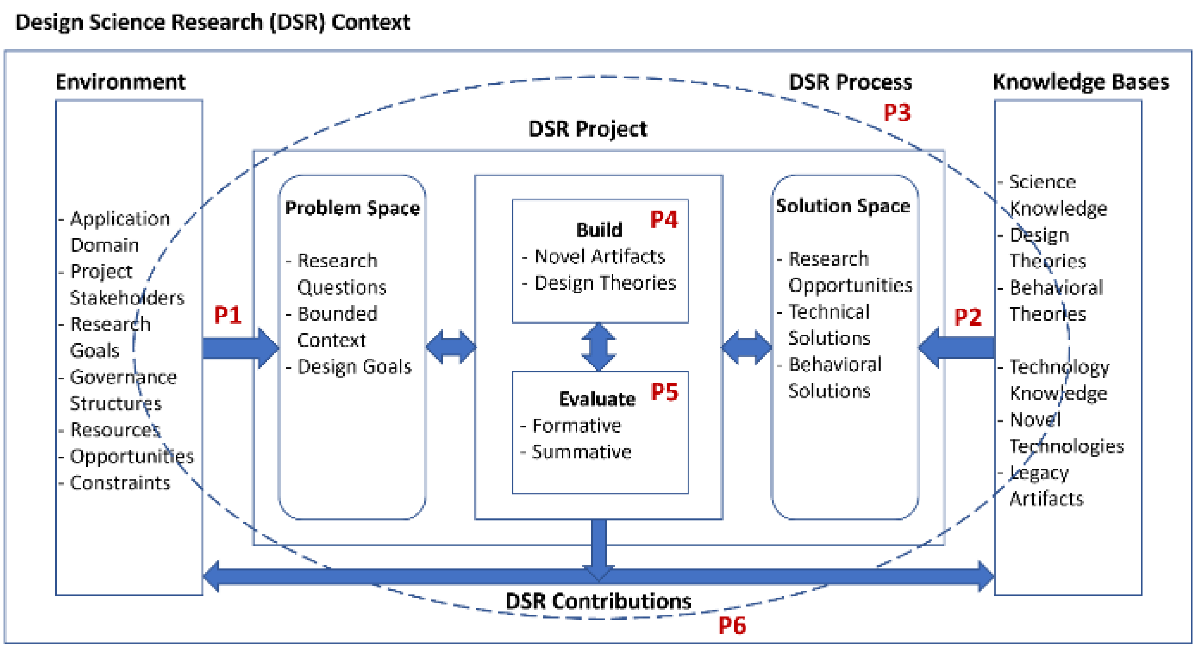

Figure 1. Design Science Research Proficiency Model

objectives of the students as well as the expertise and teaching style of the instructor (Leung, 2020). A design science research (DSR) educational pedagogy must be grounded on transmitting the knowledge of DSR concepts and providing the proficiencies (i.e., skillsets) to apply these concepts to rigorous and relevant DSR projects. Drawing upon the extant DSR literature (e.g., Drechsler & Hevner, 2022; Hevner et al., 2004; Hevner, 2007; vom Brocke et al., 2020), Figure 1 presents the *DSR Proficiency Model* – a comprehensive, yet concise, view of the DSR context and the DSR project that is performed within that context with its research and practice goals. In the following, we identify six essential proficiencies with the associated knowledge that a DSR student must master to perform an effective DSR project.

Each of the following proficiencies can be assessed at different maturity stages, such as (1) initial, (2) basic, (3) specialized, (4) experienced, and (5) expert. In principle, DSR education must train students to master all these proficiencies at appropriate levels for student education goals. When planning a specific DSR course, we recommend developing an educational plan based on prioritizing the proficiencies to be developed at specified maturity levels. Such planning needs to consider the specific context of a DSR course, as presented in the next section. While planning, specific teaching activities are defined to build the proficiencies. The proficiency model is adaptable for various activity sequences, including feedback iterations to reinforce learning. In the application examples, we show different strategies for building the proficiencies according to the contextual constraints and opportunities.

2.1 Representing the Problem Space (*Proficiency P1*)

DSR projects are based on pragmatic goals of solving real-world problems and making measurable impacts in application practice. The first DSR proficiency requires that students be able to define and represent a tractable Problem Space for the DSR project. The essential challenge is managing the complexity of the application environment to bound a relevant and doable project.

Research in Information Systems has long studied complexity by recognizing the need to understand complex socio-technical systems, which are diverse, interdependent, connected, and adaptive. Simon (1996) identifies the importance of studying complexity because of the need to understand the world's large-scale systems, including the diverse application environments in which the systems operate. In DSR, complexity is addressed by bounding, capturing, and representing the relevant *Problem Space* and the specific wicked problems to be addressed by the research project. Capturing and representing the problem space involves domain knowledge to provide the context as well as an understanding of the research questions and objectives. The context is influenced by the domain, stakeholders, time, and space. The goodness of the solution is assessed by goals and evaluation measures to assess achievement of the goals.

Students gain an understanding of the challenges of problem space complexity via an appreciation of the socio-technical system focus of the IS field (Sarker et al., 2019). Nielsen and Persson (2016) discuss issues of formulating IS research problems. The importance of capturing both fitness and sustainability goals in the DSR research project is addressed in Gill and Hevner (2013). zur Heiden (2020) analyzes the DSR literature and finds that, despite its importance, the context of DSR studies is predominantly underspecified and therefore presents guidelines for considering the context.

Pragmatic advice for identifying, defining, and applying research goals and respective evaluation criteria is provided in Hevner et al. (2018). Maedche et al. (2019) define concepts to describe the DSR problem space, specifically (1) needs, (2) goals, (3) requirements, and (4) stakeholders; and Baskerville and Pries-Heje (2014) allude to the notion of projectability of design knowledge as it can relate to different levels of situatedness in context. Beyond positioning DSR in the problem space, Winter and vom Brocke (2021) emphasize the importance of DSR courses to particularly "spark a fascination for real-world contributions" together with the understanding and confidence that students can make such contributions through DSR projects.

2.2 Capturing Extant Knowledge in the Solution Space (*Proficiency P2*)

For DSR to be rigorous research, it is important to review extant contributions in the DSR knowledge base (Drechsler & Hevner, 2022; Gregor & Hevner, 2013). Importantly, this includes exploring available solution spaces to identify potential technology solution candidates or solution approaches. The key challenge in this proficiency is to capture all applicable knowledge from both the technical and scientific knowledge bases to effectively perform the DSR project.

vom Brocke et al. (2009, 2015a) have developed guidelines for conducting rigorous literature reviews that have proven useful for providing transparency in the process of capturing extant knowledge in the solution space. Specifically, the approach supports the documentation of the coverage of the search process, including the "search string," "time frame," and "data bases." Due to the multitude of possible solutions and the dynamics with which new solutions are constantly emerging, such transparency in the search process is crucial to bound the scope of the search. As opposed to author- or concept-centric reviews (Webster & Watson, 2002), DSR reviews can be characterized as solution-centric: They (1) identify potential solutions, (2) set requirements against them, (3) evaluate how the solutions identified fulfill the requirements, and (4) conclude by deriving the design needed to satisfy the design objectives.

A systematic literature review provides information about what existing solutions have been identified, what limitations they still face in meeting the requirements of a particular problem, and what aspects of a problem they do cover satisfactorily by indicating what prior solutions to build on. In DSR, the review of extant literature and potential new technical solutions is essential to make a significant contribution (Hevner et al., 2004) and provide transparency for readers to build on and extend DSR contributions (vom Brocke et al., 2020).

2.3 Controlling the DSR Process (*Proficiency P3*)

The performance of a DSR project requires knowledge of and attention to process control of research activities and intellectual control of the emerging problem and solution artifacts. DSR projects emphasize adaptive learning based on applying incremental, controlled search methods (Hevner, 2017). This approach can be used with fast-changing problem environments with great amounts of uncertainty. The DSR team immediately begins the iterative cycles of building and refining the artifact in a controlled manner. Later, upon reflection of the design results, identification and extension of relevant design theories may occur (Gregor & Hevner, 2013). Dealing with uncertainty and fast-changing environments along the DSR process, the DSR methodology includes measures for risk management (Pries-Heje et al., 2014). Venable et al. (2019) provides a comprehensive list of potential risks and corresponding treatments for DSR projects.

Several proposed process models for scheduling and coordinating design activities exist. Peffers et al. (2007) propose and develop a design science research methodology (DSRM) for the production and presentation of DSR activities. This process model includes six steps: problem identification and motivation, definition of the objectives for a solution, design and development, demonstration, evaluation, and communication; and four possible entry points: problem-centered initiation, objective-centered solution, design and development-centered initiation, and client/context initiation. Kuechler and Vaishanvi (2008) present a process of "learning through the act of building" which consists of five iterative steps: (1) awareness of the problem, (2) suggestion, (3) development, (4) evaluation, and (5) conclusion.

By combining the research methods of action research with DSR, Sein et al. (2011) propose an Action Design Research (ADR) process model. Their model begins with a problem formulation stage followed by multiple iterations of the build, intervention, and evaluation stage, along with reflection and learning in each iteration. The ADR project completes with a stage of formulation of learning for system evolution. Action research principles of guided emergence, iterative intervention, and co-creation between research and practitioner are highlighted. An elaborated ADR (eADR) process model has been proposed by Mullarkey and Hevner (2019). This model identifies separate ADR stages of diagnosis, design, implementation, and evolution to provide distinct entry points into the project and novel artifacts produced by iterative eADR stages.

Given the dependency of the research process on the situated contextual factors of a DSR process, it is important to document and reason the research processes applied in a specific project. vom Brocke et al. (2021) have introduced the concept of "journaling" DSR processes, which allows researchers to apply a DSR process that is best oriented towards the specific conditions of a DSR project, and to provide transparency and reasoning accordingly. DSR education needs to provide the proficiencies to plan and document the DSR activities conducted to accomplish specific DSR goals.

2.4 Building Innovative Design Artifacts (*Proficiency P4*)

Once the first three proficiencies have been mastered in a DSR project, the creative activities of building innovative design artifacts commences. This is the stage of creating novel ideas and of reasoning in the choice of the best idea to move forward to implementation. According to Burkus (2014, p. 15), "creativity is the starting point for all innovation" where creativity is defined as the process of developing ideas that are both novel and useful. Amabile (2012) posits that four components are necessary for a creative response:

- Domain-relevant skills include intelligence, expertise, knowledge, technical skills, and talent in the particular domain in which the innovator is working.
- Creativity-relevant processes include personality and cognitive characteristics that lend themselves to taking new perspectives on problems, such as independence, risk taking, self-discipline in generating ideas, and a tolerance for ambiguity.
- Intrinsic task motivation is seen as a central tenet. "People are most creative when they feel motivated primarily by the interest, enjoyment, satisfaction and challenge of the work itself – and not by extrinsic motivators." (Amabile, 2012)
- The social environment, the only external component, addresses the working conditions that support creative activity. Positive organizational settings stimulate creativity with clear and compelling management visions, work teams with diverse skills working collaboratively, freedom to investigate ideas, and mechanisms for developing new ideas and norms of sharing ideas.

Effective solution design requires more than just the generation of many creative ideas. Successful innovation also requires the intellectual control to refine creative thinking into practical IT solutions. Such control is dependent on the cognitive skills of reason and judgment. Human reason reflects thinking in which plans are made, hypotheses are formed, and conclusions are drawn based on evidence in the form of data, experience, or knowledge. While creativity often calls for divergent thinking to break out of mindsets, reason calls for convergent thinking to refine ideas into practical artifacts and actions. Moving design ideas from "blue sky" to artifact instantiations requires goal setting. The goal-setting activity in the problem space now comes into play as the criteria for ranking the creative ideas produced to address the problem into one design candidate to move forward into implementation and evaluation. The iterative DSR build and refinement activities of the creative design cycles are studied in Baskerville et al. (2019).

2.5 Measuring the Satisfaction of Research Goals With Rigorous Evaluation (*Proficiency P5*)

Rigorous evaluation methods link solutions (in the solution space) to problems (in the problem space) and provide evidence of the extent to which a solution solves a problem using the chosen evaluation methods. Conceptually, both formative and summative evaluations can be distinguished in the DSR process (Venable et al., 2016). DSR evaluation can be described as a continuously organized process (Sonnenberg & vom Brocke, 2012) throughout all stages of a DSR project. Evidence produced by DSR evaluations promote stakeholder confidence in the research results. The level of research confidence assesses such qualities as the types of evaluation performed, the rigor of the evaluation methods, and the convincing nature of the evaluation results.

Not all DSR projects have the opportunity to test new design artifacts in realistic environments. In such cases, opportunities for evaluations in artificial environments should be considered (e.g., simulation) (Prat et al., 2015). Given the great variety of different methods and application scenarios for evaluations, transparency of both the process and the results of the evaluation are important confidence criteria for DSR contributions.

2.6 Contributing to Science and Practice (*Proficiency P6*)

The ultimate results of a DSR project are its contributions to both science and practice. Two dominant types of design knowledge contributions are defined as research outcomes from a DSR project—design artifacts and design theories (Baskerville et al., 2018; Gregor & Hevner, 2013). Students must understand how to position DSR contributions toward providing both real-world solutions and rigorous contributions to design knowledge. A DSR project needs to meet the theoretical requirements of academic journal publication in the form of new or extended design theories (Gregor & Jones, 2007), and at the same time, to solve a practical problem or to address an interesting class of problems.

Basic knowledge can be represented by two major types: (1) research activities that primarily grow Ω-knowledge (comprising descriptive, explanatory, and predictive knowledge), and (2) research activities that primarily grow λ-knowledge (prescriptive and design knowledge). Contributions to Ω-knowledge enhance our understanding of the world and the phenomena that technologies harness (or cause). Contributions to λ-knowledge typically deal with technological (in the sense of means-end) innovations that directly impact individuals, organizations, or society and enable the development of future technological innovations. Research projects may combine both genres of inquiry and contribute to both knowledge bases (Baskerville et al., 2015).

The relationships of specific design knowledge created in DSR projects and the general knowledge bases (Ω and λ) are analyzed in Drechsler and Hevner (2022). Paired modes of consuming and producing knowledge between the DSR project and the descriptive and prescriptive knowledge bases are described. Knowledge can be projected from the application research project into nascent theories around solution actions, entity realizations, and design processes based on the new and interesting design knowledge produced in a DSR project. Avdiji and Winter (2019) identify a number of knowledge gaps that must be bridged in DSR projects as researchers move between the problem space and solution space in the consumption and production of design knowledge.

Many DSR projects are longitudinal efforts involving multiple research teams. vom Brocke et al. (2020) propose models for the accumulation and evolution of design knowledge in an organized DSR body of knowledge. Guidance is presented on how to position design knowledge contributions in wider problem and solution spaces via (1) a model conceptualizing design knowledge as a resilient relationship between problem and solution spaces, (2) a model that demonstrates how individual DSR projects consume and produce design knowledge, (3) a map to position a design knowledge contribution in problem and solution spaces, and (4) principles on how to use this map in a DSR project. vom Brocke et al. (2021) present guidelines on how to engage with practice from the outset of a DSR project and applying the analogy of a "dance" they identify specific activities related to both academia and practice in making DSR contributions of high practical relevance.

3. A DSR EDUCATIONAL CONTEXT MODEL

When planning a DSR course, the specific educational context needs to be considered to develop a course outline as well as the delivery details of the DSR pedagogy. In Figure 2, we distinguish a set of key factors in a DSR Educational Context Taxonomy. Many of the factors to be considered in planning a DSR course are typical factors in planning a course design. Their implications, however, are specific to developing the DSR proficiencies. Concise descriptions of the context factors follow.

Type	Academic	Training	Executive
Discipline	Focused	Bounded	General
Geography	Local	Regional	Global
Duration	Days	Weeks	Term
Class	Small	Medium	Large

Figure 2. DSR Educational Context Taxonomy

Type: While academic education is geared toward students' advancement through BSc, MSc, and PhD education, we have been involved with industrial training and executive programs geared toward practitioners who desire knowledge of more rigorous design methods for real-world applications. When designing DSR courses, different student backgrounds and expectations must be incorporated into course planning. For example, in academic settings, some prior knowledge of research strategies and strategies can be assumed, while in executive programs, knowledge and rich experiences with real-world problems from the work environment can be built on in the course.

Discipline: Considering both the interdisciplinary nature of "design" as well as the wide range of possible applications of DSR, the diversity of disciplines represented among the student participants matters when planning a DSR course. The course planning can consider whether student disciplines are focused, bounded, or general. When students share a common disciplinary background or work environment (e.g., an industry training seminar), the course design can be tailored towards this discipline by focusing on the extant disciplinary knowledge, the specific challenges of the application, and relevant disciplinary kernel theories. A course with students from multiple disciplines provides opportunities to leverage an interdisciplinary perspective on the solution of real-world problems, such as grand societal challenges (Becker et al., 2015; Lee, 2015; Watson et al., 2010). vom Brocke et al. (2015b), for instance, have engaged students in DSR projects to address the 15 global challenges of the "millennium project" – a project preceding the United Nations Sustainable Development Goals – and subsequently published the results in a joint book.

Geography: While educational programs typically would be organized and hosted by a single organization, such as an academic institution, educational programs in DSR are increasingly offered with the collaboration of multiple institutions. This has particularly proven effective in cases of which single institutions would be limited in resources to start and establish a course of their own. Winter and vom Brocke (2021), for instance, report on a DSR doctoral seminar, which was originally offered over a semester in the PhD program at the University of St. Gallen. This program evolved first into an intense four-day in-person seminar for students across the German-speaking (DACH) community and then, due to

COVID, into a two-week online program which allowed more time for group work and reflection. The online version attracts global participants from all over Europe, the Americas, and the Asia Pacific region. The more local, the more the course design can make use of on-site experiences. The more global, the more it can leverage different regional backgrounds, and in online formats, it can leverage smaller learning units spread over a longer time period. Thus, understanding the geographic impacts of the DSR education provides different opportunities and constraints in delivery.

Duration: The duration of the DSR course will enable different mixes of student activities and assignments. A 15-week semester allows sufficient time for more in-depth DSR projects drawing from the course learning objectives. Shorter, more intense seminars of one or two weeks will require more focused deliverables to demonstrate proficiencies. The duration specifically impacts the mode of engagement with the participants. Regardless of the time frame, we strongly recommend an activity or assignment that involves students in their own DSR projects (Winter & vom Brocke, 2021). The quality of such involvement depends on the time and rhythm applying to the course. In a one- or two-day intense course, for instance, time for individual DSR projects is limited. One strategy can be to focus on the early phases of scoping and planning DSR projects rather than on details of subsequent phases, such as implementation and evolution. Given a course that expands over an entire term, more degrees of freedom would be given to engage students in building prototypes and performing evaluations in application contexts.

Class: One of the most obvious factors that will dictate the conduct of the DSR course is the number of students. With large numbers of students, such as in global seminars or undergraduate classes, there will be a great diversity of application contexts among the class. Smaller classes, such as in PhD seminars, will provide more opportunities for students and instructors to work on application-specific DSR projects. The goal of individual student mentoring should be a key feature of all DSR education (Hevner, 2021; Winter & vom Brocke, 2021). Mentoring in large classes will require additional instructors or graduate assistants to ensure individual attention is provided. Large classes may need to use innovative approaches to engage all the students in learning activities, for example, peer-to-peer feedback systems (Donia et al., 2022; Lehmann et al., 2016). Automated DSR toolsets can also be integrated into the instructional environment to support student-team collaborations and instructor/student interactions (Morana et al., 2018).

These DSR environmental context factors are essential for course planning but are by no means complete. Other factors, such as budgets or facilities constraints, may play a large role in the course design. However, the above factors provide a starting point to illustrate the impacts the educational context has on the development of an effective DSR course design. Effective course planning will map the DSR proficiencies into the specific course design based on the existing context factors. Thus, there is no one standard course template for DSR education. In the next section, we demonstrate how we have adapted our DSR educational model to archetypical academic programs and the differing teaching contexts.

4. ACADEMIC EXAMPLES OF DSR EDUCATION PLANNING

While extant contributions to DSR education largely focus on PhD student education, in this section, we address different academic DSR audiences. We realize that different stakeholder groups have different entry points into DSR, each providing both challenges and opportunities. To give concrete examples, we distinguish between three academic levels, PhD, Executive Doctoral (DBA), and an online environment with a mix of academic degree programs. Each example supports a focus on the different student backgrounds, expectations, and educational contexts. That way, we apply the DSR educational context taxonomy introduced above by using the “type” dimension to structure our examples. In discussing the examples, we also draw on the other dimensions of discipline, geography, duration, and class. The following discussion reflects our personal experiences providing DSR courses in these educational programs.

4.1 DSR Education for PhD Students

The authors have had experience in teaching DSR courses at the PhD level both in the US and in Europe. PhD class sizes are typically small, with less than 10 students making individual attention possible and allowing for more flexible teaching approaches in presenting the material. Doctoral seminars are normally full term, allowing plenty of time for in-depth assignments that accommodate the design and evaluation of novel artifacts. In what follows, we present both key strengths and challenges of presenting DSR material to PhD students. We conclude with a concise summary and actionable recommendations.

Strengths: DSR education on PhD level can build on basic knowledge in research processes (P3 - Controlling the DSR process) and research methods, such as qualitative (interviews, focus groups) and quantitative (statistical data analytics) (P5 - Measuring the satisfaction of research goals with rigorous evaluation). Also, PhD students usually bring a disciplinary interest associated to their PhD topic with a good command of the discipline’s literature and relevant theories (P2 - Capturing extant knowledge in the solution space). Most of the doctoral students will have prior experience in publishing and would be familiar with the disciplinary discourse and outlets (P6 - Contributing to *science* and practice).

Challenges: We find that the creative nature of DSR in building solutions to real-world problems (P4 - Building innovative design artifacts) is comparably new to most PhD students. Prior courses in doctoral programs focus mostly on the traditional scientific method with data gathering, hypothesis testing, and theory building. The challenge is to “break the mold” of investigating what currently exists to imagine *what could be* with the design of novel artifacts in the student’s problem space. The goal is to challenge doctoral students to “change the world.” Their disciplinary focus might be thinking out of the box and looking at a problem from different angles and disciplinary perspectives. Students must become familiar with DSR processes that are different from traditional research processes (P3 - Controlling the DSR process). Also, while they would be familiar with the academic discourse in their field, they typically are less experienced with capturing and representing the complexities of a problem in practice (P1 - Representing the problem space) as well as the opportunities and constraints relevant for making an impact in practice (P6 - Contributing to science and *practice*).

Recommendations: We recommend PhD courses in DSR to specifically (1) encourage and train creative and "out of the box" thinking, to (2) leverage inspiration from diverse disciplines, and to (3) emphasize the importance of making a measurable contribution to the practical disciplinary environment. We summarize the key strengths to build on and the key challenges to further develop PhD students in DSR education, along with ideas to develop a teaching strategy in Table 1.

Strengths	Challenges	Strategies
- P2 - Capturing extant knowledge in the solution space: Know discipline's literature and research methods. - P3 - Controlling the DSR process: Experience in research processes. - P5 - Measuring the satisfaction of research goals: Background in research methods. - P6 - Contributing to science and practice: Understanding of contributions to science.	- P1 - Representing the problem space: Need skillset to capture complex real-world-problems. - P3 - Controlling the DSR process: More experience in DSR processes. - P4 - Building innovative design artifacts: Creative mindset to build innovative solutions to problems. - P6 - Contributing to science and practice: Understand importance of engaging with practice and making practical contributions.	- Build on student research interests with focus on DSR contributions in PhD projects - Encourage and train a creative mindset - Research goal is to improve the world beyond just understanding how the world works - Leverage inspiration from diverse disciplines - Expose participants to practice and practitioners

Table 1. PhD DSR Educational Opportunities and Challenges

4.2 DSR Education at an Executive Level

DSR has proven particularly useful to engage executives and experienced practitioners in research projects to design and build innovative solutions to real world problems. Academic programs for executives, such as the Doctor of Business Administration (DBA), have been very receptive to DSR courses in the curriculum. Executive classes are of medium size with from 10-20 students typically. Students come into the program with well-defined application contexts and research problems based on their real-world experiences. Both authors have presented DSR instruction to executive students. Based on this experience, we can report the following strengths and challenges of teaching DSR on executive level with actionable recommendations how to develop an appropriate teaching strategy.

Strengths: Executive students bring the advantage of a rich problem space understanding (P1 - Representing the problem space). Typically, they bring their own problems, which they have experienced in a real-world environment, and they are highly motivated to find solutions to these problems. They understand the complexities of their problem spaces. We have also experienced the creativity of this group comparably high in building novel artifacts and discovering innovative solutions (P4 - Building innovative design artifacts). Executive students often have access to real-world interventions at their place of work. This is a tremendous advantage for performing rigorous and relevant evaluations of their research artifacts (P5 - Measuring the satisfaction of research goals). This audience also tends to understand what it takes to apply solutions in context and how to measure practical impacts (P6 - Contributing to science and *practice*).

Challenges: Based on our experiences in executive education, a key challenge is to build up research skills regarding research processes (P3 - Controlling the DSR process competences) and research method competences (P5 - Measuring the satisfaction of research goals). Skillsets are also needed for rigorously reviewing existing solutions and relevant theories (P2 - Capturing extant knowledge in the solution space). Often, this group also is challenged by the time it takes to build and perform such competencies and perform related tasks. Further, the experience and ability to publish and to make academic contributions can be less assumed and requires specific consideration (P6 – Contributing to *science* and practice).

Recommendations: We recommend building on the executives' experiences and motivations for desiring a research degree. They come with an extensive understanding of their problem domain and have specific creative problem-solving capabilities. Thus, (1) it is important to link the course materials to their own practical problems. As part of the course, (2) basic understanding of research process, methods, and contributions must be provided to establish rigorous research foundations. Further, (3) actionable methods and tools need to be introduced that support the participants in applying DSR both effectively and efficiently. Exposing the participants to DSR cases conducted by experienced researchers (e.g., vom Brocke et al., 2020a) helps to provide an efficient access to the DSR methodology. These recommendations lead to an inductive approach to teach DSR in executive education, in which the participants depart from their very situated problem, and through multiple iterations increase the projectability and confidence of the solution (vom Brocke et al., 2020).

We summarize the key strengths to build on and the key challenges to further develop executive students in DSR education along with ideas to develop a teaching strategy in Table 2.

Strengths	Challenges	Strategies
- P1 – Representing the problem space: Executives come with a rich problem understanding. - P4 – Building innovative design artifacts: Background in creativity techniques and innovative thinking. - P5 – Measuring the satisfaction of research goals: Access to real-world intervention opportunities for evaluations. - P6 – Contributing to science and practice: Understand how to measure practice contributions and impacts.	- P2 – Capturing extant knowledge in the solution space: Skillsets required to review the academic literature and be aware of extant knowledge. - P3 – Controlling the DSR process capabilities: Training needed to plan and scope research processes. - P5 – Measuring the satisfaction of research goals: Skillsets needed to conduct rigorous research methods. - P6 – Contributing to science and practice: Communication skills for scientific publications.	- Build on executive's experiences and motivations to perform research. - Provide basic foundations for understanding and applying research processes, methods, and contributions. - Provide research toolsets to support efficient and effective DSR projects. - Expose executive students to successful DSR case studies for modeling their projects.

Table 2. Executive DSR Educational Opportunities and Challenges

4.3 DSR Education for BS/MS Students

DSR education provides significant value for students at academic levels of Bachelors (BS) and Masters (MS) programs. Such courses have been taught at the Universities of St. Gallen and Liechtenstein (Winter & vom Brocke, 2021). Based on this experience, we understand that DSR courses on this level should be designed as introductory courses, which intend to develop a fundamental understanding of DSR, its principles, goals, and key methodological aspects. Such BS and MS classes can be larger with 15 to 30 students with a semester long period of instruction. Both authors have also been involved with more intense, week-long industrial training programs for employees in design-oriented projects which share many of the strengths and challenges detailed here.

Strengths: Students are typically younger and self-select into the DSR courses, motivated by design interests and challenges. We find such students to be open minded, creative, and highly motivated (P4 – Building innovative design artifacts). They desire to contribute to important problems with projects that have real-world impacts (P6 – Contributing to science and *practice*). Often, they have a good understanding of contemporary solutions (e.g., data analytics, blockchain, Internet-of-Things, prompt engineering or the metaverse) that they learned in their programs and want to apply in design solutions (P2 - Capturing extant knowledge in the solution space).

Challenges: BS and MS students cannot be assumed to have extensive knowledge of research processes and methods (P3 - Controlling the DSR process and P5 - Measuring the satisfaction of research goals). Many also lack the practical work-related experience with real-world problems (P1 - Representing the problem space). Also, the ability to make effective contributions to academia or practice is yet to be built at that level (P6 - Contributing to *science* and *practice*). The larger class size makes it challenging for individual attention on each student's project.

Recommendations: (1) Link these courses to real-world challenges from the students' field of experience via industry case studies or practical internships in which the students are exposed to industry projects. (2) Educational attention should be on core elements of DSR as introduced very simply in summary papers and books (e.g., vom Brocke et al., 2020a). (3) It is important to train the students how to formulate problems and review existing solutions by providing templates, tools, and instructional examples. (4) Further, organizing team-oriented sessions to creatively envision new solutions has been found to be motivating and well suited to inspire students for DSR. (5) Guest speakers who have effectively used DSR methods are encouraged. (6) Students can design and implement artifact prototypes (e.g., using 3-D printers) and discuss them with practitioners help to convey key principles of DSR.

In essence, DSR courses at BS/MS program levels tend to require more fundamental instruction. Key learning outcomes would be to equip the students with the basic understandings of DSR projects as well as the skills to plan and scope DSR projects, for instance, outlined in the DSR Grid, outlining core dimensions for effectively planning and communicating DSR Projects (vom Brocke & Maedche, 2019). Students must be engaged by hands-on projects that can apply their learnings. We summarize the key strengths and challenges for BS and MS students in DSR education along with ideas to develop a teaching strategy in Table 3.

Strengths	Challenges	Strategies
- P2 - Capturing extant knowledge in the solution space: Familiar with potential solutions from program courses and excited to apply solutions to real problems. - P4 - Building innovative design artifacts: Creative and open minded. - P6 - Contributing to science and practice: Motivated to contribute to design projects.	- P1 - Representing the problem space: Lack experience in actual problem spaces. - P3 - Controlling the DSR process capabilities: Need skillset to plan and perform a DSR process. - P5 - Measuring the satisfaction of research goals: Need skillset to conduct fundamental research methods. - P6 - Contributing to science and practice: May not be able to contribute to science at this level.	- Build on real-world cases from the students' field of experience - Deliver DSR fundamentals based on summary introductions to DSR. - Provide templates and tools for problem formulation and review of solutions - Organize team-oriented session to creatively find solutions - Guest speakers on effective DSR projects - Build prototypes and mock-ups and present to practitioners

Table 3. BS/MS DSR Educational Opportunities and Challenges

4.4 Educational Examples Discussion

Abstracting from the three archetypical educational contexts, we identify two key dimensions relevant in planning and scoping a DSR course based on the DSR Proficiency Model: the predisposition about *problem understanding* and the predisposition about *solution understanding* (see Figure 3). A DSR course should ultimately result in a rich understanding of both the problem space and the solution space. With these foundations, students should also be able to execute relevant and rigorous DSR projects that produce innovative design artifacts and, ultimately, generate new and interesting design knowledge.

Figure 3 illustrates the starting points for the academic programs and their directed learning objectives in a 2x2 matrix with axes of knowledge in the solution space (x) and knowledge in the problem space (y). While the desired course outcomes are set to acquire a specific degree of the DSR proficiencies in the upper right quadrant, the starting points for participants are different. Thus, educational contexts must manage different strengths and challenges that suggest specific learning strategies.

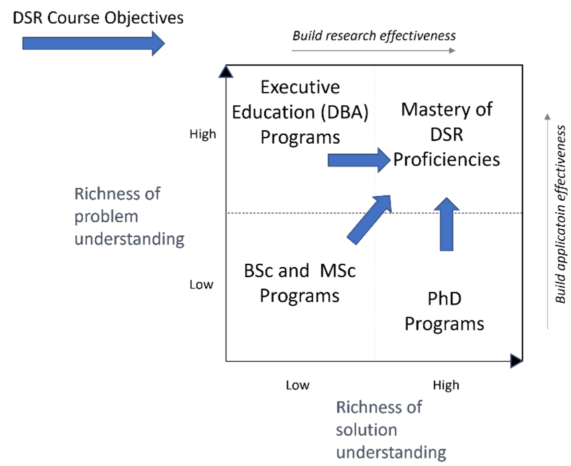

Figure 3. Education Strategies for Mastering DSR Proficiencies

5. DSR TEACHING RESOURCES

It is important that instructors have access to a wide range of teaching resources and materials as they plan their specific DSR course. In this section, we provide specific, actionable guidance from our course experiences and provide pointers to additional DSR resources. We provide examples of a DSR PhD seminar, an Executive Doctoral Program DBA, and an DSR Online Training, that has been applied both on PhD and BS/MS level.

5.1 DSR PhD Seminar

A standard fifteen-week semester curriculum for a rigorous DSR Doctoral Seminar can be designed around the two dimensions of DSR proficiencies and IS research fields as selected by the students. The curriculum template in Table 4 has been used effectively at the University of South Florida for the past several years.

Week#	Topic
Week 1	Introduction to Course - Syllabus - Assignments - Class Participation Design Science Research Foundations - DSR Basics and Foundational Paper - Research Challenges and DSR Proficiencies
Week 2	Student Introduction Presentations - Background and Research Interests - Exemplar DSR Paper of Interest - Discussion of DSR Application Discipline Interests
Week 3	Representing the Problem Space (Proficiency 1) - The Challenge of Complexity - Socio-Technical Information Systems - System Goals and Evaluation Criteria - Fitness-Utility Models of DSR

Week 4	Capturing Extant Knowledge in the Solution Space (Proficiency 2) - DSR Externalities - Literature Reviews in Application Domains - Knowledge Bases (Descriptive and Prescriptive)
Week 5	Controlling the DSR Process (Proficiency P3) - The Challenge of Control - DSR Process Models - Action Design Research and the Elaborated ADR
Week 6	Building Innovative Design Artifacts (Proficiency P4) - The Challenge of Creativity - Creative and Collaborative Teams - Digital Innovation
Week 7	Performing Rigorous Evaluation (Proficiency P5) - The Challenge of Confidence - Evaluation Methods (Formative and Summative) - Interior and Exterior Evaluations
Week 8	Contributing to Science and Practice (Proficiency P6) - The Challenge of DSR Contributions and Impacts - Innovative Artifacts - Design Theories - Knowledge Accumulation and Evolution
Week 9	Mid-Term Student Presentations - Research Paper Proposal - Targeted Research Conference - Discussion and Feedback
Weeks 10-14	DSR Application Domains to be determined by student interests. Each student will lead class in discussion of how DSR is relevant and is applied in research topic. Potential Research Topics: - Data Science - Artificial Intelligence (AI) - Human Computer Interaction (HCI) - Cybersecurity - NeuroIS - Others
Week 15	Final Student Presentations - Discussion and Feedback - Final Research Papers

Table 4. DSR PhD Course Template

DSR Basics and Student Introductions and Interests (Two Weeks): The first two weeks are devoted to a review of the fundamental ideas and concepts of the DSR paradigm. Readings included Hevner et al. (2004), Hevner (2007), Gregor and Hevner (2013), and Baskerville et al. (2018). References to exemplar DSR case studies are provided for further study (e.g., vom Brocke et al., 2020a). The range of IS research fields are described and each student selects one of the research fields as a semester focus for study.

DSR Proficiencies (Six Weeks): One week is devoted to an in-depth study of each of the six DSR proficiencies as discussed in Section 2. As the challenges are analyzed, each student prepares and interacts with the class as to how the challenges apply to their chosen research topic. During the ninth week, each student makes a formal presentation and delivers a white paper on potential open research questions in their chosen research field. Interactions with the instructor and peer students provide guidance on proposing a final semester research paper.

DSR Research Topics (Five Weeks): The selected IS research fields and topics for that semester are presented and discussed in one class session. If one of the students has chosen that week's field, then the student and the instructor jointly present that session. The broad coverage of multiple IS research fields exposes the students to multiple research opportunities with a focus on the DSR challenges across the fields of study.

Final Student Research Presentations (One Week): Over the final six weeks of the semester, the students are required to refine their mid-term white papers into research papers that can be targeted to appropriate conferences in their research field. The research contributions of the papers address both theory and practices in the chosen field of research.

5.2 Executive Doctoral Program (DBA)

There is a going movement for talented and experienced managers returning to academia for Executive Doctoral Programs, such as the Doctor of Business Administration (DBA) program at the University of South Florida. One of the co-authors has team-taught DSR methods in this program for over six years. The intense course structure is one weekend (Friday/Saturday afternoons) per month over three months. Each class period is four hours, thus, total class time is 24 hours = six classes @ 4 hours. Class size is from 16-24 students. The following Table 5 provides a summary overview of the course materials.

	Friday Class	Saturday Class
Weekend 1	Introduction to Course (2 hours) - Design Science Research Foundations - DSR Basics and Foundational Paper - Research Proficiency Model - Course DSR Proposal Assignment Student Breakout Sessions (2 hours) - Five Person Teams to discuss DSR projects for individual student research interests - Instructors Moderate Discussion to focus on DSR goals and opportunities	Lecture on DSR Proficiencies (2 hours) - P1: Problem Space - P2: Solution Space - P3: DSR Processes Student Breakout Sessions (2 hours) - Five Person Teams to discuss application of lecture to student DSR projects - Instructors Moderate Discussion
Weekend 2	Lecture on DSR Proficiencies (2 hours) - P4: Building a	Guest Lectures on DSR Projects from Industry (2 hours)

	Novel Artifact - P5: Evaluating the Artifact - P6: Science and Practice Contributions Student Breakout Sessions (2 hours) - Five Person Teams to discuss application of lecture to student DSR projects - Instructors Moderate Discussion	Students Present DSR Proposals in Breakout Sessions (2 hours) - Five Person Teams provide peer feedback - Instructors provide feedback for final paper
Weekend 3	Student Presentations to Class (4 hours) - Feedback from Peers and Instructors	Lecture on DBA Opportunities to Publish in Conferences and Journals (2 hours) Student Wrap Up and Feedback Session (2 hours)

Table 5. DSR Executive DBA Course Template

It is important to note the educational emphasis on team-oriented breakout sessions with plenty of peer-to-peer feedback and discussion. With class sizes around 20 students, instructors are not able to provide the close working relationships that can be found in smaller PhD classes. Thus, a combination of instructor and peer feedback is invaluable.

The course assignment is a working draft of a research paper that applies the DSR process and methods to the student's area of research interest. Since a DBA class includes students with varying business area interests, not all topics will be in IS, but we emphasize that all business topics can demonstrate a DSR artifact as contributions to theory and practice.

5.3 Online DSR Training Program

An online DSR training program for mixes of industrial and academic students at various program levels can provide DSR proficiencies in an international virtual setting with diverse application disciplines. The curriculum template in Table 6 has been used effectively in many DSR training sessions, as organized by the German Association for Business Research (VHB). Since 2020, one of the co-authors has conducted over ten training seminars involving students from over 20 countries in Europe and beyond (Winter & vom Brocke, 2021). This course has been conducted on PhD level but the format has been applied for a MS level as well, and in what follows we point to specific adjustments recommended for MS level application.

The core principle of the course template is to develop the DSR proficiencies by working on specific DSR projects and providing ongoing feedback and mentoring to do so. The course makes use of "flipped classroom" principles, in that it engages students to familiarize themselves with the fundamentals of DSR prior to the joint classroom sessions. We provide a comprehensive reading list and student assignments upfront to make space for group work and joint discussions in a virtual class. The course blends online sessions with self-study sessions both individually and in groups. While on PhD level, we allow for a self-study period of one week, on the MS level, we offer additional sessions to guide and mentor the preparatory phase.

The course is designed for a maximum of 18 participants, allowing for a productive and engaged online learning atmosphere. While the initial target was doctoral student training, the well-defined entry requirements support a wide range of students with many educational backgrounds and goals. As seen in Table 6, the estimated overall student workload of the course is 150-180 hours, corresponding to 6 ECTS (European Credit Transfer and Accumulation System). When applied on the MS level, we have integrated the format into a research methods course, so the two weeks course design worked very well to include further approaches and research methods, such as literature reviewing, computational research, survey design, or qualitative empirical research.

Applying the flipped classroom principle, students are familiar with the key characteristics and most seminal articles in DSR when meeting online for the first time. This provides a basis for rich discussions and developing the DSR proficiencies in application. The course intends to develop DSR proficiencies beyond the provision of technical knowledge by (a) linking DSR to projects the participants are working on in their ongoing academic programs or workplace environment, (b) sharing a fascination for making contributions to real-world challenges through their DSR research, (c) experiencing and maneuvering the complexities of DSR in application, and (d) producing tangible results of utility the participants can continue working on beyond the course.

The opening session creates a sense of community and initiates a conversation around the various backgrounds and ideas in the classroom and how they link to key aspects of DSR. A session on fundamentals of DSR makes sure that all participants would share a joint understanding of key concepts and methods, complemented by Paper Reading Panels on selected aspects of the DSR proficiencies. Then, already at the end of the first day, a marketplace is organized where students can pitch and define ideas for group work on DSR mini-projects of their choice. As part of the DSR training, students will work continuously on these projects and receive feedback and mentoring in a total of five iterations. In our own courses, we apply co-teaching of two to many lecturers, so that students receive feedback from different perspectives. The ambition of the project work is to bring each group project to the level of a research in progress (RIP) paper. A de-briefing session serves assurance of learning as well as planning of further activities. Many of the projects have been developed into conference presentations and journal publications. If applied on the MS level, instead of aiming for publications we aim for creating a rich and thoughtful exposé for a potential master thesis applying DSR.

Week#	Topic	Mode
Week 1	Preparatory work - Course Information - Reading List - Individual Assignments	Self-study (individual)
Week 2 – Day 1	Welcome Session - Getting to know one another - Sharing a fascination for DSR	Online group discussion

	Design Science Research Fundamentals - DSR Frameworks and Processes - DSR Examples Paper Reading Panels (1/2) - Detailing DSR proficiencies - Panels on groups of papers in the reading list - (e.g. three papers plus a discussion form a one-hour panel) DSR Cases Market Place - Definition of DSR mini projects - Pitching project ideas and group building - First project sketch (version 1) - Presentation and feedback (feedback 1)	Online lectures and discussions Student presentations and discussions online Online group discussion
Week 2 – Day 2	Cases Project Work (1/4) (half day) - Groups work on DSR mini projects - Drafting and discussing alternative research designs in the each DSR mini project (version 2) Walk Through (1/3) (half day) - Presenting version 2 in class - Discussion of the research designs - Derivation of actionable guidance further developing each project (feedback 2)	Self-study (group work) Online student presentations, group discussions and mentoring
Week 2 – Day 3 and 4	Cases Project Work (2/4) (full days) - Deeper reflection of the DSR projects in groups - Desk research on specific aspects of the DSR project - Preparation of a more complete presentation of the DSR project (version 3)	Self-study (group work)
Week 2 – Day 5	Paper Reading Panels (2/2) (half day) - Three papers plus a discussion form a one-hour panel - Panels according to the reading list e.g. one panel on each DSR proficiency Walk Through (2/3) (half day) - Presenting version 3 to the class - Discussion and derivation of actionable guidance for each group to further develop their project (feedback 3)	Student presentations and discussions online Online student presentations, group discussions and mentoring
Week 3 – Day 1	Cases Project Work III (3/4) (full day) - Revision of the DSR projects in groups - Detailing the DSR research design - Preparation of a presentation of the DSR project including showcasing intermediate artifacts (version 4)	Self-study (group work)
Week 3 – Day 2	Cases Project Work (3/4) continued (half day) - See Week 3 day 1. Walk Through (3/3) (half day) - Presenting the DSR project (version 4) to the other groups and the lecturers - Discussion and derivation of actionable guidance for each group to further develop their project (feedback 4)	Self-study (group work) Online student presentations, group discussions and mentoring
Week 3 – Day 3 and 4	Cases Project Work (4/4) (full day) - Revision of the DSR projects in groups - Detailing the DSR research design - Preparation of a final course presentation of DSR mini project (version 5)	Self-study (group work)
Week 3 – Day 5	Final Presentation - Presenting the DSR project (version 5) to the other groups and the lecturers - Discussion and derivation of actionable guidance for further developing this research beyond the course (feedback 5) Debriefing, Closing, Follow ups - Summary of key learnings - Open discussion on selected topics - Advise on continuing and publishing results	Online student presentations, group discussions and mentoring Online group discussion

Table 6. DSR Online Training Template

6. CONCLUSION AND FUTURE RESEARCH DIRECTIONS

DSR is an important research paradigm for the field of Information Systems to contribute to the solution of complex, real-world challenges. Over the past decades, DSR has matured, and a well-understood set of principles and methods is available, which is increasingly applied in research in many academic disciplines. In education, however, standards on how to teach DSR are still largely lacking, both in terms of learning objectives and didactics, hindering the dissemination of DSR competences to students and slowing the positive impact of DSR through via rigorous science and relevant practice contributions.

This article provides a thorough DSR educational pedagogy for widespread use. We begin with a formal DSR proficiency model which defines six core DSR proficiencies essential to the effective conduct of DSR: Representing the Problem Space (P1), Capturing Extant Knowledge in the Solution Space (P2), Controlling the DSR Process (P3), Building Innovative Design Artifacts (P4), Measuring the Satisfaction of Research Goals with Rigorous Evaluation (P5), and Contributing to Science and Practice (P6).

In applying these proficiencies, we recognize the different educational environments and student backgrounds that DSR courses must accommodate and provide actionable guidance for mapping the proficiency model to academic, training, and executive audiences. Based on our experiences in teaching DSR courses, we present the strengths and challenges of teaching DSR to different target audiences and present strategies how to adapt the student instruction to the strengths and meet the challenges in educational designs, specifically for Doctoral (PhD), Executive (DBA), and Masters/Bachelor (MS/BS) programs. We also share templates of specific DSR courses we have taught based on the DSR proficiency model in different educational contexts.

We hope to provide colleagues with usable guidance for effectively planning and delivering DSR education in a variety of disciplines. The recommendations we have made are based on our own experience in contributing to the further development of the DSR methodology as well as in developing and conducting DSR education over the past decades and in many different settings. As such, we are aware of the limitations of our own thinking, and, thus, we hope to also stimulate a discourse on the further development of standards for DSR education. We encourage the DSR community to build and expand on our ideas with new insights and experiences (e.g., Thuan & Antunes, 2022).

Future research should collect more data on the design and impact of DSR courses in different contexts of use to improve our understanding of important contextual factors and how to address them in effective DSR education. The DSR Proficiency Model presented in this paper provides the starting point for such a discussion and research, to which we invite contributions from many different disciplines and perspectives. We encourage educators from all disciplines to embrace the ideas in this paper and to stimulate DSR by designing innovative and impactful DSR courses in their academic and training programs.

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