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Research Paper

Challenges in capstone project supervision by academic faculty: A case study

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Abstract. Supervision of capstone projects in engineering programs is an interdisciplinary challenge, for both students and Faculty. The project considered the highlight of the undergraduate program, summarizes all the knowledge students have accumulated throughout their studies and aims to train them for the challenges of graduate engineers. Although the project is usually perceived as leading to successful products and learning outcomes, pedagogical disparities are emerging, emphasizing a deep need for change. This study examines the essence of capstone supervision in Mechanical Engineering, the faculty's role within it, and stakeholders' perception, using questionnaires, semi-structured interviews, participant observation, and analysis of primary sources. The study reveals that in contrast to the significance of supervision found to stakeholders, Faculty are under considerable pressure and perceive the significance of supervision as low, and as a time-consuming task, without proper compensation. The current processes show significant pedagogical disparities and limitations, resulting in low interest from academic supervisors. In addition, the academic institution was found to have dissatisfaction with the faculty's supervision, even though there are no clear definitions or guiding methods for the supervisors. Accordingly, academic institutions must create greater motivation, interest, and compensation among Faculty. It is necessary to reduce the load on supervisors and to foster independent functioning by students. Effective supervision is essential for success and student development, which requires a deep need for proper preparation and training Faculty to be supervisors. Desired learning outcomes should be updated in order to optimally prepare the students for their future role, and maintain the relevance of academic institutions.

Keywords: Capstone project supervision, final project in engineering, supervisor-lecturer, engineering education, engineering faculty, instructional methods (syn: pedagogy), faculty training.

INTRODUCTION

In the last decade, academic institutions have developed many different initiatives offering courses that integrate practical experience in engineering programs. The aim is to adapt academic teaching and learning processes to the modern employment world and to increase graduates' relevance to the workplace. This adaptation is critical and vital for academic institutions, faculty members and students, in order to remain relevant and influential (González and Calderón, 2018; Umachandran *et al.*, 2019).

In many academic institutions, the capstone project in engineering is perceived as the highlight of the undergraduate program. The project intended to summarize all the knowledge acquired by students (up to the stage they are at), train them for the challenges of engineering, and facilitate a natural transition to the professional world (Shacham and Davidovitch, 2010; Hauhart and Grahe, 2015; Howe and Goldberg, 2019). In light of the Industry 4.0 changes and processes led by leaders of the higher education system, a fundamental transformation could have been expected over the years in the capstone project as well, however despite its central role in training, the project and the supervision process, commonly carried out by academic lecturers, have remained nearly unchanged for decades (Hauhart and Grahe, 2015; Shurin *et al*., 2019). In order for academia to remain relevant, it must be pedagogically adapted to the changes of Industry 4.0, such that graduates who choose to turn to industry will be capable of dealing with the technological transitions and their impact (González and Calderón, 2018; Umachandran *et al.*, 2019). This necessary adaptation is also strongly linked to the current tasks of academic institutions.

The current study examines the supervision of the capstone project and the role of academic faculty as supervisors of undergraduate projects, in a case study conducted in the Department of Mechanical Engineering (ME) at Shamoon College of Engineering. At the academic college selected for the study, there is a strong emphasis on teaching methods such as project-based learning (PmBL), and in recent years, about 95% of the department's graduates have joined the positions of Mechanical Engineers in industry. The capstone project and the supervision in this college have very similar characteristics in a few other universities in Israel as well as in the US and Australia. The college is well-known and is the largest college in Israel for engineering studies, with about 6,500 students, and two campuses where engineering subjects are studied for the bachelor's and master's degrees. The graduates of the college make up about 15% of the engineers in Israel.

The study aims to reveal disparities in capstone project supervision by faculty, including disparities in supervision definitions, faculty roles, supervision sessions and different stakeholders' perceptions. The study consisted of mixed methods, combining quantitative and qualitative methods. Combining these two very different methodologies gave a complete picture of the researched topic, and strengthened the reliability and validity of the research, especially in light of the fact that one of the researchers holds a role in the organization researched by him. The study uses several research tools such as Questionnaires for students during their capstone project; Semi-structured interviews with key figures and stakeholders; Participant observation of academic faculty, and more. The purpose of the study was to identify how faculty members and students perceive the supervision, the supervision sessions, and their contribution to the development process.

THEORETICAL FRAMEWORK AND LITERATURE REVIEW

The perception of teaching in an era of industrialization and computerization

In recent years, the boundaries between the physical and digital worlds have become blurred, following the integration of new technologies and the transition to a digital world (Shwab, 2016). As a result, new technological and human knowledge is expanding and becoming accessible to anyone interested. The development of academic programs has undergone many changes, not the least of which is the transition from imparting higher education as a goal, where the main value is expanding knowledge, inquiry, and exploration – to imparting professions and education as a means, with an emphasis on technological studies and utilitarian-applied science (Shacham and Davidovitch, 2010).

The role of academic faculty in training engineers

Academic faculty members accompany students throughout their undergraduate academic training and impart those tools and knowledge for about 4 years, using an array of pedagogical methods and tools, such as feedforward, which helps to improve student learning, points to future work, and helps more effective feedback (Orsmond *et al.*, 2013). Although the "traditional" face-to-face method is still very common, in recent years there is an increasing demand that academic faculty function as leaders, outlining and accompanying learning in groups using other teaching methods (Bentur *et al.*, 2019; CHE, 2019). Academic faculty are expected to be less oriented toward conveying knowledge, rather creating discussions and reinforcing students' self-learning, and challenging students to think which can also reduce the load on the academic faculty (Goldberg *et al.*, 2014; Akili, 2011).

This portrayal of faculty members is manifested primarily in the problem/project-based learning method (PmBL/PtBL), where students discover knowledge independently, and learning takes place in a process of developing and designing products and/or processes. Although the method principles are similar in different places, there is really no PmBL/ PtBL approach that fits all institutions, and the application of the method may look a little different in each one (Fisk, 2017). In this method, lecturers that serve as supervisors and experts, ask the students questions and help them get through the various stages of the process (Hmelo-Silver, 2004; Todd *et al.*, 1993). The method, which is also compatible with the STEM (Science, Technology, Engineering and Mathematics) approach, has been found over the years to be beneficial for learning, provides a multidisciplinary practical experience of the theoretical material, and is appropriate for the contemporary period, has shown to increase student involvement and motivation to learn and to facilitate the development of several skills such as cognitive flexibility, creativity, independent learning capacity, entrepreneurship, and integration of different disciplines, while connecting contents to reality (Hmelo-Silver, 2004; Davidovitch and Shiller, 2016; Moon-Soo, 2015; Munakata and Vaidya, 2015; Hotaling *et al.*, 2013; Zaher and Damaj, 2018; Breiner, 2012).

The capstone project

The capstone project is the most conspicuous PmBL/PtBL project, and it is considered the highlight of the undergraduate program in engineering. During the 1980s and 1990s, there was a sharp rise in the popularity of the project, and in recent years this project is offered or required by more than two-thirds of academic institutions (Hauhart and Grahe, 2015). The project has a double function, serving both for learning new content and for examining students using tools accumulated during their studies. Students are given a relatively high number of credits for completing the project, and considerable efforts are required from the students, the department, and the academic institution, with regard to logistics, time, and resources (Shacham and Davidovitch, 2010).

In many cases the project includes the development of a product or a process, and its main aims are increasing students' learning output, causing them to experience a process of product development or a real process and training them for the challenges they will encounter as graduate engineers (Shacham and Davidovitch, 2010; Hauhart and Grahe, 2015; Howe and Goldberg, 2019; Hotaling *et al.*, 2013; Núñez *et al*., 2017). In a recent study, all stakeholders perceived the project as fundamental for training and students even perceived it as more important than any other theoretical paper or course in their studies (Shurin *et al.*, 2020). The project is also important for the academic institution itself, as a road mark for young students, a concluding act, imparting a sense of efficacy to students, and a tool for attracting candidates. Accordingly, academic institutions have a unique opportunity to utilize the project, to impart the most significant learning outputs and skills, and to use it as a tool for reducing the gap between achievements in academia and industry with its varying needs (Shurin *et al.*, 2020).

Supervising the project

The project topics are proposed by the department, the students, or the supervisors themselves upon their fields of interest. The students' work in the project is often done in teams but can also be done individually. Supervision is usually provided by a single lecturer but sometimes a pair of lecturers do so jointly. Moreover, sometimes projects are also supervised by external lecturers, industry figures or external counselors. They supervise projects in their professional field, usually in topics on which the external supervisor is a content expert. These external supervisors operate in an independent framework, related to their workplace. Although the external supervisor is very knowledgeable about the specific issues he deals with, he usually does not know all the department's procedures, and therefore it is mandatory that in such a case, an academic supervisor is added to the supervision as well, who knows the department's requirements. The initial contact with industry supervisors can be made at the request of the department, or through the student, based on familiarity or content expertise (usually as part of his or her work). In this case, it requires the approval of the department. Most often, industry supervisors take part in supervising a capstone project with no real reward or only a symbolic reward.

The academic supervisor is the main link between the student and the institution during the project and usually serves as an examiner of the students' functioning versus the requirements and definitions set by the department and institution. The supervisor is responsible for directing the student in writing the report, checking it, and ensuring that the project and the report are on a proper academic level and that the project's grade reflects the student's academic level. The institution must prepare guidelines for project execution, both for the students and for the supervisors, with a clear definition of the latter's role (CHE, 2012). Advising sessions usually take place once every week or two, as required by the supervisor and by the department procedures. Academic supervisors guide the projects as part of their role definition. Sometimes, if supervise more projects than required, they will receive additional financial rewards. Despite the supervisor's accompaniment, navigating the milestones of the development process is the student's responsibility.

During the process, the students mainly utilize independent work and information received from the supervisor, who follows the students' progress, accompanies the development process, confirms the design, reads reports, checks feasibility and calculations, and constitutes a main factor in the evaluation and in grading the project.

Disparities in the capstone project

Real and clear learning outcomes or pedagogical aims are most often missing for both students and faculty, as well as clear criteria for assessing a successful project, and definition of the capabilities to be achieved through the project. One of the main aims of the capstone project is to prepare students for Industry, but it is apparent that this goal suffers from a lack of clarity regarding its interpretation and translation into action (CHE, 2012). Moreover, following Industry 4.0 changes, an essential transformation is expected in the project's structure and outcomes. However, there is often a lack of dynamism in the project, and over the years it has become a "traditional" act, where the process and methodology of the project and its supervision have remained unchanging over generations, in contrast to the surrounding shifts, and no innovative added value is obtained compared to projects carried out decades ago (Shurin *et al.*, 2019; CHE, 2012).

This type of project involves a great deal of frustration. Some academic supervisors have no background in the industry or familiarity with current processes and changes in the industry, and there is even a lack of professional expertise by the faculty on certain topics (CHE, 2012; Upson-Saia, 2013). In this type of project, academic supervisors move constantly between their role as a lecturer and their role as examiners and evaluators of the student's progress and work processes. The supervisors' involvement differs by their personal preferences and capabilities and by the project type or theme. Although the project indeed presents most students with new situations (Shurin *et al.*, 2020), more "mature" students will have a more independent approach to the development process and will need only minimal supervision (Shacham and Davidovitch, 2010), which means not all projects require the same supervision and the supervisor must adapt himself to each project.

Similar capstone projects exist in different disciplines, and despite the differences, it is also possible to detect similarities in the work performed and in the various problems that arise. Sometimes students have little motivation or are offered limited time for assistance by the department. Moreover, the pressures applied during the project do not allow students to reach proper learning outputs, and some academic staff even recommend canceling the project (Upson-Saia, 2013; Saar, 2011). At the same time, researchers argue that the problems originate with the project rather than with the students or the department resources (Upson-Saia, 2013).

RESEARCH METHOD

The paper examines the supervision of the capstone project and the role of academic faculty as supervisors of undergraduate projects, aiming to answer several major questions:

1. How do academic faculty who serve as supervisors perceive the supervision and their role?
2. How do the academic institution and the students perceive the supervision?
3. How proficient are the supervisors in performing their role?
4. To what degree do the supervision process and sessions contribute to the development of the project?

This case study is part of a more extensive study on the capstone project in engineering. The study combines quantitative and qualitative methods and focuses on departments of Mechanical Engineering where capstone projects are conducted every year, the large majority of them in the domain of product development.

Research tools

1. Questionnaires – the questionnaire consisted of 14 questions on several topics related to the capstone project. In this case study the research focused only on topics related to the supervision of the capstone project, perceptions of the supervision process, and the role of the supervisor. The questionnaire was administered to 80 students in their senior year of studies, during the process of carrying out their capstone project (about 40 teams). The questionnaire was administered through Google Forms and the participants were not compensated. The students were asked to provide their replies on a scale of 1 to 5 (Likert scale), where 1 is very little and 5 is very much.
2. Semi-structured interviews with academic faculty members and graduates. Each interview took about 30 minutes and was conducted as a peer dialogue. The interviewees' anonymity was maintained at their request. A total of 20 interviews were held, including 2 deans and 3 department heads. The interviewees were selected by their position in academia, Seniority and experience; graduates were selected by the capstone project performed during their studies and by their current place of work.
3. Participant observation of capstone project supervision and observations of academic faculty engaged in providing supervision. In addition, participation in panels, exhibitions, project conclusion conferences, and others.
4. Analysis of primary sources – documents from Israel's Council for Higher Education and documents from the Department of Mechanical Engineering at the Shamoon College of Engineering (CHE, 2012; SCE, 2018).

The research took about a year, during which the semi-structured interviews and questionnaires were carried out. The students were in the fourth and final year of their studies. The ordinal data is analyzed by Spearman's correlation coefficient and Kendall's tau-b correlation coefficient, which are nonparametric indices of stratification that measure the association between two variables based on their ranking. The research questions were based mainly on questionnaires in two main studies: the questionnaire conducted by Shacham and Davidovich (2010), and the questionnaire conducted by Heller-Hayun *et al.* (2011). From the Shacham and Davidovich questionnaire, questions were examined regarding the perception of the project, students' satisfaction with the supervision, and perception of skills imparted during the project. From Heller-Hayun *et al.* questionnaires, issues were examined such as supervision, project contribution to processes and challenges in engineering work, exposure to new skills, the importance of the project in engineering training, and knowledge gaps between Academia and Industry.

Uniqueness of the study

Many studies have investigated engineering programs, but few focused on the supervision of the capstone project in

Table 1. Statistical data from the questionnaire responses.

Q	Min	Max	Mean	Median	SD
2	1	5	3.846	4	0.904
3	1	5	4.315	5	0.933
4	1	5	4.263	4	0.890
5	1	5	3.71	4	1.088
6	1	5	4.052	4.5	1.137
7	1	5	3.868	4	1.143
8	1	5	3.868	4	1.143
9	2	5	4.131	4	0.875
10	1	5	2.789	3	1.297
11	1	5	2.868	3	1.189
12	1	5	2.078	1.5	1.343
13	2	5	4.526	5	0.761
14	1	5	3.473	4	1.083
15	1	5	3.421	4	1.328

Source: Shurin *et al.* (2020).

engineering and on the academic faculty's task. Moreover, this study examined all stakeholders related to the project. In addition, previous studies usually explored the perspective of graduates, but this study also examines how students are currently engaged in performing the project and perceive the role of the supervisor.

RESEARCH FINDINGS

Results of student questionnaires

This study is part of a more extensive study on capstone projects in engineering programs. The current study focused on the aspect of supervision by academic faculty, its perception and its impact. All the respondents who completed the questionnaire were students (85% men and 15% women) at a college of engineering. The mean age was about 28.96% of the respondents who carried out the project in teams. The general reliability of the questionnaire is α = 0.81 (Table 1).

The results of the questionnaire analysis show that the students relate to supervision as a meaningful and important factor that contributes to the development process, where some 70% indicated that supervision is highly to very highly helpful for them. About 65% of the responding students indicated that the supervision sessions are held in an organized and clear manner. More than 60% of the students claimed that the project allows them to learn about additional aspects rather than only the "traditional" areas of engineering, at a high to a very high degree.

As evident from Tables 2 and 3, correlations were found between the contribution of the supervision and improving independent learning, as well as perceptions regarding the contribution of the project to one's studies, such that the more the supervision contributes to the process, the more the student perceives the capstone project differently than any other undergraduate course. This means that the supervisor and the supervision process have a meaningful role in the student's perceptions of the project (Tables 2 and 3; Appendix B. items 2, 6.).

A strong correlation was found between organized and clear sessions and the contribution of the supervision to the project (Tables 2 and 3; Appendix B. items 6, 7). Furthermore, constant and organized sessions involving the supervisor and student have a meaningful impact on students' perceptions and it is evident that the more organized and clear the sessions are (where the frequency is known and the structure is clear), the more the students feel that the development process is clear and feel less "lost" in the process (Tables 2 and 3; Appendix B. items, 7, 8; 7, 11). Moreover, the study hypothesized that a strong negative correlation would be found between item 6 and item 10, which deal with the concept of wasting time if the supervision is not helpful, and though a negative correlation was found (-0.36), it is not sufficiently strong to indicate a compelling association between these issues. In addition, no association was found between the contribution of supervising and learning new things by students in the process (in contrast to findings about independent learning). This may indicate that learning new things is necessarily derived directly from the supervisor, rather than from the students themselves or other elements (Tables 2 and 3; Appendix B. items 3, 6).

Additional findings

Multiple tasks of faculty in academia

The lecturers have many tasks that must be managed

Table 2. Spearman's rho Correlation Coefficient (from Shurin *et al.*, 2020).

	Q		2	3	4	5	6	7	8	9	10	11	12	13	14	15
Spearman's rho	2	Correlation coefficient	1.000	.357*	.607**	.357*	.457**	.480**	.447**	.709**	-.474**	-0.274	-0.269	-0.023	.573**	.450**
	3	Correlation coefficient	.357*	1.000	.512**	0.309	0.065	0.133	0.306	.383*	-0.275	-0.207	-0.248	0.038	0.301	.514**
	4	Correlation coefficient	.607**	.512**	1.000	.394*	.409**	0.304	.589**	.645**	-.485**	-0.165	-.481**	0.148	.583**	.350*
	5	Correlation coefficient	.357*	0.309	.394*	1.000	0.233	0.292	.641**	.383*	-.599**	-.424**	-0.166	-0.002	.454**	0.183
	6	Correlation coefficient	.457**	0.065	.409**	0.233	1.000	.746**	0.311	.344*	-.350*	-.323*	-0.282	-0.090	0.304	0.290
	7	Correlation coefficient	.480**	0.133	0.304	0.292	.746**	1.000	.496**	.374*	-0.270	-.464**	-0.225	0.019	.511**	.450**
	8	Correlation coefficient	.447**	0.306	.589**	.641**	0.311	.496**	1.000	.575**	-.579**	-0.255	-.400*	0.205	.637**	0.236
	9	Correlation coefficient	.709**	.383*	.645**	.383*	.344*	.374*	.575**	1.000	-.444**	-0.147	-.415**	0.191	.568**	.417**
	10	Correlation coefficient	-.474**	-0.275	-.485**	-.599**	-.350*	-0.270	-.579**	-.444**	1.000	0.262	0.222	-0.073	-.396*	-0.250
	11	Correlation coefficient	-0.274	-0.207	-0.165	-.424**	-.323*	-.464**	-0.255	-0.147	0.262	1.000	-0.006	-0.150	-0.055	-.386*
	12	Correlation coefficient	-0.269	-0.248	-.481**	-0.166	-0.282	-0.225	-.400*	-.415**	0.222	-0.006	1.000	-.328*	-0.136	-0.218
	13	Correlation coefficient	-0.023	0.038	0.148	-0.002	-0.090	0.019	0.205	0.191	-0.073	-0.150	-.328*	1.000	-0.046	-0.106
	14	Correlation coefficient	.573**	0.301	.583**	.454**	0.304	.511**	.637**	.568**	-.396*	-0.055	-0.136	-0.046	1.000	0.252
	15	Correlation coefficient	.450**	.514**	.350*	0.183	0.290	.450**	0.236	.417**	-0.250	-.386*	-0.218	-0.106	0.252	1.000

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Table 3. Kendall's tau-b correlation coefficient.

	Q		2	3	4	5	6	7	8	9	10	11	12	13	14	15
Kendall's tau_b	2	Correlation coefficient	1.000	.333*	.575**	.321*	.406**	.421**	.409**	.658**	-.416**	-0.239	-0.234	-0.021	.511**	.389**
	3	Correlation coefficient	.333*	1.000	.486**	.281*	0.055	0.119	0.268	.349*	-0.249	-0.180	-0.223	0.039	0.268	.461**
	4	Correlation coefficient	.575**	.486**	1.000	.360*	.369*	0.271	.547**	.615**	-.441**	-0.144	-.437**	0.141	.528**	.302*
	5	Correlation coefficient	.321*	.281*	.360*	1.000	0.204	0.257	.576**	.342*	-.530**	-.352**	-0.146	-0.007	.410**	0.150
	6	Correlation coefficient	.406**	0.055	.369*	0.204	1.000	.670**	.277*	.313*	-.314*	-0.263	-0.254	-0.083	.276*	0.239
	7	Correlation coefficient	.421**	0.119	0.271	0.257	.670**	1.000	.436**	.326*	-0.230	-.393**	-0.199	0.018	.444**	.381**
	8	Correlation coefficient	.409**	0.268	.547**	.576**	.277*	.436**	1.000	.526**	-.506**	-0.215	-.355*	0.197	.577**	0.191
	9	Correlation coefficient	.658**	.349*	.615**	.342*	.313*	.326*	.526**	1.000	-.411**	-0.127	-.376**	0.185	.507**	.350*
	10	Correlation coefficient	-.416**	-0.249	-.441**	-.530**	-.314*	-0.230	-.506**	-.411**	1.000	0.208	0.197	-0.057	-.338*	-0.203
	11	Correlation coefficient	-0.239	-0.180	-0.144	-.352**	-0.263	-.393**	-0.215	-0.127	0.208	1.000	0.000	-0.125	-0.046	-.323*
	12	Correlation coefficient	-0.234	-0.223	-.437**	-0.146	-0.254	-0.199	-.355*	-.376**	0.197	0.000	1.000	-.301*	-0.114	-0.193
	13	Correlation coefficient	-0.021	0.039	0.141	-0.007	-0.083	0.018	0.197	0.185	-0.057	-0.125	-.301*	1.000	-0.037	-0.091
	14	Correlation coefficient	.511**	0.268	.528**	.410**	.276*	.444**	.577**	.507**	-.338*	-0.046	-0.114	-0.037	1.000	0.197
	15	Correlation coefficient	.389**	.461**	.302*	0.150	0.239	.381**	0.191	.350*	-0.203	-.323*	-0.193	-0.091	0.197	1.000

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed)

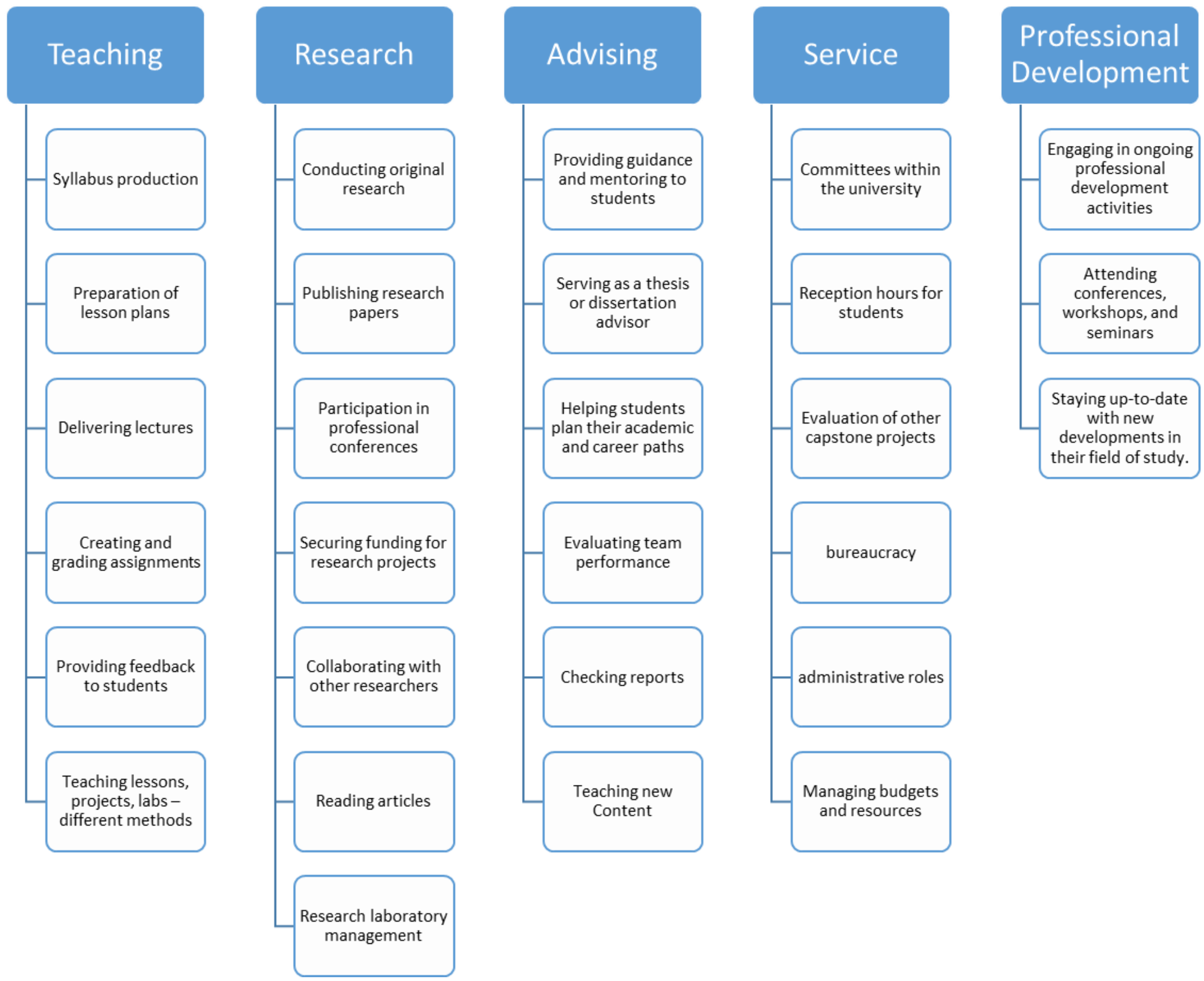

Figure 1. Faculty main tasks in Academia.

concurrently with the supervision. As evident from Figure 1, there are several main tasks for academic faculty besides supervising capstone projects, such as teaching various courses (some in the PtBL/PmBL methods), ongoing work with the department and students, and research and professional development tasks. In addition, lecturers have additional tasks such as reviewing other projects in the department (that they are not supervising) and advising different project members in their fields of expertise. Moreover, many lecturers also have various roles in academic committees within the institute.

The task of supervising capstone projects, demands a great deal of time with no proper compensation. In some cases, academic supervisors deal with topics that are outside of their field of expertise mainly due to a lack of human resources, financial or bureaucratic matters. This type of supervision on project topics in fields that differ from their main occupation exists in many other institutions and makes it hard to provide proper supervision and requires additional time to become familiar with the subject, even if only on a basic level.

Significance of the supervision as perceived by the supervisors

In contrast to the significance of supervision as perceived by students, the academic supervisors perceived the significance of supervision as low. The supervisors were the only group among the stakeholders observed to show a lack of agreement regarding the significance of the supervision. The interviews indicated that despite the lecturers' awareness of their influence and significance, some 60% of them claimed that when the project is not in their field of expertise, the supervision has no real contribution to them and they would prefer not to be engaged in it if possible. Supervision is perceived as a task that takes a great deal of time, and moreover, they would not recommend it to other lecturers. "*I have enough assignments, "I think that for most people it takes up too* *much time… Projects like ours generate a prototype, in other places it wouldn't be done because it's not good material for articles, it's not material for research*" (lecturers). Only 40% of the lecturers indicated that supervision is essential for them (wish to learn new things, to constantly develop, satisfy, and contribute to the students). These findings are reinforced by Shacham and Davidovitch (2010) who claim that faculty members would be more involved if they would be those who propose the concept of the project and guide its implementation.

Supervision as perceived by the academic institution

The academic institutions relate supervision as a meaningful factor for the project's success. This is manifested in the students' achievements in the projects, whether positive or negative. About 60% of the deans and heads of departments expressed a lack of satisfaction with the project supervision, although there are no precise definitions of output and of what the capstone project seeks to achieve. The main topics in which the academic institutions indicate disparities among supervisors are lack of knowledge and experience in specific areas, a topic that is far from their field of expertise, lack of current information by lecturers, and misunderstanding the project's goals. Following the lack of change both in the project and in its supervision over the years, a large part of the academic faculty who supervise projects experienced a very similar capstone project as students, with a very similar method, supervision, schedule, and main milestones.

Supervision sessions

The students are commonly required to participate in weekly or biweekly sessions with the supervisors. Most of the sessions take place with no organized method and are based mainly on the students' questions or on the supervisors' requirements and abilities. However, About 64% of the responding students indicated that the supervision sessions take place in an organized and clear manner. The observations and interviews show that the sessions have no real criteria or defined structure, and each supervisor has different emphases and priorities. "It's fluid, sessions are scheduled when needed. *When we meet I wish to see what they did" (supervisor). "We usually meet once every two weeks, and report on what they did. And I say in general what I expect and how I want them to do it. Then we discuss how to do it and how to make up the differences. Once a month there is a report, where I also ask to know what they did not manage to do" (supervisor). "I usually let them lead. In the first sessions, I explain the topic and refer them to the literature. Then they raise problems etc*." (supervisor).

In addition, 60% of the supervisors claimed that there is a problem with a lack of clarity in the supervision process. They stated that it is not always clear to them what they should advise about and what supervision emphasizes for which they are responsible, and that it is hard for them to supervise a project that is not in their field of expertise (unless they have experience in developing projects as a result of work in the industry). "*Someone who had always been in academia and had no experience and never really produced a product may have a problem… However, you also need academic experience, and the combination is extremely helpful for the student. Projects with lots of content etc*. are projects where there is a great deal of involvement by the supervisor" (supervisor).

The project and its supervision are not always carried out taking into account the required "figure of the graduate" and/or the output that is necessary in order to achieve it. The "figure of the graduate" for which academic institutions strive is updated every few years (due to changing jobs, adjusting to change, etc.). This is also supported by a study showing that general goals such as "summarizing the knowledge accumulated by the student" lead to a lack of clarity regarding their interpretation and translation into action (Shurin *et al*., 2020), making it hard to provide efficient supervision and creating a lack of clarity regarding the goals. "*The supervisor guides us, but not really, he himself didn't know and wasn't familiar with the field. It was more of an attempt rather than something well-established. I think that in the industry they know better what to do" (graduate). "Despite all the paperwork I read here I didn't find a guide to what I am supposed to do*" (supervisor).

Navigating the project process

The project timeline (start point, final presentation, etc.) is constant, as are the logistic requirements and bureaucratic criteria for execution versus the department (such as monthly and midterm reports). Nonetheless, some projects may be more complex, and some students may struggle and require the supervisor to devote a great deal of time to the supervision. Academic products at an insufficient level can cause the supervisor to stop the project. The observations show that despite the supervision and consultations with the supervisor, students often do not have enough knowledge about their current state in the project, the quantity of work needed, proper planning, etc. About 66% of them feel lost during the development process and do not always know how to proceed with the process. In addition, the burden of other courses that are taken concurrently with the project makes it hard for students and they contend that it disrupts the development process. "*If there is a semester when you only work on the capstone project with no other courses, then you can finish the entire process in one semester*" (graduate).

Research limitations

Despite the great significance of the current findings, there are also research limitations. First, this study focuses on Mechanical Engineering and not on all engineering programs. Secondly, the study deals mostly with capstone projects type that involves developing a physical product, rather than exploratory/ research projects. Thirdly, this study deals only with academic supervisors and not with others such as supervisors from the industry. Future work will deal with all these limitations, as it will consist of all engineering programs, different capstone project types in different fields, and industry and external supervisors involved in the capstone projects.

SUMMARY AND CONCLUSIONS

The study described in this paper examines the supervision of capstone projects in Mechanical Engineering. The study revealed a number of disparities that shed new light on the subject. Regarding research question 1, the major disparity relates to the perceived significance of the supervision by the faculty members themselves. Despite the great significance of the development process in the project, and in contrast to the significance for all other stakeholders, the supervisors ascribe little significance to the supervision and are usually not interested in supervising undergraduate capstone projects. If the projects are not in their field of expertise, they do not see any real contribution to the supervision. This situation is similar in many academic institutions, where there is a shortage of human resources - especially in the engineering field, and the level of financial compensation is limited. Therefore, it is impossible to share the supervision “burden” among many faculty members, to reward them generously, or to match their expertise to the project. The academic supervisors treat this as a task or an additional course, perform the work with a lack of interest, and would not recommend it to other lecturers. As a result, the supervision is less than optimal, and all stakeholders are negatively affected by it. This should be considered when assigning students to supervisors before the beginning of the project, and defining a criterion for matching supervisors’ backgrounds with the project theme.

Regarding research question 3, there are no clear definitions for carrying out the supervision, and the supervision method is ”rolling” from generation to generation, without substantial changes over decades. As a result, the supervisors do not necessarily know what and how they should guide the project, and the supervision is usually carried out based on their experience, familiarity with the field of development, or how they were guided in their own capstone project as students. There is no real preparation for supervisors on how to supervise the capstone project, and this should be dealt with and changed in order to produce graduates that are capable of contending with the real world and maintaining the relevance of the academic institutions and the skills they impart to students.

Furthermore, following research question 2, it was discovered that the academic institution shows a lack of satisfaction with the supervision provided by academic supervisors. The academic institution must define a clear purpose of supervision, teach the lecturer how to become an efficient supervisor, and how to guide projects. Academia must define the outcomes that it would like the supervisor to convey during the process, in light of the desired “graduate figure”, each institution defines following its values, aspirations, and skills required for real-world challenges.

With regard to faculty members, it is evident that they are under considerable pressure, where in addition to their many tasks, they are also required to supervise several projects concurrently, check, challenge, teach, and instill in students' skills, all this while evaluating students’ coping with the assignment throughout the development process. Moreover, following research questions 4 and 2, the study shows that holding regular and constant supervision sessions is very significant and that they contribute considerably to students’ perception of the supervision’s contribution to the project and to understanding the process.

In light of these findings and in light of the important role of supervisors and their impact on the project process, this case study and its findings can be used by many academic institutions. Academia needs to create greater motivation, affiliation, interest, and compensation among academic supervisors. If there are bureaucratic or human resources limitations, Academia needs to lead to a situation where supervisors' involvement and wish to accompany the process will not depend only on their field of interest or expertise. For this purpose, two solutions should be considered:

1. A rewarding compensation mechanism should be developed for lecturers who supervise projects.
2. It is necessary to act to reduce the supervision burden on the lecturers and by initiating more independent work by students on the project.

As noted by all stakeholders, the skills of independent learning and independent conduct of the students, and imparting them during the project are extremely important in the face of the abilities required from the graduate engineer. For this purpose, it is necessary to allocate resources and perhaps even to change or renew the familiar method of the project. As a result of this course of action, supervisors will be able to become “mentors” or counselors for the project, as defined by Goldberg *et al*. (2014) in their study. The supervisors will be able to generate more discussions and open questions with the students which will lead to a better thinking and learning challenge for the students. This will enhance students’ understanding of the demands of self-work, and reduce some burden from the supervisors, such that the supervision will not be perceived as a task or as another course they must teach as part of their academic role.

In summary, supervision of the undergraduate capstone project and the work of the supervisor are a complex and extremely important assignment, in which significant disparities were found. Despite the great importance of supervision for developing the project and students' perception, the academic institution is not satisfied with the current process and most of the lecturers are not interested in performing this task. Also due to its importance for the success of the project, better supervision will probably lead to a rise in satisfaction with the institution and with one's studies. Academia must detect how to help supervisors to provide the necessary skills and how to ease the supervision task, and even find ways in which the supervision can contribute to the supervisor, and perhaps even be as essential to him as his other tasks as part of his academic role. All of the above raises a deep need for a change in capstone project supervision, and for adapting this unique and important academic activity to the current era and its transitions, in order to create added value for all stakeholders.

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APPENDIX A

Ethical Statement

Institutional Review Board Statement:

The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Ethics Committee of Ariel University.

The Ethics Committee for Non-Medical Studies

To: Prof. Nitza Davidovitch
Department of Education
Ariel University, Israel

I was convinced that the study about Academic Supervising the undergraduate engineering students is not a medical experiment involving human participants, and that it upholds the conditions detailed in the procedure for approval of studies that are not medical experiments involving human participants.
Date: May 26 2022

Approval number: AU-SOC-ND-20220529.

Dr. Ephraim Grossman

Head of the Ethics Committee for Non-Medical Studies at the Humanities and Social Sciences Faculty at Ariel University.

Appendix B

Selected Items from the Questionnaire (referred from section 4.1)

2. To what extent does learning in the capstone project contribute to you compared to learning in other courses that you took during the degree?
3. To what extent do you learn new things during the capstone project?
6. To what extent does project guidance contribute to the development process?
7. To what extent are the counseling sessions held in an orderly and clear manner?
8. To what extent do you feel that the capstone project helps you understand what a development process is?
10. To what extent did you feel during the project that you were wasting time?
11. To what extent during the project did you feel that you were "lost" and did not know how to proceed?