Descriptions of concept 'Research within Design' in STEM design projects

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Abstract

Design projects within STEM education often involve research, with students actively experimenting and testing to generate new insights. Even more often, the acquisition of existing knowledge necessary for designing takes place. In fact a previous study showed a discrepancy between what students indicate that research in design should be and what they actually recognize in their own design practice; actually often research consisting of looking up existing facts and knowledge. Students can articulate what research is and should be in design, but they do not recognize this in their own design practice and identify knowledge acquisition as research. This discrepancy suggests a lack of in-depth understanding of the concept of research in a design project. Therefore, this study examines teachers' descriptions of research that should be conducted within design projects. This is crucial because teacher-developed project descriptions form the foundation for design-based learning in the first three years of STEM subject Research and Design (R&D) project education (grades K7-9) at Technasia. The main goal is to determine based on these descriptions what is expected of students in a design assignment when it comes to research, to map the methods and tools used, and to determine at which stage of the design process research is considered. Twelve descriptions of design projects, one per school, from twelve different Technasium schools, selected by their teachers, are analysed for the required research implementation within the design assignment. Preliminary results indicate that most requested research takes place in the first phases of the design process during exploring and formulating the design problem. The required level of research suggests an informal, exploratory approach, trial and error, leading to little or no need for reliability and validity of the requested research.

STEM, Design based learning (DBL), Design projects, Design and Technology Education, Research and Design (R&D)

1. PROJECT-BASED STEM DESIGN EDUCATION

Design-based learning (DBL) is a key principle of project-based STEM education. This approach involves learning through design processes and context-specific design projects. Drawing upon scientific inquiry, design, engineering, mathematical reasoning, and technology, DBL is used to solve real-world problems (Zheng et al., 2020). Rather than transmitting ready-made knowledge, DBL focuses on actively constructing coherent knowledge and action (Oo, Kadyirov, Kadyjrova & Józsa, 2024). As there are no standard textbooks, it is the unique projects that form the foundation of learning. Consequently, the curriculum remains dynamic, with teachers coaching students through the design process.

At Dutch Technasium schools, the STEM Research and Design (R&D) subject involves students working in teams on realistic research or design projects set by external partners (Technasium, 2025). Each project focuses on a different technical discipline, with students acting as technical specialists. Projects for younger students (grades K7–9, aged 12–15) are created by teachers in collaboration with companies, institutions and technical experts (e.g. architects and software developers). These project descriptions generally follow a fixed structure according to Technasium guidelines and contain, general information, details of the assignment, assignment sub-steps, a description of the expert's professional role and assessment.

Although design-based learning focuses on design, research and design are intertwined. To explain this relationship, it is first necessary to clarify the definitions of "research" and "design".

1.1 Research

There are many different definitions of research, and while there are similarities, there does not seem to be a single, all-encompassing definition that is endorsed by everyone involved in research. Grover (2015) emphasises that the main purpose of research is to obtain new knowledge about reality through carefully chosen methods, whereas Creswell (2008) states that 'research is a process of steps used to gather and analyse information to enhance our understanding of a topic or issue'.

1.1.1. Purpose of Research

In addition to the many definitions of research, there are also various approaches to it. For example, research is often categorised as either fundamental (scientific) or applied. The former aims to generate knowledge, while the latter uses knowledge to solve practical problems. Both types of research must follow a structured, verifiable approach. According to Stokes (1997), there are four categories of research based on two binary dimensions. The first dimension is the search for fundamental knowledge about the world around us and the second is how this knowledge can be applied. Stokes distinguishes four quadrants, providing the following examples of researchers: fundamental research with little application (Bohr); applied, problem-solving research (Edison); use-oriented research combining knowledge and relevance (Pasteur); and creative, practical experimentation through trial and error, where chance leads to new insights (no example scientist). This model helps to distinguish between different perspectives in science, engineering and technology.

1.1.2. Characteristics of Research

Creswell and Poth (2014) explain that theory development and literature research lay the groundwork for research questions and analyses. Subsequently, Verschuren and Doorewaard (2015) emphasise that research must be systematic, well-structured, and follow a clear, planned and reproducible method. All decisions made during the research process must be explicitly stated and substantiated, enabling readers to understand the rationale behind them. Creswell and Creswell (2018) stress that this transparency is essential to ensure the verifiability and reliability of research, which in turn are important for research credibility (Booth et al., 2016). Conclusions must be based on systematically collected valid data in both applied and scientific research (e.g. observations, interviews and documents). In summary, research can be characterised by the following key features: it is systematic and transparent; it is based on valid data collection; it is verifiable and reproducible; and it is founded on a theoretical basis with clear relevance.

1.1. 3. Mode of Knowledge Acquisition

Building upon Creswell and Creswell's (2018) descriptions of quantitative, qualitative and mixed methods, as well as Pedaste et al.'s (2015) inquiry-based learning steps, the methodological options have been organised into three progressive levels of knowledge acquisition. Each level represents an increasing degree of analytical complexity, learning autonomy and search for factual knowledge, whether existing or self-discovered. This composite framework is solely used here to structure the analysis and does not claim to represent the taxonomies of Creswell or Pedaste. One possible classification consists of three constructive ways of acquiring knowledge, which are explained below:

(i) Based on existing knowledge.
Curiosity-driven/basic exploration: The collection of factual and non-factual information without in-depth analysis. This is an informal search for understanding based on existing information. Examples include Googling, visiting websites, learning by experimenting with materials and tools, summarising articles, making simple observations and conducting experiments.

(ii) Partially Structured Knowledge Inquiry
Situated between (i) and (iii), this involves students collecting existing knowledge in a more methodical and structured manner or seeking new, self-discovered factual knowledge using a clear guiding question, interviews, repeated observations, triangulation or identifying relationships between variables. However, this does not yet constitute a fully systematic approach resulting in reliable, reproducible findings.

(iii) Based on new facts that have been discovered independently.
Systematic/advanced: This is the search for new factual knowledge that builds upon a systematic approach and offers transparent, reliable and reproducible results. This approach constitutes a fully systematic approach resulting in reliable, reproducible findings.

1.2 Design

As with research, there are many definitions of design. Of particular interest is the definition provided by the Accreditation Board for Engineering and Technology (ABET) (2015), which

describes technical design as the process of creating a system, component, or process to address a specific need and solve technical problems. Moore et all (2014) states that, although the focus differs by discipline, design processes are central to engineering practice. Ralph and Wand (2009) describe ICT design as an activity, whereas Van Dooren et al. (2013) view architectural design as a complex, personal and creative skill. Cross (2006) characterises industrial design as 'the conceiving and realizing of new things'. Despite these differences, common principles emerge; design is context-driven, iterative and creative (IDEO, 2023; Klapwijk & Stables, 2023). In essence, design aims to develop or improve products and services (De Vries, 2005).

1.2.1. Design process

One model that is often used in Dutch primary and secondary design education to clarify the design process is the visualisation of the design phases according to the 'Guide to Inquiry-Based and Design-Based Learning' by Klapwijk and Holla (2018). This design cycle model consists of six phases and provides teachers and students with guidelines. Design process phases by Klapwijk, R., & Holla, E. (2018):

(i) Exploring and Formulating the Problem
(ii) Generating and Selecting Ideas
(iii) Developing and Selecting Concepts
(iv) Prototyping
(v) Testing and Optimizing
(vi) Presenting

1.3 Research and Design

In addition to being difficult to define, the processes of research and design closely resemble each other. Both begin with the problem analyses, knowledge acquisition and knowledge implementation, leading to solutions, conclusions, evaluation, and reflection. Creswell and Creswell (2018) describe research as a systematic process for gathering and analysing information to promote understanding. Lawson (2006) and Cross (2006), highlight that design is also an iterative process that encompasses analysis, synthesis and evaluation. The essential difference lies in the end goal. Research aims to generate new, reliable knowledge characterised by transparency, reproducibility, and objectivity. According to Creswell (2018), 'research is a systematic process aimed at increasing understanding of a subject or problem'. Design, on the other hand, focuses on creating a solution to a specific problem and is characterised by contextuality, creativity and often subjectivity. Lawson (2006) states that designers work with 'design intelligence' to create solutions that do not yet exist. Design thinking (Brown, 2009; IDEO, 2015) places emphasis on empathy, ideation and prototyping, whereas research focuses on generating hypotheses and evidence.

2. RESEARCH WITHIN DESIGN PROJECTS

This study focuses on conducting research within design, as research plays a variety of roles in the design process. For example, it is often an integral part of the design process, such as investigating material properties, collecting user data, testing usability or conducting empirical research. Frankel and Racine (2010) describe the role of research in design as 'research for design',

which they define as research that makes design possible. Conversely, design also encompasses looking up existing knowledge, such as exploring previous studies, analysing trends and consolidating relevant information. This is crucial for making design decisions, as well as for collecting and synthesising existing insights.

Despite this distinction, teachers and professionals often classify both activities as 'research in design', creating an interesting paradox. Why is collecting and analysing existing knowledge considered 'true' research in design? The ambiguity surrounding the nature of research in design education forms the basis of this study. It highlights the need to distinguish more clearly between research, which aims to acquire new knowledge, and looking up, which involves synthesising existing knowledge for practical use. Previous pilot research (de Haan et al., 2025) revealed a gap in students' reasoning regarding research and knowledge acquisition in design. While students can articulate what research in design is and should be, they do not recognise it in their own design practice. This discrepancy suggests a lack of in-depth understanding of the concept. Consequently, this study examines how teachers describe the research that should be conducted within design projects.

3. DATA COLLECTION AND ANALYSIS METHODS

The study analysed research descriptions requested by teachers within design projects. The content of these descriptions and their implications are investigated systematically. The main objectives were to identify the research required by teachers within design projects, to map the methods mentioned in assignments and to determine the stage of the design process at which research is considered and the mode and type of research involved.

Using conceptual content analysis, the descriptions of various written design projects from lower secondary education (grades K7–9) submitted by twelve Technasium schools in the Netherlands were examined for a request for research. Parts of the written design project were coded when 'research' was requested. Additionally, text fragments mentioning direct implications for research, such as 'testing a design for use', were coded. The research description, methods and activities (e.g. surveys, interviews or user analysis) were thematically coded and categorised if mentioned. All text fragments were categorised, resulting in various code groups and subgroups.

Furthermore, the descriptions were placed within the design phases based on the six-phase model of the design cycle (Klapwijk & Holla, 2018). The study also examined how acquiring the necessary knowledge is classified, as described in the three constructive modes of knowledge acquisition.

Table 1

Twelve Analysed Design projects

Project title	Class	Design Assignment
Repurpose design	K-7	Design a reusable product from hard-to-sell waste streams. Create a 'making-of' video and promotional materials.

Natural North!	K-8	Create a working model for one concept: a self-sufficient vertical herb garden, high-tech scarecrow, chicken feeder or smart snail killer.
Village farm	K-7	Design a mobile shelter and a rotation plan to ensure the well-being and natural behavior of the sheep, donkeys and goats. Also design a visitor walking route providing continuous visibility.
4D Experience at the Museum	K-7 to K-9	Design an interactive exhibition that engages at least two senses and tells an object's story, offering visitors a new experience while forming part of a coherent whole.
A healthier canteen	K-7 to K-9	Investigate the current canteen situation. Propose a new design that makes the food offers significantly healthier for students.
Fast Fashion	K-7 to K-9	Design a campaign component highlighting the clothing industry's negative impact and fitting within an info campaign including a video, pop-up store and card game.
Underwater	K-7 to K-9	Provide a model and before-and-after photos of a redesigned municipal site to show how it is used to reduce flooding or create water storage.
Plastic waste in a river	K-8	Design a plastic-filter system for a river in a foreign country.
On the radar	K-7 to K-9	Design a user interface for one value proposition, then develop and test a new one.
Designing an interchange (hub)	K-7 to K-9	Design a city interchange (hub) that improves future traffic and transportation flows.
Developing an attractive solar park	K-8	Design a solar park that meets residents' needs by generating energy while also fulfilling at least one additional community function
Mist nets for a green wall.	K-8	Design a pilot to green a 5-hectare Moroccan desert using mist nets to harvest water for agriculture and tree-planting.

4. RESULTS

4.1 Requested research within design project assignments

Nine of the twelve participating schools (75%) requested research, or variants such as preliminary or user research. Eight of these nine schools also requested research via research methods or activities. Of these nine schools, a total of 37 requests for research were made within the design project (n=37). All nine schools requested research in the project component, in which the assignment is divided into sub-steps.
When schools requested research, they asked 'research' seven times without further specification. When further specification was provided, it concerned exploratory research (six times), target group research (two times) and research results, such as a research poster (two times). Other types of research mentioned once included comparative research, source research, a research plan, a research question and a research report.
The most requested research activities were testing (six times) and analysis (four times), followed by methods such as interviews (two times), experiments (two times) and site visits (one time).

4.2 Requested research within the design process phases

The results obtained were categorized into six design phases:

(i) Exploring and Formulating the Problem
Research was required in 45.9% of the descriptions (n = 37) in the first phase of the design process. The various actions required in this phase varied from project to project. For example, the following was requested for the project '4D experience at the museum': 'During your research, answer at least the following questions: In what year was the museum object created or discovered? Who created or discovered the object? Etc.'

(ii) Generating and Selecting Ideas
In the second phase of the design process, 21.6% of project descriptions required research. For instance, a project concerning a healthy canteen required comparative research. 'During your research, make a list of the existing canteen products that are good and those that could be improved. Use this information to generate new ideas for your recommendations.'

(iii) Developing and Selecting Concepts
In the third phase of the design process, 8.2% of project descriptions required research. The following question was asked in the 'Project Repurpose Design': 'Interview at least three potential users about your ideas.'

(iv) Prototyping
No research was required during the fourth design phase.

(v) Testing and Optimizing
In this phase, 18.9% of projects required research. For instance, the project on water harvesting in the desert using mist nets required research. 'The client has

asked you to conduct research using the test setup to determine the water yield of both concepts.'

(vi) Presenting
In the sixth design phase (presentation), 5.4% of project descriptions requested that preliminary research results be presented in the form of posters or reports.

4.3 Mode of the research asked

A large share of the research tasks outlined in the project documentation fall under mode (i), which involves searching for existing information, carrying out simple observations, or conducting basic experiments. In total, 65.7% (n = 37) of the required research falls into this category. This work is not scientific research aimed at generating new knowledge; rather, its primary purpose is to gather information needed for the design process. A semi-scientific approach (mode II) was required for 34.3% of projects. Systematic or advanced scientific research (mode III), intended to produce new factual insights, was not required.

5. DISCUSSION

According to the results, nine of the twelve participating schools requested research activities within the design project. The research is requested using terms such as 'research' or 'initial exploratory research', and via research methods (analysis) or research activities (testing). Research activities are primarily requested in the early stages of the design process, as a means of acquiring the necessary knowledge, or as a process of trial and error. Secondarily in the later stages of the design process, in the testing and optimization phase. The descriptions do not specify how this research should be structured, nor whether validity and reliability must be guaranteed. This is relevant because, in response to the open question in an earlier pilot study (de Haan et al. 2025) regarding the required research mode in a design assignment, 12 of the 16 teachers chose the partially structured mode (ii), which involves students collecting existing knowledge in a more methodical and structured manner or seeking new, self-discovered factual knowledge using a clear guiding question, interviews, repeated observations, triangulation or identifying relationships between variables. This suggests research that goes beyond (i) curiosity-driven or basic exploratory knowledge acquisition. However, their own project descriptions, as described in the current study, show that in 65.7% (n=37) of cases, a curiosity-driven approach (i) a basic exploratory approach were requested. Why do they usually ask for these more basic methods of knowledge acquisition in the written project descriptions and effectively focus only on existing knowledge, while previous research has shown that teachers prefer a partially structured mode? This question aligns with the findings of the already mentioned previous research, which shows that students understand research in theory, but in practical examples primarily describe the trial-and-error method and the search for existing information. It is therefore important to further investigate what level of validity and reliability teachers expect from students in their research, how their descriptions and intentions correspond, how students interpret this, and what causes the discrepancy between students' theoretical knowledge of research and the practical research examples they cite. The following research steps, based on focus group interviews with teachers and students, are aimed at clarifying these agreements and gaining a better understanding.

6. DISCLOSURE STATEMENT

Artificial Intelligence (AI) technologies were (minimally/marginally) used solely to enhance clarity and structure of the written text. All scholarly contributions, theoretical perspectives, and analyses were produced by the authors.

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