

# Guided process to enhance undergraduate engineering students' thesis work

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**Abstract—** This innovative practice paper examines the impact of structured guidance on students' thesis work process. Many engineering students focus on their professional future, and therefore do not understand the need to learn to research. Yet, the universities' strong emphasis on scientific research, and the need for new generations of researchers requires that research skills are embedded also in the engineering curricula even at undergraduate level. As many engineering students are reluctant to read and write, the development of their scientific literacy skills requires many kinds of support. This paper describes pedagogical interventions implemented in a mechanical engineering bachelor's thesis course to improve the quality of references of the theses and the completion of the thesis process in time. It also discusses the effects of systematic scaffolding of information literacy. Results show that the guided thesis process significantly improved the completion of bachelor's thesis in the given time frame. However, statistically significant improvement in the quality and quantity of cited references could not be observed. This indicates that adding teaching sessions on information retrieval, scientific referencing, and scientific writing is not sufficient without close connection to the actual thesis supervision process performed by faculty.

**Keywords—** *Information literacy, scientific literacy, guided thesis process, social scaffolding, mechanical engineering*

## I. INTRODUCTION

Finnish universities have a two-cycle degree system [1]. Undergraduate students in Finnish universities are required to complete a 180-credit bachelor's degree as an intermediate degree prior to a higher university qualification. To receive their bachelor's diploma, students complete a research project on a topic related to their academic program. This is part of the degree requirements because university education aims at providing students with the ability to perform scientific tasks.

According to literature, students who engage in undergraduate research experience better understanding of the scientific process [2]. However, carrying out an independent research process has proven to be challenging for undergraduate students with the task of formulating a research question being especially difficult [3]. Hence, there have been different initiatives to support students in their thesis work. Ferlin et al. [4] present a case where a graduation

thesis course was created to support students in computing science. The aim of the course was to consolidate program content and context to support students in a project reconciling theory and practice. A different approach to support students' thesis work is described by Koznov and Nemeshev [5] who emphasize the importance of guiding students especially in the writing process.

The authors of this paper have discovered that students who work on their thesis experience problems in keeping to the schedule, writing academic text, finding scientific source information, and even completing the work in general. Similar problems have been discussed by LaCourse and Rock [6] whose solution was to create an online course to support students' communication with the instructor. In our case, the created course is run by faculty and university support staff together and all teaching, support and guidance is given to students on a same course platform. The guided thesis process is divided into timed weekly lessons, which consist of lectures, web sites, presentations, and learning assignments addressing a specific topic.

The pedagogical idea of viewing teaching and learning as guided participation suggests that promoting the active engagement of individual learners is best achieved with adjusting the forms and levels of social scaffolding according to the needs of the learner [7]. The levels of scaffolding evolve from very concrete hand-over-hand guidance to mere encouragement without specific instruction by gradually reducing the strength and direction of the support. The seven levels of scaffolding as suggested by Mascolo are illustrated in Table 1 with examples relating to the support of scientific literacy.

TABLE 1. ILLUSTRATION OF SCAFFOLDING ACTIVITIES FOR SUPPORTING THE ENGINEERING STUDENTS' INFORMATION LITERACY SKILLS; DESCRIPTION OF LEVELS ADOPTED FROM MASCOLO [7] TABLE 1.

Type of Scaffolding	Example
<b>1. Encourage/Prompt.</b> Expert provides encouragement, prompts, reminders, or praise without specific direction or instruction.	Thesis supervisor reminds student about the need for referencing in scientific texts.
<b>2. Sequential Direction-and-Independent-Action.</b> Expert explains concepts or models target operations. Afterward, novice performs task without further assistance or support from the expert during student's execution.	Information specialists lectures the students about the general principles of information retrieval.
<b>3. Asymmetrical Assistance.</b> Expert supports novice's action by breaking down the task, performing part of the task or otherwise providing support so that the novice can complete the rest of the task.	Students complete an information retrieval and reference writing task, which consists of different phases.
<b>4. Distancing.</b> Expert creates cognitive demand on novice, motivating constructive action in a particular direction (e.g. requests for evaluations, inferences, comparisons, open-ended questions, probes and Socratic dialogue)	Thesis supervisor checks student's reference list and gives feedback (i.e. asks to pay special attention to certain issues)
<b>5. Direction.</b> Expert provides explicit and specific directions about how to perform an action or procedure, or explains to-be-acquired meanings as in lecture.	Information specialist explains in detail, how to conduct a literature research using certain tools and systems.
<b>6. Concurrent Direction for Student Action.</b> Expert provides direction and guidance while the student is in the process of performing a given task. Student adjusts action concurrently to expert's guidance.	Students complete information retrieval tasks simultaneously with the information specialist.
<b>7. Concurrent Physical Guidance for Student Action.</b> Expert uses hand-over-hand guidance, physical contact or highly directive gestures to direct a student's attention or actions.	Supervisor/expert guides a single student in adding information in the reference list by telling the student bit by bit what to write next.

In the university environment, teaching typically provides scaffolding and support at a rather low level as the students are expected to already master several things and quite general prompting and modelling of activities is thought to be sufficient. Especially if the academic librarian resources are scarce and the supervisors think that teaching writing is not their task [8] there is a danger that the level of support the students get is too low compared to what they would need. Although the highest levels of support may not be needed and are difficult to accomplish due to the lack of resources, especially the middle levels (3-5) might prove to be beneficial for the development of students' information literacy skills.

In engineering education, many students focus on their professional future, and therefore they do not understand the need to learn to research. Their goal is to become a professional engineer, not an academic [9]. However, universities have a strong emphasis on doing scientific research and graduates are supposed to be able to have gained necessary research skills during their studies. Therefore, research skills are embedded in the university curricula even at undergraduate level.

All research is based on previous findings. Therefore, to success in their work, researchers need to be able to find proper scientific literature. In their studies prior to university, students may have used solely open internet sources. To provide them with indispensable information searching, using, and evaluation skills, they need to participate in information literacy (IL) education. Universities have

different IL education practices. IL instruction is most often given by academic librarians either as separate IL courses or embedded in faculty courses [10].

The effectiveness of information literacy instruction for undergraduate engineering students was studied in a systematic literature review [11]. One of their key findings confirmed librarian-faculty cooperation to have a positive impact on the effectiveness of the information literacy instruction. According to Phillips et al., in embedded IL education the ties to the class content were clearer and the information literacy topics had more context. Moreover, the strongest indicator of IL instruction effectiveness that emerged in the literature review data was collaboration with disciplinary faculty. [11]

#### *Supporting scientific writing in mechanical engineering bachelor's thesis course*

Before 2020, the bachelor's thesis course for Mechanical Engineering students, where students learned the basics of academic researching and completed their thesis, included three lectures and individual quizzes related to the lectures. The first lecture discussed cornerstones of scientific research and the structure of the research report, the second was titled Research methods and reliability of research, and the third covered Retrieval and use of information. At the end of the course, students recorded a three-minute 'elevator pitch' on the topic and published it on the learning platform. Students' supervisors gave support for technical aspects of the thesis, but support for writing was not at a satisfactory level. This led to a situation where many students could not complete their thesis within six months, which is the time when the thesis should have been finished after the topic had been approved and the student's supervisor had been appointed. For some students, it took over twice the prescribed time. Extended working times caused problems for the supervisors who were tied up with guiding students sometimes all year round.

LUT University's electrical engineering students have been noted to be rather reluctant to read and write [12], and it is likely that mechanical engineering students are not any different. In general, students prefer preprocessed teaching material like lectures and lecture notes to finding information in textbooks or scientific articles (ibid.). A study on the academic literacy skills of the electrical engineering doctoral students showed that enhancing the writing skills of doctoral students requires attention paid to the issue already in the earlier stages of engineering education and more systematic scaffolding to support the development of the literacy skills. [13]

To solve the problem of students' theses not being completed on time, the faculty decided to redesign the bachelor's thesis course to guide students more efficiently in their thesis process. The designing principles directing the changes to the course in question were that it should save supervisors' time resources, make students keep to the schedule, and improve the coherence of guidance by different scaffolding activities, such as information literacy (IL) education, to the curriculum. All instructions were to be given to the entire group of students at the same time and all students were supposed to complete the weekly tasks by due dates. It was also imperative that all texts which students wrote could be used as part of the final thesis. To save the

supervisors' time and work, students were given six months to finish their thesis work after the topic had been approved.

The improved bachelor's thesis course was implemented for the first time in autumn 2020. Because of the Covid-19 pandemic, the course was designed to be completely online. It consisted of lectures, exercises, and workshops, which prompted the student directly to produce text for the thesis. The content of the bachelor's thesis course is presented in Table 2. The learning objectives of the course covered understanding the nature of scientific inquiry and implementing systematic work during the process. Moreover, students were expected to learn the key research methods for analyzing the available data. To acquire relevant and reliable source information, students learned to use the available scientific databases and the library information portal. An important part of the course was also learning to write a research report according to the IMRAD structure. [14]

According to the principles of the course, information literacy instruction was included in the content to promote students' thesis work. The instruction was performed in three parts. The first part consisted of a lecture on the information literacy mindset [10], the theory of information retrieval, and learning to use the University library search portal and the user interfaces of the most important databases in the students' field of science. These can be considered level two scaffolding, where an expert explains concepts or models target operations. The second part dealt with adopting theoretical knowledge into students' own searching by performing searches on their topic individually. Students reported their information retrieval results to the IL instructors. This counts as level three scaffolding, where an expert supports the novices by breaking down the task and helping with the execution, if needed. The third part was a workshop where information retrieval and using references were discussed in detail. The workshop enabled scaffolding in levels five to seven, where students could get concrete hands-on advice to their individual questions and tasks.

TABLE 2. WEEKLY CONTENT OF THE GUIDED BACHELOR'S THESIS COURSE

Before course	Pre-assignment – questions about completed studies and plans for graduation time
Week 1	Introduction to course – presentation of course assignments and thesis topics
Week 2	Selecting topics and appointing supervisors Lectures 1 and 2. The topic, aim and significance of the thesis, research problem and questions
Week 3	Lecture 3. Research plan Discussion about topic with advisor, Teams meeting
Week 4	Lecture 4. The structure of the thesis Teams meeting with advisor about assignments 1 and 2 (aim and significance of thesis, research problem and research questions)
Week 5	Lecture 5. Methodology and reliability Lecture 6. Information literacy and information retrieval
Week 6	Individual searching for references Discussion about assignments 3, 4 and 5 (index, research plan, methodology & reliability) with advisor
Week 7	Information retrieval workshop, Zoom meeting
Week 8	free
Week 9	Lecture 7. Compiling results Lecture 8. Layout and references
Week 10	Advisors' set appointments in Teams
Week 11	Advisors' set appointments in Teams Lecture 9. Studies after bachelor's graduation
Week 12	Advisors' set appointments in Teams
Week 13	Discussions about assignment 6 (compiling results)

Weeks 14 and 15	Final discussions: student, advisor, supervisor
Week 16	Layout and plagiarism check

In the guided thesis course, the major change in IL education was that the connection of the research problem with the information retrieval process was emphasized instead of just teaching the techniques to use the available information sources like it had been done before. The goal of information retrieval is to find answers to the research questions. Therefore, prior to doing their individual information retrieval task, students were advised to define their research problem and the research questions to which they needed to find answers. To find those answers, students were then advised to formulate information search questions on which their information retrieval would be based.

The search technique instruction is essential and was presented from the viewpoint of the search engines. Firstly, search words have no semantic meaning to the search engines but are only chains of characters, which the system looks for in the text mass. Secondly, all search tool operations follow the principle of seeking character chains whether it is using truncated words, phrases, or words at a certain distance from each other. Thirdly, the searched character chains can appear in different fields of the data record and the searcher's responsibility is to define where the chain should be.

During the two-week period between the IL lesson and the workshop, students performed information searches individually on their topic, wrote a report about their search experience, and listed retrieved references. To help them in their work, they received the first lecture content as online material -- video and slides -- and instructions on how to cite by using reference management software. The reports were studied by the instructors and the findings were used in designing the contents of the workshop. The reports showed e.g., if there were shortcomings in students' ability to describe their research problem and if they had problems in turning the problem into relevant and efficient information searching. Moreover, the IL instructors examined the reference lists to see that they were written according to the Harvard referencing style.

In the workshop, students received oral feedback about their search reports. They were taught how they could improve their searches and use search tools more efficiently to get better search results. Citing referred documents is often a challenge to students. Therefore, repetition of the use of the reference management system was included in the workshop agenda.

## II. METHODS

This paper aims to answer the following questions: Does supporting students' research process systematically improve the quality of referred literature in research reports? Can students complete their bachelor's thesis within the scheduled time if the research process is systematically supported?

The performance of two student groups was studied. A student group that did their work in 2019 when there was no systematic support was compared with the 2021 group, which attended the systematic support course.

Information literacy performance was evaluated by performing a bibliometric cited reference analysis [15] of reference lists. The reference types of cited references in

students' final theses were analyzed by using a seven-category frame:

1. Academic journal article
2. Conference proceedings
3. Web site
4. Book / book chapter / handbook / research report / EU document / law / patent / statistics
5. Thesis
6. Standard
7. Other (e.g. interview, non-scholarly publication)

The frame was based on the results of earlier research [16], where the effects of IL instruction were studied in comparable student groups. The original frame did not include the Standard category. It was added because standards are an important form of information in mechanical engineering.

The analyses were verified by researcher triangulation. First the information literacy instructor, an academic librarian, coded the listed references using the above-mentioned classification. The coding was validated by a researcher who coded a random sample of reference lists. The coding was compared, and different views were discussed to make the two views congruent. Finally, the academic librarian re-coded all reference lists according to the congruent procedure.

The changes in thesis completing times were calculated by comparing the starting and finishing dates of the thesis work. Starting date is the date when the student started the course and finishing date is the date when the student uploaded the thesis to the publication repository of the University. The students could submit their thesis to the repository at the earliest after the final discussions were held (week 14).

### III. RESULTS

Results indicate that after implementing the guided thesis process, a significantly greater number of students completed their thesis work within the set time frame. The cited reference analysis did not reveal statistically significant differences in the quality and quantity of cited references between the student group, which attended structured thesis process guidance and the reference group, which did not have structured guidance. This is in line with prior literature and indicates that including teaching sessions on information retrieval, scientific referencing, and scientific writing is not very effective without close connection to the actual thesis supervision process performed by faculty. [11]

One of the main problems with the unguided thesis work was that students were unable to complete their final theses within the prescribed time. When the average working times were combined before and after the implementation of guided thesis process, it was evident that a great deal of that problem was solved. Before starting the guided thesis process, effective thesis writing time was between 14-40 weeks, the average being 27 weeks, while in case of the guided process the average time decreased to 22 weeks and writing times varied from 14 weeks to 27 weeks. The fastest students finished their theses in 14 weeks which was the duration of the course and the shortest possible time. In Fig. 1 the

effective writing times for the two studied student groups are presented.

Reference lists in students' final theses were analyzed by using the previously mentioned frame and the coding was verified by peer reviewing. There were 34 final theses returned in 2019 student group while the number of completed theses in the 2021 group was 35. The required number of referred sources in the thesis was not specified. Therefore, there were remarkable differences in the number of cited references in the analyzed theses. In the 2019 group, the number of references in individual works varied from 3 to 84 and in the 2021 group from 5 to 36. Therefore, the absolute numerical values of referred documents are not presented here but the average percentages of each reference type are presented in the table. The results of 2019 and 2021 final theses are compared in Table 3.

TABLE 3. REFERENCE TYPES (%/YEAR) IN FINAL THESES.

Reference type % / Year	2019	2021
Journal article	19	23
Conference	4	4
Web site	27	26
Book etc.	34	31
Thesis	1	1
Standard	5	6
Other	8	9

Students searched for references individually after attending IL instruction given by an academic librarian and studying the online learning material. Both the academic librarian's lecture and the online learning material focused strongly on finding scientific source material on their topic. Students reported their search results after the individual working period. In 2019, they were assigned to draft a short report about their research problem, research questions, where they completed the search, and what search terms they had used. They also listed retrieved references. Quality wise the reports varied considerably. It was challenging to evaluate how they succeeded in their task because not all of them answered all questions and many of the reports were vague in general. Therefore, to get comparable reports of students' individual information searching, this part was modified in 2021. Instead of writing a single document, students were made to give their answers to the same questions as before but this time into text boxes in the learning platform. The first task was to describe their research problem and present their search terms. Then, from a given list, they selected information sources which they had used. In the third section, they explained if they used a reference management tool or cited manually, and in the last text box they listed retrieved sources. The distribution of percentages of reference types in the individual search assignments is presented in Table 4.

TABLE 4. REFERENCE TYPES %/YEAR IN INDIVIDUAL SEARCH ASSIGNMENT.

Reference type % / Year	2019	2022
Journal article	45	47
Conference	3	7
Web site	3	4
Book etc.	40	36
Thesis	4	5
Standard	4	0
Other	0	1

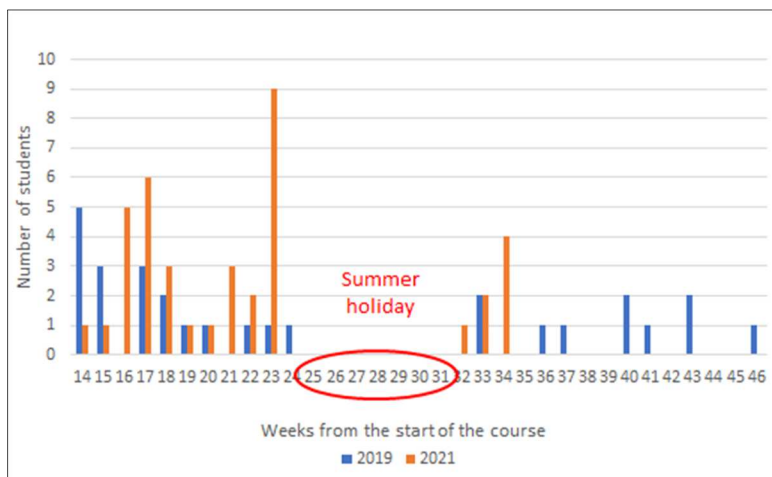


Fig 1. Thesis finishing times (weeks from the start of the course) of the students before guided thesis process (2019) and after guided thesis process (2021).

Before implementing the systematically guided thesis process, students who worked on their bachelor's thesis had attended an information search lecture given by the academic librarian. Therefore, the students of the 2019 group were familiar with the available search tools. The guided process did not cause a significant difference in the distribution of presented information sources in the individual search assignment. However, when the results of the individual search assignment and the analysis of the final theses were compared, the percentages of journal articles in the individual work reports were twice as high in comparison with the final theses. Alternatively, in the final theses the percentage of cited web sites was ten times the share of web sites in the individual work reports. The percentage of books, book sections, reports etc. was high in both cases but somewhat higher in the individual search assignment reports.

Although the individual search assignment reference analysis did not show any notable changes in the shares of reference types, the evaluation of structured answers made the supervisors work less laborious. The data could be exported to a spreadsheet where it was easier to analyze it. Moreover, the answers were better comparable compared with essay-type answers because students answered all questions.

According to general feedback, students felt that the guided thesis process helped them to keep to the set time frame which could be verified from the teachers' documents. The lectures and exercises about thesis writing and guided literature search were perceived to be somewhat useful whereas conversations with teachers and individual feedback from them were rated very helpful.

#### IV. DISCUSSION

Results show that the guided thesis process significantly improved the completion of bachelor's thesis in the given time frame. However, statistically significant improvement in the quality and quantity of cited references could not be observed. The used research method cannot detect changes in the use of references in the text and this issue needs further investigation. Further research is needed to study other aspects of the quality of the theses as well as the interplay between the systematic support provided by the course advisors and the personal guidance provided by the thesis supervisors.

It is apparent that students learn to find scientific sources when attending IL instruction. Why is the share of academic sources lower in the final theses than in the individual information search reports which are written as part of IL instruction? It can be presumed that in the individual search assignment, student focus on themes which have been covered in IL education. Depending on the characters of their final thesis topics, there may not be scientific documents which would meet their practical information needs.

To help students in understanding the scientific level of their source literature, a self-evaluation of the bibliography could be worthwhile to include in the course after they have finished writing the literature review of the thesis. Moreover, when students act as the opponents of their peers, they should be advised to pay attention to the cited literature and its academic level.

Writing academic text appears to be challenging to some students. The University provides students with a template for thesis writing and, in the template, there are instructions on how to cite different forms of literature. Nevertheless, the information in students' reference lists is often incomplete both in the individual search assignment and in the final theses. Moreover, the texts sometimes lack scientific writing style. Therefore, the guided thesis process could be improved by connecting the available Academic writing course with the bachelor's thesis course as an integral part of it. Students could then write academic texts under the supervision of language teachers and thus produce higher quality theses.

Young students need a great deal of support when they work on their first individual research task. Online support appears to be useful but according to student feedback, personal communication with faculty is imperative. Therefore, we can conclude that if this hybrid kind of guided thesis process is implemented it should include plenty of personal students' communication with faculty.

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