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Research paper

Teachers' and Students' Needs for Supporting Digital Research Skills in Secondary STEM Education

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ABSTRACT

This qualitative study explores the support needed for the acquisition of digital research skills (DRS) in secondary STEM education. We approached this from both teachers' and students' perspectives, based on semi-structured focus group interviews. The findings reveal a strong consensus among participants on the importance of incorporating DRS into regular lessons. Teachers emphasize the need for better curriculum integration and specific support structures, while students primarily seek practical, step-by-step guidance for applying DRS. After combining these findings with a literature search, we propose ten suggestions to enhance support for guiding and developing DRS in secondary (STEM) education. These ten suggestions initiate concrete steps to bridge the gap between secondary and higher education in DRS. In doing so, we contribute to the ongoing discussion on strengthening essential skills in education and provide actionable insights for curriculum developers, educational institutions, publishers, tool developers, and teachers.

Keywords: digital research skills, secondary education, digital literacy, inquiry-based learning, scaffolding

The purpose of STEM education in secondary schools extends beyond the mere acquisition of domain knowledge. It encompasses the development of essential skills that prepare students for future challenges in this rapidly evolving world (English, 2016; González - Pérez & Ramírez - Montoya, 2022). Among these skills are critical thinking, problem-solving, collaboration, and research skills (van Laar et al., 2017; Voogt & Pareja Roblin, 2010; Tiemann et al., 2026). As digital technology continues to advance, the need to combine these essential skills with digital skills becomes increasingly important (Bond et al., 2018; Nadrljanski et al., 2022; Silber-Varod et al., 2019). As teachers implement digital technology in their classroom (Fraile et al., 2018; Guillén-Gámez et al., 2020; Mishra et al., 2011; Polly et al., 2010), students are expected to adapt to new tools and methods in their research projects (Varías-Palacios et al., 2023; Williams & Beam, 2019). In this context, digital research skills (DRS) are defined as essential digital skills specifically applied during the design, implementation and reporting of a research project (Blankendaal-Tran et al., 2023). They are described as the subset of digital skills that is essential for performing and communicating research in science. The difference between DRS and digital skills and DRS and research skills is not trivial. We will further elaborate on this in the theoretical framework below. Examples of DRS are advanced search techniques, accurate data handling, secure storage, and the use of software for visualization and presentation. These skills address research capabilities that secondary school STEM students need to acquire to confront the digital demands of modern science, e.g., within a STEM study in higher education.

Exemplified by the definition of 21st-century skills (Ananiadou & Claro, 2009; Griffin et al., 2012), educational curricula in Western societies have shifted towards skills development alongside subject knowledge. For instance, Finland's education system highlights critical thinking and problem-solving skills, which are integrated across various subjects, including STEM (Halinen, 2018; Lavonen, 2020). Similarly, Singapore has revised its science curriculum to prioritize inquiry-based learning, encouraging students to ask questions, conduct experiments, and analyse data (Jocz et al., 2014; Yeo et al., 2021). In Canada and the United States, 21st-century skills are explicitly integrated into the science curriculum (Amadi, 2023; Cai & Gut, 2020). Norway has been proactive in updating its science curriculum at least three times in the past 20 years to, among other things, emphasize (meta-)skills and practices needed for general academic performance (Mork et al., 2022; Nilsen & Gustafsson, 2014).

In the Netherlands (the context of this study), STEM school subjects in which the aforementioned skills are central were introduced into the upper secondary school curriculum: general science, academic skills, "nature, life & technology", "research and design" (Schijf et al., 2023; Vossen et al., 2018). These subjects focus more on cross-curricular skills, such as research skills, design skills, and academic writing skills (van der Valk et al., 2015; Vossen et al., 2021; Wientjes & Veenhoven, 2022) than on being able to apply specific knowledge across different subjects. The skills these subjects aim to develop include - but are not limited to - search techniques in online databases, using software to perform calculations, processing and displaying data in graphs, and making digital reports and/or presentations. The skills can be classified as DRS and are particularly important within the context of a full-scale STEM research project and writing the corresponding research project report (Akbar et al., 2023; Maddens, 2021; Julien and Barker, 2009).

Despite an increase in attention towards research skills, including DRS, teachers in academia report that freshmen students are often found wanting in this respect (Blankendaal-Tran et al., 2023). For instance, university science teachers report that when students are confronted with constructing specific graphs by digital means, the results are often insufficient (Donnelly-Hermosillo et al., 2020; Mustaffa et al., 2022). Students are also reported struggling with the use of scientific sources and appear to be unaware of how search engines identify potentially relevant sources or do not regularly use clear evaluation criteria when searching for information (Hyytinen et al., 2017; Julien & Barker, 2009; Salehi et al., 2018; Walraven et al., 2009). Lastly, students entering academia show a lack of adequate scientific writing skills in several studies (e.g., Wollscheid et al., 2021).

We (Blankendaal-Tran et al., 2025) showed that pre-university STEM students do demonstrate some level of DRS in their science project reports, but only to a limited extent. For example, the data obtained were often not presented properly, and improper use of word processor automation features resulted in an unclear text structure, which could lead to confusion or misinterpretation of results. Additionally, secondary school students rarely use peer-reviewed sources, often use footnotes instead of a bibliography, and include inadequate references or no references at all. Furthermore, students are prone to inserting tables without clearly distinguished column headings, graphs without axis titles, and incorrect formulas due to improper use of a formula editor. These secondary STEM students use graphs with lines drawn from data point to data point instead of a trendline through the data points, increasing the risk of research data being interpreted incorrectly. The challenge lies in identifying and addressing the diverse needs of both teachers and students in terms of DRS, as students are clearly not acquiring all the skills they need for an academic career in the STEM field.

The question thus arises of how the level of DRS can be improved before secondary school students start a STEM study. What is the required skill level? How can these kinds of skills best be taught? What support is there for teachers to be able to guide learners in applying digital skills or research skills? What support is there for students to see to what extent they are mastering the skills well?

In this study, we aim to design and formulate guidelines to supports both teachers and students in the developing DRS in secondary STEM education.

Our main research question is: What do students and teachers report regarding the support for developing digital research skills (DRS) in secondary STEM education?

To answer this question, we gathered insights from both teachers and students through semi-structured interviews with focus groups. We then compared these outcomes with existing literature to arrive at practical guidelines.

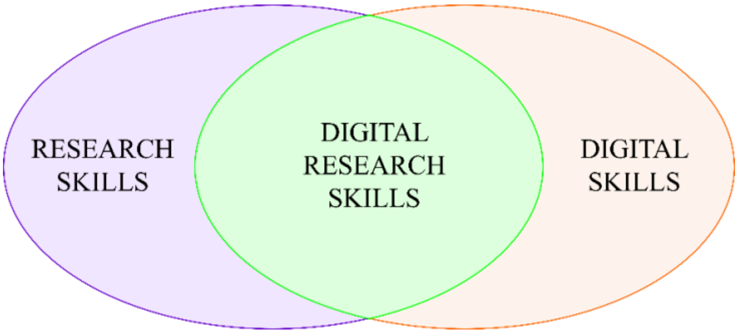
THEORETICAL BACKGROUND

DRS in STEM education

We define digital research skills (DRS) as essential digital skills for the design of, conduct of, and communication on a research project (Blankendaal-Tran et al., 2023). The categories in the DRS framework align closely with competence areas described in international models. For example, DRS categories "Browse, search and filter information" and "Analyse, transform and visualise content/data" correspond to the "Information and data literacy" competence area of the European Digital Competence Framework for Citizens (DigComp) (Blankendaal-Tran et al., 2023; Carretero et al., 2017). Broader digital literacy models, such as the International Computer and Information Literacy Study (ICILS) also show parallels with the competencies included in the DRS framework, such as those related to transforming, managing, and using digital information and content. (Fraillon et al., 2014). As seen in the diagram in **Figure 1**, digital research skills represent the overlap between research skills and digital skills. DRS always involve a combination of a digital technique and a research skill. They encompass the specific skills needed to conduct research within a digital environment.

Figure 1

Diagram of digital research skills, as the overlap between research skills and digital skills



Many skills involved in composing a scientific report are DRS but DRS are not limited to reporting. **Table 1** shows typical DRS examples. To illustrate, consider the process of searching for reliable and relevant sources. While this is a research skill, the application of search techniques, such as the use of Boolean operators in online databases, is a digital skill. When these digital skills are performed to find and select reliable and relevant sources for research, the combined practice becomes a DRS. Similarly, using a formula editor is a digital skill. However, correctly notating elements such as fractions, exponents, and superscripts in digital environments, requires DRS. In these contexts, both precision and appropriate formatting are essential.

It is important to note that not all research skills are DRS, and neither are all digital skills. The distinction between research skills and DRS, as well as between digital skills and DRS, is not trivial.

Table 1

Three examples of DRS with associated research skills and digital skills

	Research Skills	Digital Research Skills	Digital Skills
1	Search for reliable and relevant sources.	Use search techniques to select reliable and relevant sources.	Search techniques in online databases.
2	Understand the data from the study.	Apply the steps needed to display data in a graph that fits the study.	Techniques to convert data into graphs.
3	Understand of formulas, symbols, fractions, powers, and superscripts.	Use a formula editor to display formulas with a correct notation of symbols, fractions, powers, and superscripts.	Steps to insert and edit formulas in a formula editor.

DRS: abstract and concrete

Rentawati et al. (2018) divided 21st-century skills into two main categories: abstract and concrete skills. Based on Bloom's Taxonomy (Huitt, 2011), higher-order thinking skills belong to the abstract skills, whereas communication and collaboration skills are concrete. Similarly, DRS can also be divided into abstract and concrete skills. Concrete DRS mainly involves knowledge about specific tools or functions, such as the steps required to format a table or insert a caption. They could be mastered through direct instruction or online tutorials. Concrete DRS can, however, become challenging when large amounts of data, text, figures, and tables in a report are considered. They correspond to the operational and formal skills described by Van Deursen et al. (2014), which involve knowledge of how digital applications are used. In contrast, abstract DRS align with the information navigation and strategic skills identified by Van Deursen et al., which focus on higher-order cognitive processes. Abstract DRS involves higher-order thinking, understanding of the context in combination with the concepts during application. These skills are less about the specific tools or steps and more about understanding the underlying principles and methods.

To give an example, a DRS such as "Gather, measure and collect digital content/data" (**Table 2**) requires a series of cognitive steps, such as comparing, evaluating, and assessing information. To apply this DRS, students also need specific knowledge on how to work a digital search engine. This includes being able to search by year for recent sources and advanced searching using Boolean operators, making this skill an abstract skill (which requires additional concrete skills to perform).

Similarly, representing data in a diagram is a digital skill that requires consideration of the context and underlying research steps. Interpreting and visualising data requires an understanding of the dataset and the context in which it is used. This requires both an understanding of the best way to present the data and knowledge of the steps to digitally represent this understanding. **Table 2** lists abstract and concrete DRS.

Table 2

Abstract (A) and concrete (C) DRS (Blankendaal-Tran et al., 2023, p.7)

	DRS category	Explanatory note	Abstract (A) or Concrete (C)
1	Browse, search and filter information	Using search engines and databases. Filtering information.	C
		Employing advanced search techniques by combining keywords with operators. Utilizing search engines and databases to find peer-reviewed sources. Recognizing scholarly sources and applying search strategies in digital search engines.	A
2	Gather, measure, and collect digital content/data	Selecting scientific literature. Knowledge and use of digital/online environments to (automatically) acquire data. Avoiding plagiarism through quoting and paraphrasing. Comparing and evaluating the reliability and validity of digital content and research methods.	A
3	Determine the accuracy and validity of sources	Comparing and evaluating digital sources/information. Evaluation of information/data for timeliness and accuracy. Verifying the credibility of sources.	A
5	Analyse, transform and visualise content/data	Digitally processing large amounts of data using software with calculation functions. Creating selection diagrams that display data from various types of measurements and multiple data sets in a single diagram. Drawing structural formulas. Programming/Technical drawing.	A
		Creating and formatting graphs with axis titles, trend lines, legends, and error bars. Displaying and formatting tables. Incorporating and displaying pictures/images. Representing reaction equations.	C
6	Write a research paper using digital tools	Inserting figures, graphs, and tables with references and captions. Processing and formatting content using a digital application. Formatting text with italics, subscript, superscript, symbols, and listings. Utilizing layout functions such as line spacing, text wrapping, alignment, margins, headers, and footers. Implementing styles, headings, subheadings, and an automatic table of contents. Using automatic numbering for pages, figures, graphs, and tables. Inserting a reference list. Using a formula editor for calculations.	C

The boundary between abstract and concrete DRS is not always very sharp. Inserting figures may seem like a concrete DRS, but it involves more than just knowing the buttons to insert the figure into the right place. A student needs to ensure that the figure matches the content of the text. An image that is too small or too dark can be solved with concrete steps, but a figure that contains a watermark requires more effort to solve. For this, a student needs to have knowledge of licence conditions and come up with creative solutions to get the desired figure.

Supporting DRS

The current level of DRS of pre-university STEM students in the Netherlands, as evidenced by their research reports, has recently been studied, and several issues have been identified (Blankendaal-Tran et al., 2025). Literature discusses scaffolding as an effective teaching strategy for the development of skills (Gunawardena & Wilson, 2021; van de Pol et al., 2010; Chi, 2022; Amka & Dalle, 2022; Toupin & Lévesque, 2025; Sultan et al., 2025). Scaffolding, as proposed by Wood et al. (1976), essentially involves providing just-in-time support or assistance to learners as they engage in problem-solving activities. In general, scaffolding is interpreted as support given by a teacher to a student when performing a task that the student might otherwise not be able to accomplish. Some common characteristics, such as students' responsibility and calibrated support, are shared by the many different exact definitions of scaffolding. Van de Pol et al. (2010) described effective interactions in educational settings. According to Verenikina (2003), the importance of scaffolding in terms of its conceptual significance and practical value for teaching is illustrated by the large body of educational research in this field (e.g., the meta-analysis of Belland et al. (2017)).

Quintana et al. (2004, p. 369) presented a widely referenced scaffolding design framework for the context of digital technology. Although it was developed for inquiry learning, it can be applied more broadly. This scaffolding framework was, for example, effective in helping increase and integrate higher-order skills in STEM education (Belland et al., 2017) and fostering secondary school students' intrinsic motivation towards performing science practicals (Meulenbroeks et al., 2023).

The framework has seven main scaffolding guidelines:

(1) Use representations and language that bridge learners' understanding.
(2) Organize tools and artifacts around the semantics of the discipline.
(3) Use representations that learners can inspect in different ways to reveal important properties or underlying data.
(4) Provide structure for complex tasks and functionality.
(5) Embed expert guidance about scientific practices.
(6) Automatically handle non-salient routine tasks.
(7) Facilitate ongoing articulation and reflection during the investigation.

To achieve a given guideline, Quintana et al. (2004) provided 20 scaffolding strategies divided over these seven guidelines.

In the next section, we will use these strategies as a basis for the development of support strategies for DRS. We use a qualitative study to examine the extent to which students and teachers need support and what kind of support is desired. For clarity, we decided to address a more differentiated representation of the scaffolding guidelines at a later stage (**Table 3**).

Table 3
Scaffolding strategies for DRS support based on Quintana et al. (2004)

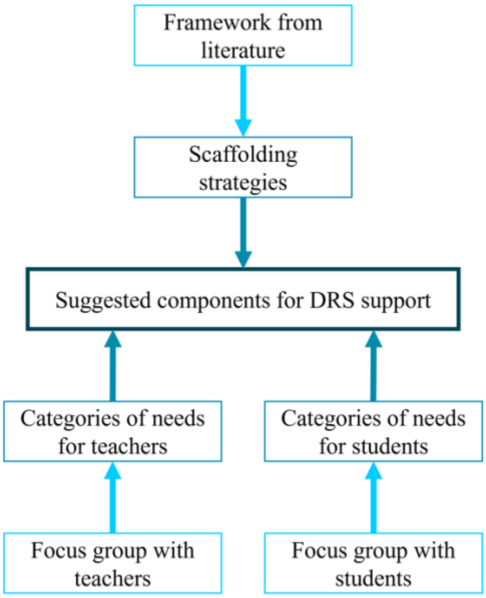
Scaffold guidelines	Scaffolding strategies (shortened)
1: Use representations and languages that bridge learners' understanding	1a: Visualize concepts
	1b: Understanding concepts
	1c: Use and apply content
4: Provide structure for complex tasks and functionality	4a: Setting boundaries
	4b: Structure tasks
	4c: Constrain the space
5: Embed expert guidance about scientific practices	5a: Clarify characteristics
	5b: Indicate rationales
6: Automatically handle non-salient, routine tasks	6c: Facilitate navigation
7: Facilitate ongoing articulation and reflection during the investigation.	7b: Provide reminders

METHOD

The research question calls for a qualitative approach. Accordingly, we collected data using semi-structured focus group interviews with both teachers and students. The answers given were then grouped bottom-up into categories of needs. These categories of needs were then compared with existing literature to identify suggested components for supporting DRS. An overview of the study is given in Figure 2.

Figure 2

Methods roadmap to suggested components for DRS combining an existing framework with data from focus groups with teachers and students



Teachers' focus groups

Context and participants

The STEM teachers for the focus group were acquired through a call on social media. The call was addressed to physics and chemistry teachers who had experience in supervising research projects in both lower and upper secondary classes in the Netherlands. Eight teachers responded and gave their informed consent. We conducted two online semi-structured interviews with them (N = 4+4) in June 2023.

Participants were physics and chemistry teachers in the Netherlands who met the following criteria: experience teaching both lower and upper secondary classes and supervising student science research projects at both levels

Instruments

The focus group interviews were based on questions derived from the results of two of our previous studies (Blankendaal-Tran et al., 2023, 2025). These questions were on the three categories in which academic teachers were least satisfied with their students:

0 What are your experiences in guiding STEM project reports?
1a How do your students manage to search and use sources?
1b In what way would you like support in guiding students in searching and using sources?
2a How do your students manage to collect and process data?
2b In what way would you like support in guiding students during the processing data?
3a How do your students manage to write research reports?
3b In what way would you like support in guiding students during the writing of a research report?

Question 0 is a general open question. Questions 1a and 1b are related to the DRS category "Browse, search and filter information". Questions 2a and 2b are related to DRS category "Analyse, transform and visualise content/data digitally," and questions 3a and 3b are related to DRS category "Write a research paper using digital tools".

After each open-ended question, the answers given prompted further questioning for more information. Consider questions such as: "What difficulties do you encounter?", "How do you support them?" "Can you give an example?", "Is this also your experience?" or "Could you add to this?" Each teacher's focus group interview took approximately 40 minutes.

Students' focus groups

Context and participants

All students of one NLT (Nature, Life and Technology) class in a large-scale urban secondary school in the centre of the Netherlands were asked to participate in the on-site focus group. NLT is a multidisciplinary course in secondary education that introduces students to various topics in natural sciences and technology in an inquiry-based way. Fourteen students agreed to participate, giving both verbal and written consent. The two focus groups (N=7+7, April 2023) were conducted onsite during student breaks. The students were told that no grades were involved and no rewards or prizes were offered. These sessions were conducted after the completion of the science project paper process, once all school exam marks had been finalized. Note that the researcher, being a teacher at the school, was not in any power relation with any of the students, i.e., did not teach these students.

Instruments

During the focus groups with students, the following six questions were asked:

1. "What positive and negative experiences have you had with the science project report?"
2. "What aspects have you learned during the completion of your science project report?"
3. "In which aspects did you receive comments, tips, or help from your supervisor?"
4. "How would you like support in processing data or writing a report?"
5. "In which aspects did you encounter difficulties and wish you had more, better, or different support? For example, in processing data or writing a report?"
6. "Can you specifically mention what type or form of support you would have wanted during the data processing or report writing phase?"

Questions 1 and 2 are general. Based on the results and concerns raised in our previous studies (Blankendaal-Tran et al., 2023, 2025), questions 3 to 6 explore students' experiences and preferences regarding guidance, particularly in relation to data processing and writing a report.

As with the focus groups with teachers, the answers given prompted further clarifying questioning. Consider questions such as: "Can you give an example?" "Is this also your experience?" or "Could you add to this?" Each student focus group interview took approximately 30 minutes.

Data-analysis

Transcription, pseudonymization, and identification of self-contained quotes

The eight teachers formed a homogeneous group with similar backgrounds, consistent with literature supporting saturation with six to twelve participants (Guest et al., 2006). The relatively small focus groups encouraged active participation from each teacher, providing deeper insights into their experiences. Data-saturation was considered achieved when participants no longer contributed new ideas or additions to those already identified.

The online teacher focus groups, conducted via a video conferencing platform, and the on-site student focus groups were both recorded. All recordings were then transcribed and pseudonymised. Subsequently, 46 self-contained quotes were selected from the transcription, based on their relevance to the research question. Twenty-five quotes were gathered from focus groups with teachers, and twenty-one quotes were gathered from focus groups with students.

Open coding was employed: quotes were first selected based on their self-contained (i.e., not needing explanations) nature and their focus on the support of DRS. These quotes were then grouped into categories, resulting in a codebook identifying the categories.

In coding, we used a bottom-up approach: the quotes were grouped into needs categories, resulting in a codebook identifying these categories. For second coding, all quotes were independently coded by a second researcher using the predefined categories. After completing the coding, we calculated interrater reliability by determining the percentage of quotes that had been assigned to the same category by both coders. This procedure yielded a high agreement of 98%, indicating near-perfect interrater reliability.

Grouping the quotes related to a scaffolding framework

The identified categories of needs were then compared with the scaffolding strategies described by Quintana et al. (2004). During twenty weekly one-hour discussions, the authors reviewed these findings and reached a consensus on suggestions for a support strategy that allows students to learn DRS and teachers to guide DRS effectively.

We thus identified support structures top-down for both concrete DRS and abstract DRS. For example, in supporting concrete DRS, the strategy "Provide structure for complex tasks and functionality" (see **Table 2**) can refer to step-by-step instructions for concrete DRS tasks, such as the use of a formula editor. The same applies to the strategy of "Automatically handle non-salient routine tasks"; by automating routine tasks during the insertion of page numbers or maintaining a resource list, students can focus on the content or more complex tasks.

In the case of abstract DRS, the strategy "Use representations that learners can inspect in different ways to reveal important properties or underlying data" provides a way to compare and evaluate multiple digital visualisation options (such as scatter diagrams and histograms) to make a choice that clearly displays the data and fits the research question. The same applies to the strategy "Embed expert guidance about scientific practices", which helps students formulate appropriate research questions or set up good methodological experiments using built-in tips and best practices from experts.

In selecting the strategies that can be used for supporting the development of DRS, we adopted the following criteria: they aim to improve skills needed in conducting research in secondary education, they contribute to understanding and learn to apply DRS, they effectively structure tasks within clear boundaries, and they provide direct support. The other ten strategies have been excluded because they do not apply to supporting DRS. To give two examples, storyboards could be used when planning a lesson series and structuring educational videos. However, this only indirectly contributes to understanding and applying DRS. Second, it is possible to adapt data queries using DRS; however, it is difficult to adapt DRS by adapting data queries.

RESULTS

In this section, we categorize the responses provided by both teachers and students during the focus groups. We present selected quotes for each category from both teachers and students to illustrate the points.

Focus groups with teachers

The teachers indicate that they encounter several problems while guiding students in writing a report, searching and using sources, or processing data. They consider writing a report a very difficult task for their students. Their students need a lot of guidance in this regard. It is notable that none of the participating STEM teachers are satisfied with their students' application of DRS, and all agree that more time should be spent on DRS during regular lessons:

Teacher LT said: They start off very poor at finding sources that fit the assignment they are given. They just look for the answer on [a website with tools and information for students] or something similar and then that is the only source.

Teachers' desire for support in guiding students while applying DRS is reflected in **Table 2**. Six categories emerged for the teacher interviews: 1. Integrate in regular class; 2. concrete support for students; 3. Training for teachers; 4. Continuous learning trajectory; 5. Collaboration with other subjects; and 6. Teaching material. An overview of the categories of needs is given in **Table 4**.

When the teachers in the focus groups were asked: "How would you like support in guiding students to process data or write a report?", all teachers indicated that they would especially like to devote more time and attention to DRS in lessons.

Teacher AB said: Learning preferably with more time and we don't have that. By showing it in class, by practicing it a lot which we do try then.

Teacher YN said: I should actually allocate at least a whole lesson as preparation for it. So not just a lesson on content, but also how to write a scientific report, how to make graphs, etc.

Four teachers express their preference for a continuous learning trajectory in secondary education from lower classes onwards, with clear concrete support available for students.

Teacher MdN said: You have to educate students in that, and I don't think you start doing that until the final exam year, that you get that right, because then it takes a lot of energy out of them.

Four teachers mentioned they need specific and concrete support for students to guide them in DRS. Teachers indicate a particular need for concrete support for students in the form of checklists including examples or rubrics to provide feedback.

Teacher NM said: We tried it with one of those Google Docs files. We then put those headings in there and then made empty boxes, that they then start filling in in the second then and then as we get higher in the learning years that we remove more and more in there. It gives some people a handle at least. They don't know where else to start, which at least gives a bit of structure to it.

As for working with Excel and the use of sources, some teachers said they would like to have guidance themselves. Three teachers mention that they are not fully proficient in all DRS and are unsure about how to assess and evaluate the skills.

Teacher YN said: (...) I'm still a bit searching for how to give feedback. In my teaching material, for example, it doesn't say that, so I have to go there and find for myself what do I think is important? What is my rubric?

Two teachers would like to have teaching material to specifically teach DRS to students.

Teacher NM said: I find with a module like that, I would immediately think with us those nonsensical lessons huh? Then I think well, I would rather have those STEM students do that module [on graph making].

Three teachers mentioned they need training for teachers to guide DRS. One teacher mentioned no support is needed to guide DRS, that only students need support.

Teacher RB said: Because I didn't think the general manual was good enough for physics, I made a manual specifically for physics in the course of the last school year, because I also found the assessment rubrics to be very general, especially to deal with the processing of data and then you're often faced with a coordinate transformation and the meaning of a slope, for example. Well, I didn't see that reflected in the assessment rubrics of the general manual.

Three teachers indicate that the guiding and teaching of DRS is not only needed in STEM subjects and indicate that they would like to collaborate with other subjects.

Teacher VM said: You should actually do something together with [other STEM subjects] to learn how to work with Excel. Huh, because that's obviously a win-win situation for both sides. Then maybe you could free up some class time for that as well. Do they then come up with concrete assignments with their laptop, or computer lab. Concretely, of course, they just have to work on it themselves with certain pre-cooked Excel files, though. Do they have to work on it themselves? Because that's the basics after all.

Table 4

Categories of needs obtained bottom-up from the focus groups with teachers (N = 4+4)

Category	Description	Quote example	Number of teachers
1. Integrate in regular class	Indicates that support is given during regular class times.	"Students used to learn how to work with (...[DRS]...) a bit with the subject teachers. Yes, students do deserve support in that."	8
2. Concrete support for students	Refers to specific support that conveys do's and don'ts.	" I find that I have to give students a lot of handles of what should be where on a chart. (...) otherwise they can't start."	4
3. Training for teachers	Indicates training or exploratory work for teachers.	"I know it can be done in Excel, but I almost never use that myself, because then I have to figure that out all over again."	3
4. Continuous learning trajectory	Indicates that attention is paid to and built upon each year, in both the lower and upper grades.	"You want to do all those skills earlier, in lower secondary. That you just start every year with another (…[set of skills]...), so you could say the same with those reports."	4
5. Collaboration with other subjects	Indicates collaboration or arrangements with other subjects.	"We would start, I think, with all the subject groups to map out where [DRS] fits in the chapters and what exactly we want to repeat and then set up for each year what we want to do when."	3
6. Teaching material	Indicates the need for teaching modules including explanations, examples, or assignments.	"I think a separate module. I think a lot of people would like to use that in the classroom somehow."	2

Focus groups with students

The students indicated that they needed more guidance in the research process. Problematic experiences include the lack of practical guidance, resulting in the implementation not going smoothly. Students indicated that they learned several skills during writing the research report, such as using sources, writing a theoretical framework, learning to plan, and using images in the report.

All students mention that they received comments, tips and help from their teacher during the research process, but only to a limited extent. In most cases, the feedback received was about the results and not about the rest of the report, such as the theoretical framework. The students mainly received tips and help about conducting a specific test, where to find information, and using software to collect data. They also mention that there was little or no guidance while writing the actual research report.

Student 2.1 said: Our supervisor mainly helped in making the test itself. If things went wrong, we would go to him to ask and in depicting the results properly.

Student 2.6 said: I think we only received comments on the execution of the tests. We did the writing of the report ourselves and their comments or tips were only about the execution of the tests.

Students struggle to identify which support they need. They do indicate getting stuck with certain functions in Word and Excel, such as inserting auto-numbering figures, displaying a formula, using an automatic table of contents, and drawing a correct graph.

Student 2.2 said: No, I didn't understand that [automatic table of contents], I did it manually. No also that header which then gets confused and then I have a different kind of header and then, that never goes well, then it takes a whole text with it, for example. I can't manage that. Yes, sometimes it just takes the text in the header, then I can't get it to normal size anymore. That takes a while.

The type of support the students would have in applying was grouped into five different categories by the authors: 1. Checklist; 2. Step-by-step instructions; 3. Online tutorial; 4. Manual; and 5. Feedback. An overview of the categories of needs is given in **Table 5**.

Table 5

Categories of needs obtained bottom-up from the focus groups with students (N = 7+7)

Category	Description	Quote	Number of students
1. Checklist	Indicates the need for an overview of what steps and components are needed.	"In advance, that there is a clear indication of what is or is not expected […]. A kind of checklist."	2
2. Step by step instructions	Refers to classroom step-by-step explanations and answering personal questions.	"I would just say: demonstrate, literally see the steps. Maybe teach it a few times in class."	8
3. Online tutorial	Refers to online tutorials at their own pace and own chosen time.	"Watch explanatory videos on YouTube."	5
4. Manual	Indicates the need for a manual.	"Just give a manual and practice a lot with it."	2
5. Feedback	Indicates the need for feedback during the process.	"Well, for me the stumbling block was mainly that I thought I was doing it right, and then you make the same mistake every time, so those feedback moments those are really important."	3

Eight out of 14 students indicate they need step-by-step explanations from the teacher, where onsite in-class explanations are preferred. They can apply many DRS but get stuck when using certain functions.

Student 1.4 said: Explaining WORD with those formulas. I don't really have any tips for that, but it's really very awkward. If you've put something in and then if you want to make it bigger or smaller, everything shifts again, it's very complex, because once you've put it in, if you then want to adjust it, other fonts come in and other sizes, nice and handy or something. I think almost everyone has to use those in physics.

Student 1.3 said: No, no manual, it's more convenient if you just see it from how to do it. I'd rather listen to the teacher than look at a booklet. (...) and then also just say right away that the figure numbering is demonstrated instead of it, that it's already done, before say.

Two students indicate they would like a checklist to know what is needed when to apply DRS correctly. Two students advise to give them a manual containing step by step instructions.

Also, three students indicate they would benefit more with feedback during the process.

Student 2.1 said: I think it's better anyway if someone really says to you: you need to know this instead of leaving it to yourself. Well, if someone gives feedback, it should help anyway, right?

Student 2.3 said: Yes, just all feedback is improvement, so even if you say of one sentence in your report, this is not right or write this differently, you remember that and can apply that next time, because it's not the last time you will write a research paper in your whole life. So, all feedback leads to development and I think that's crucial. Just, discuss it.

As an alternative for physical step by step instructions, five students indicate using online tutorials, such as explainer videos, in situations where they get stuck.

> *Student 2.3 said: An explanation video, because videos you can watch back in your own time and don't need a one-to-one moment either, but then you film yourself for 20 minutes explaining it and then 60 men can play it again.*

From here on, the six categories from the teacher focus groups and the five categories from the student focus groups are used together giving a grand total of 11 categories of needs.

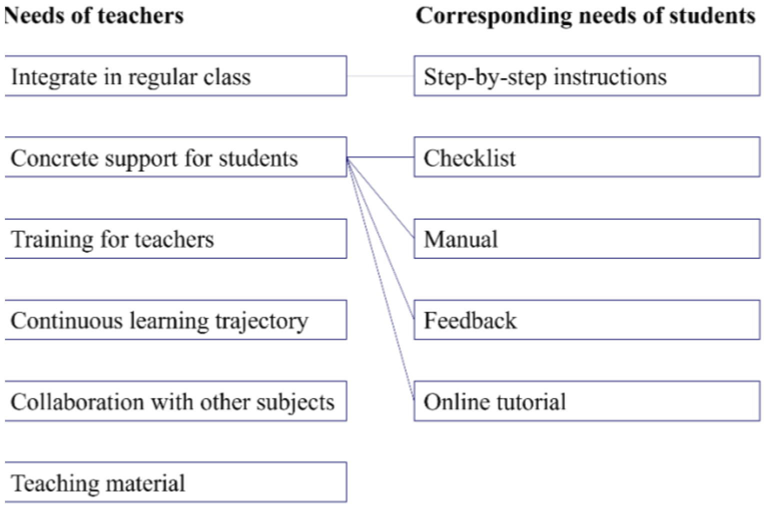
CONCLUSION AND DISCUSSION

Teachers' and students' needs

The needs expressed by students overlapped with several of the needs identified by teachers, see **Figure 3**. The quotes of the students are primarily focused on practical forms of support, such as checklists, online tutorials, and feedback moments. Teachers acknowledged these same concrete needs, but additionally considered overarching implications, such as integration in regular class practices and in continuous learning trajectories.

Figure 3

Needs of teachers, corresponding needs of students and scaffolding strategies. The lines indicate matches between the two sets of needs



For example, students' need for step-by-step instructions corresponds to the two scaffolding strategies, understanding concepts and clarifying characteristics, and students' need for a checklist aligns with scaffolding strategies to visualize concepts, structure tasks, and provide reminders.

Revisiting the research question

The research question of this study is: "What do students and teachers report regarding the support for developing digital research skills (DRS) in secondary STEM education?"

Based on Quintana et al.'s scaffolding strategies (2004) and the eleven categories of needs identified in our results (**Table 4** and **Table 5**), we formulated ten suggestions for supporting the development of DRS tailored to each scaffolding strategy. For instance, the strategy "visualize concepts" includes using conceptual diagrams and visual overviews, which aligns with the teachers' need for concrete support structures to outline necessary DRS and students' desire for checklists. This strategy also supports teachers by providing visual representations of DRS complexity levels and their applications, aiding in both assessment and physical explanations. Similarly, the strategy "understanding concepts" addressed the teachers' need for concrete support for students and teacher training, as well as students' desire for step-by-step instructions, an online tutorial, and a manual. From the perspective of the categories of needs, the category for teaching materials uses the scaffolding strategies 'understanding concepts,' 'use and apply content,' 'setting boundaries,' 'clarify characteristics,' 'indicate rationales,' and 'facilitate navigation.' This indicates that multiple categories of needs are appropriate for each scaffolding strategy and vice versa. On this basis, we formulated ten suggestions to meet the support needs of teachers and students in guiding and developing DRS in secondary (STEM) education:

For students:

1. Embed a comprehensive checklist with a rubric to provide an overview of necessary DRS.
2. In the rubric, include DRS tasks with increasing levels of complexity.
3. Provide step-by-step explanations for each DRS application, using a combination of text, images, and/or videos.

4. Include assignments with increasing levels of difficulty, content hints, and explanations of incorrect answers.
5. Use examples of common DRS mistakes and visualizations of pre-selected data to be improved.
6. Add a media library of new and existing instructional videos and other instructional materials.

For teachers:

7. Provide a visual representation of DRS complexity levels, the application of DRS, and the differences and similarities between digital skills, research skills, and DRS.
8. Include references to literature, case studies, and tips on cross-curricular integration of DRS into the curriculum.

In general:

9. Offer the possibility to monitor applications, the use of self-assessments, on-the-spot assistance, and reminders or real-time feedback mechanisms.
10. Ensure a user-friendly, accessible environment for easy navigation and quick access, and a logical categorization to help understand the hierarchy and relevance of different tasks.

The suggestions derived from our findings closely align with the examples mentioned in Quintana's (2004) framework. For example, our suggestion number 4: 'Include assignments with increasing levels of difficulty, content hints, and explanations of incorrect answers' corresponds to Quintana's scaffolding strategy 5a to 'Provide process hints in the form of explanations or information'. Similarly, our suggestion number 5: 'Use examples of common DRS mistakes and visualizations of pre-selected data to be improved', parallels the approach to 'Provide preselected data to examine' as mentioned in Quintana's scaffolding strategy 4a. These parallels demonstrate how our findings can be practically applied to support teachers and students in teaching and guiding digital research skills.

Furthermore, our findings reveal that while not all students and teachers indicate a need for DRS support, most of them stress the importance of incorporating DRS into lessons. Both teachers and students emphasize the significance of DRS in STEM education, but their specific needs differ. Teachers require better integration of DRS into the curriculum and lesson plans, along with training and teaching materials. In contrast, students seek more practical guidance through step-by-step instructions and feedback, whether in-class or online.

Limitations

As in any qualitative study, the relatively limited sample size of both teachers and students limits the generalisability of the findings. However, the method has been shown to lead to considerable depth of detail (Creswell & Poth, 2007). Even though the use of focus groups and semi-structured interviews is no guarantee to capture the full range of perspectives on DRS supervision and application, the approach does allow new insights to be brought up. Participants are invited to interact and give their views freely. By interviewing students and teachers in separate groups, we limit the occurrence of socially desirable answers by either group. Importantly, there was no power relation of any kind between the researcher and the participants. Also, second coding was satisfactory, giving confidence in the reliability of the coding process.

Several focus groups of differing composition were held, broadening the scope of the opinions. Given the inherent limitations of the method, we believe we have captured a comprehensive picture of students' and teachers' views on DRS and ways to support their development.

Implications

When transitioning from secondary to higher education, students often encounter challenges regarding specific, digital research skills (DRS), hindering their academic progress. The results of this study may contribute to bridging this gap in DRS, as described earlier (Blankendaal-Tran et al., 2023). It contributes to improving the quality of research reports in STEM education or secondary education in general. The teachers involved in this study represent diverse regions across the country, while the students come from typical schools with traditional backgrounds. This diversity supports the generalizability of our findings, suggesting that the proposed suggestions can be broadly applicable across different educational contexts.

We have demonstrated that DRS is important and that integrating DRS into lessons is not straightforward. Teachers need to discuss the importance of DRS and realize that integrating both concrete and abstract DRS can be done with relatively little effort.

With the ten suggestions, we aim to lower the threshold for teachers to emphasize DRS in existing assignments in the short term and in the long term to make DRS recurrent in assessment models and the curriculum from lower classes onwards. Concrete DRS could be addressed in the short term, and teaching abstract DRS requires repetition over a longer period of time. With the suggestions for DRS support, a support environment, where educators and institutions work together, can be developed to make this possible. Instead of DRS being tested only at the end of secondary education, this collaborative environment or tool may allow students to practice DRS on an individual basis with high flexibility and accessibility. Al Mamun et al. (2020, 2022) and Çinar and Arı (2019 described a positive implementation of online scaffolded learning modules to support students in inquiry-based learning environments. This approach can lead to a more effective and efficient learning experience as students receive step-by-step guidance and feedback at a self-selected time and teachers have access to adequate tools for assignments, feedback, and assessment. Gao et al. (2024) have compared online automated assessment systems to, for example, provide real-time textual and visual feedback during writing skills.

The suggestions for DRS support may also serve as guidelines for the development of educational technologies for students and instructional materials. Researchers and developers can use these guidelines to create effective and user-friendly tools, e.g., a dedicated website or app. Teachers will be provided with this effective type of support, allowing them to use their time more efficiently, reduce their workload, and focus on other important teaching tasks. Research on DRS extends the literature on teacher professional development and digital pedagogy. This may contribute to the development of DRS among teachers (Guillén-Gámez et al., 2020). With the concrete suggested components for DRS, textbook authors can also benefit. They can, for example, integrate the continuous learning trajectory on DRS into the exercises or incorporate DRS into the assessment model when creating assignments in their textbook.

Future study

To lay the foundation for effective support for digital research skills, it is crucial to understand the needs of both students and teachers. Based on our findings and suggestions, we recommend that the support to be an online environment where students, with different starting levels, can practice during class, allowing teachers to focus on other tasks. The online environment, in the form of a website, will serve as a freely accessible instructional manual, providing personalized step-by-step guidance on what is needed and how to perform the DRS.

An important step will be to analyse the extent to which students actually use the different suggested components in supporting DRS. These data will provide insight into where students struggle the most, where they often need help, and which methods they prefer for learning DRS. These insights will help educators to improve and customize a possible tool or environment. This method has been used, for example, by West (2012) and Fischer et al. (2020).

CONCLUSION

Digital research skills (DRS) are essential for students' STEM education. However, acquiring these skills does not occur automatically; targeted support is necessary.

In this study, we identified and systematically incorporated students' and teachers' needs for support in the guidance and application of DRS. The findings reveal a consensus on the importance of integrating DRS into lessons, despite different specific needs. Teachers emphasise the need for better integration of DRS into the curriculum, supported by appropriate tools and materials, while students express a preference for practical guidance, including step-by-step instructions and feedback. In essence, teachers focus on supporting both abstract and concrete DRS, whereas students are more concerned with effectively applying concrete DRS.

Drawing on Quintana et al.'s scaffolding strategies (2004) and our results, we propose ten tailored suggestions. These include checklists, rubrics, a media library for students, and visual representations and integration tips for teachers. These suggestions aim to address the specific needs of both groups, thereby enhancing support for DRS in secondary education.

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Ethical Statement

This study is approved by the Science-Geosciences Ethics Review Board (SG ERB) of Utrecht University (Approval number: Bèta L-20482). Written consent was obtained from all participants.

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this manuscript.

Author contributions

The corresponding author obtained and analyzed the data. The co-authors actively participated in the study and manuscript preparation. Additionally, they critically reviewed and revised the manuscript. All authors have read and approved the manuscript.

Data availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

AI disclosure

The authors declare that no generative artificial intelligence tools were used in the conception, analysis, or writing of this manuscript.

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