WP 2 - Curriculum Development I: Curriculum Structure and Courses

Outcome 2.4 - Assessment of pilot test of the key courses and improved courses

Project Acronym:	MSIE 4.0
Project full title:	Curriculum Development of Master's Degree Program in Industrial Engineering for Thailand Sustainable Smart Industry
Project No.:	586137-EPP-I-2017-I-TH-EPPKA2-CBHE-JP
Funding Scheme:	Erasmus + KA2 - Capacity Building in the field of Higher Education
Coordinator:	AIT
Work Package:	WP2 – Curriculum Development I: Curriculum Structure and Courses
WP Leaders:	Tomasz Nitkiewicz (CUT) and Pisut Koomsap (AIT)
Task Title:	Task 2.4. Assessment of pilot test of the key courses and finalize the curriculum and the courses
Task Leader:	Tomasz Nitkiewicz (CUT)
Last version date:	15/10/2020
Status:	Final
Dissemination Level:	Department / Faculty - Institution - National -International

REVISION SHEET

Version	Date	Author (Partner/Person)	The revision reason
1	12/10/2020	CUT / Tomasz Nitkiewicz AIT / Pisut Koomsap	Feedback from the teachers of pilot tested courses and from Task 2.4 team
2	14/10/2020	CUT / Tomasz Nitkiewicz AIT / Pisut Koomsap	Feedback from QCMB
3			

DISTRIBUTION LIST

Project Partner	Acronym	Responsible (for dissemination)
University of Minho	UMinho	Diana Mesquita
Chiang Mai University	CMU	Wichai Chattinnawat
Asian Institute of Technology	AIT	Huynh Trung Luong
King Mongkut's University of Technology North Bangkok	KMUTNB	Athakorn Kengpol
Thammasat University	TU	Naris Charoenporn
Khon Kaen University	KKU	Thitipong Jamrus
Prince of Songkla University	PSU	Suriya Jirasatitsin
University Politehnica of Bucharest	UPB	Tom Savu
Częstochowa University of Technology	CUT	Robert Ulewicz

Table of Contents

List of Tables

List of Figures

1 Executive Summary

The **Outcome 2.4 Assessment of pilot test of the key courses and finalize the curriculum and the courses** sums up the pilot testing of 10 selected courses from MSIE4.0 curriculum. The recommendations for MSIE4.0 curriculum eventual revision are formulated on feedback from students, teachers and partially, other stakeholders. The main instruments used for gathering feedback are surveys that included students and teachers. Questionnaires that were used for that purposes enabled gathering feedback on general course characteristics, course delivery, workshop and laboratory sessions and general perception of tested courses. Students survey has been launched in accordance to the schedule of pilot testing during autumn and spring semesters of 2019/2020 academic years. Altogether, 114 students from 9 Partner universities participated in the survey. Teachers survey has been made after disclosing the results of students survey.

General recommendations for MSIE4.0 curriculum and its elements could be categorized into individual and institutional ones and summed up in the following points:

- make effort to present the course content and use its TLMs in a way that supports the absorption and immersion of knowledge and skills by students,
- keep students informed and updated on grading policy and their performance throughout the course,
- monitor the curriculum implementation process and enable course syllabus adjustments throughout the advancements of process,
- organize appropriate conditions and support for teachers to consider the coherence between the teaching methods and assessment strategy
- provide non-biased feedback streams from the students and peer evaluations of courses and enable appropriate framework for revising the courses and optionally the program as well.
- make adjustments of MSIE4.0 curriculum in its implementation process on different Partner universities to keep it updated and matched to local conditions.

Slight feedback from external stakeholders confirms that business environment accepts and supports approach adopted within MSIE4.0 curriculum. Overall assessment of pilot tested courses is very promising and foresights that complex implementation on different Partner universities could certainly become important milestone in building sustainable and smart industry.

2 Introduction

The major objective of MSIE 4.0 project is to develop curriculum for Master's Degree Program in Industrial Engineering. After developing the curriculum, 10 out of 16 courses has been tested by partner universities within **Task. 2.3 Conducting pilot test of the key courses**. The purpose of this task is to verify the main outcomes of MSIE 4.0 project with regard to expectations of key stakeholders of the curriculum and enable eventual corrections to the curriculum as a whole and to specific courses. The main objective of **Task 2.4 Assessment of pilot test of the key courses and finalize the curriculum and the courses** is to verify whether the content, teaching methods applied and teaching materials used within the pilot tested courses are appropriate for students and teachers.

The Task 2.4 builds up on the feedback to courses that have been tested within Task 2.3. The list of courses together with the information of the University introducing it, date of launching the course and the number of participating students is presented in Table 1.

In total 10 out of 16 MSIE 4.0 courses have been tested, and two of them, course 5 and course 16, have been tested twice. Each one of the project Partners, has tested at least 1 course, while two of them, namely AIT and KMUTNB, have tested two courses each. For the purpose of testing the courses academic capabilities of all partner Universities has been used and depending on formal regulations and realized studying programs each Partner has applied frame work that is appropriate for the purpose of course testing. The solutions that have been used include:

- Introducing new elective course within existing IE related programs (adding new course),
- Introducing new course syllabus and course materials within existing IE related programs (replacing existing course),
- Introducing changes into course syllabus and course materials within existing IE related programs (replacing partially the content in an existing course).

Dates of running the courses and number of students enrolled to each one of tested courses is presented in Table 1.

Table 1. Information of pilot tested MSIE 4.0 courses

Course No.	Course Title	Time	Partner	Instructor(s)	No. of students enrolled
2	Project Management for Industry 4.0	Sep 19	UMinho	Prof. Rui M Lima	12
3	Smart Operations Management	Jan 20	CMU	Dr. Uttapol Smutkupt, Dr. Wimalin Laosiritaworn, Dr. Chompoonoot Kasemset, Dr. Anirut Chaijaruwanich, Dr. Warisa Wisittipanich	11
5	Sustainable Supply Chain Management	Oct 19	CUT	Dr. Anna Wiśniewska-Sałek	48
		Feb 20			32
6	Digital Factory	June 19	KMUTNB	Prof. Athakorn Kengpol	10
7	Advanced Optimization: Techniques and Industrial Applications	Dec 19	KKU	Prof. Kanchana Sethanan, Dr. Komkrit Pitiruek, Dr.Thitipong Jamrus	12
8	Intelligent Decision Support Systems	Dec 19	PSU	Dr. Suriya Jirasatitsin	5
9	Applied Data Analytics	Jan 20	AIT	Dr. Huynh Trung Luong	31
10	Cyber-Physical Industrial Systems (under the existing course on Experimental Research)	Oct 19	UPB	Prof. Tom Savu	12
14	Human-Centric Design for Operator 4.0	Jan 20	TU	Asst Naris Charoenporn, Dr. Jirawan Kloypayan	16
16	Communication and People Skills Development for Engineering Leaders	Aug 19	AIT	Dr. Pisut Koomsap	12
		Nov 19	KMUTNB	Prof. Athakorn Kengpol	1

In order to achieve that objective of Task 2.4 the efforts have been combined with several other tasks within the project, which are related to the development of curriculum (tasks 2.1 – 2.3) as well as to the development of teaching materials (tasks 3.1 and 3.5). The main tool used to collect data to support verification of pilot tested courses is a survey questionnaire for students and for teachers. Due to some limitations and diversified time framework, the survey has been launched at the end of the most of the courses that was tested, with two exceptions.

The course 2 and course 14 have been tested with the use of Partner specific quality assurance tools. Project Management for Industry 4.0 course has been assessed with the use of qualitative character narratives. The narratives were delivered at the end of the course and aiming at to include a self-reflection about the course, in terms of the relevance of the contents and the activities developed during the course, teaching practice and interaction with teacher and students, amongst other issues, in which students were free to present (Lima, Mesquita, Aquere, & Jesus, 2020). Human-Centric Design for Operator 4.0 course has been assessed with the use of course specific assessment tool that was similar to the main assessment questionnaire but more detailed concerning course outcomes. Table 2 shows the numbers of students surveyed during pilot testing.

Survey of teachers has been based on different questionnaire that aimed at collecting feedback on important elements of course syllabus and teaching and learning approach used. Its important role was also to identify course relationship to the MSIE4.0 curriculum as a whole and its leading topics like smart and sustainable industry 4.0.

Additionally, the survey results are supported with the results of surveys within task 3.3 and assessments of materials developed for task 3.1.

Table 2. The number of students surveyed within pilot tested courses

Course No.	Course Title	No. of surveyed students
2	Project Management for Industry 4.0	12
3	Smart Operations Management	11
5	Sustainable Supply Chain Management	7*
6	Digital Factory	13
7	Advanced Optimization: Techniques and Industrial Applications	7
8	Intelligent Decision Support Systems	5
9	Applied Data Analytics	24
10	Cyber-Physical Industrial Systems	8
14	Human-Centric Design for Operator 4.0	13
16	Communication and People Skills Development for Engineering Leaders	10
	Total	114

* does not include the students that have been surveyed in the winter semester since the syllabus has been significantly changed afterwards

3 Evaluation of pilot tested courses

The following sections of the report refer to each one of the courses that went through pilot testing in 2019/2020 academic year.

3.1 Course 2: Project Management for Industry 4.0

Project Management for Industry 4.0 (PM4I4) course has been tested by University of Minho. It was one of the courses that has been assessed withing university specific framework. The results of the assessment has been presented and published within PAEE/ALE 2020 Conference. The objective of the paper was to present the evaluation of this course based on the perceptions of the enrolled students. Th evaluation was based on written reflection of the course delivered at the end of the course by a total of twelve students. Most of students enrolled (10/12) provided a positive perspective about the course, considering that will contribute for their professional practice in the future and recommend it for other engineering students. Part of these students considered the project related to the development of a questionnaire of I4.0 in a company quite interesting and contributing for their formation and other students considered it less practical that they expected to. It is worthwhile to notice that most of the students really enjoyed the diversity of pedagogical experiences and teachers engaged in the process (a total of 4), and the development of transversal competences, but some of them would prefer to have contact with less teachers. Thus, as final contributions, it could be recommended to create better framework for the Industry 4.0 questionnaire project and create opportunities for the students to enroll in management of more practical projects related with that main theme (Lima et al., 2020).

Most of the students evaluated the course positively or very positively and above their expectations, reinforcing that idea by telling that this elective course should be delivered in the following years. A good summary for the perceptions of the students could come from the excerpt that summarizes a student's overview of the course (Lima et al., 2020):

> *"I consider the topics covered very interesting, starting with Industry 4.0, PM Canvas and SCRUM, to some more related topics with our soft skills such as teamwork, leadership, communication and coaching. The soft skills have been increasingly important in the labor market and will be for the Accenture, one of the most important requirements in the "jobs of the future." These are areas that cannot be learned, where there is no magic formula, but only trained and cultivated. I think it is very important to start instilling this in students from an early age, in order to be more prepared for the "future" market and even for the "now" market."*

As for teachers assessment, all the important elements of course syllabus and teaching approach have been well designed and performed and played effectively its roles in educational process (Figure 1). There are no specific recommendations concerning the elements of course structure.

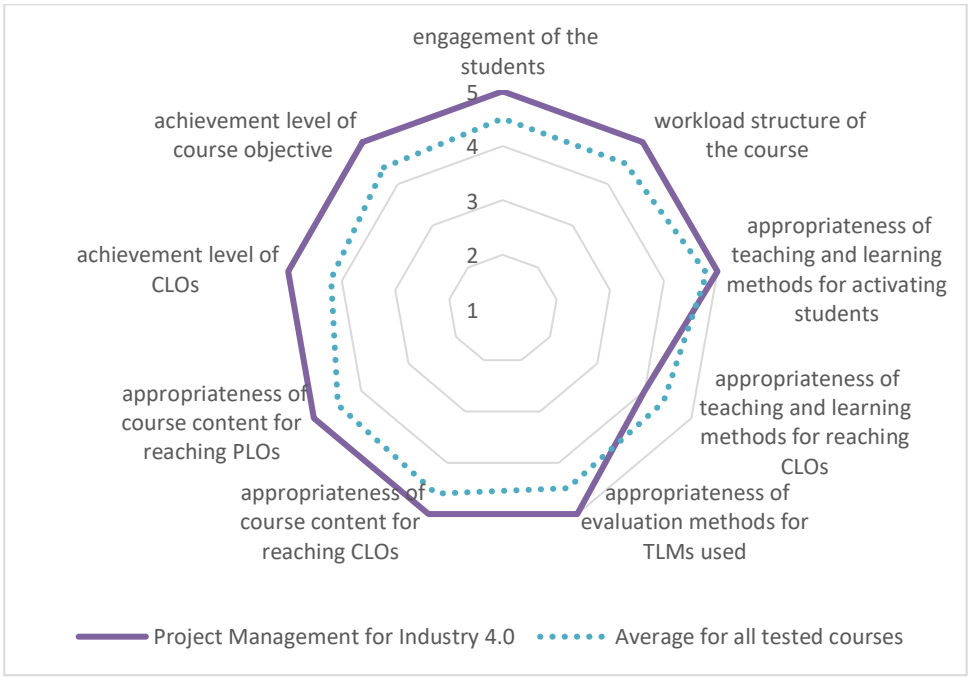

Figure 1. Project Management for Industry 4.0: course teacher perspective

General recommendations from course teacher concerning possible changes in the course content are:

> *"A improvement of the alignment between the proposed project methodology and the Industry 4.0 maturity model."*

As for the recommendations concerning the relationship of the course with other courses in MSIE4.0 curriculum:

> *"This course could be implemented with the development of an interdisciplinary project with other courses."*

As for recommendations concerning the improvement of the course relevance to Industry 4.0 and smart technologies:

> *"This course can benefit from a continuous evaluation of I4.0 concepts, methods and tools applied to Project Management."*

3.2 Course 3: Smart Operations Management

Smart Operations Management (SOM) course has been tested by Chiang Mai University. Evaluation of the course has been made through the online survey of students. Evaluation of course characteristics showed that the course is well prepared and organized, and have good potential in developing the competencies through reaching CLOs (Figure 2).

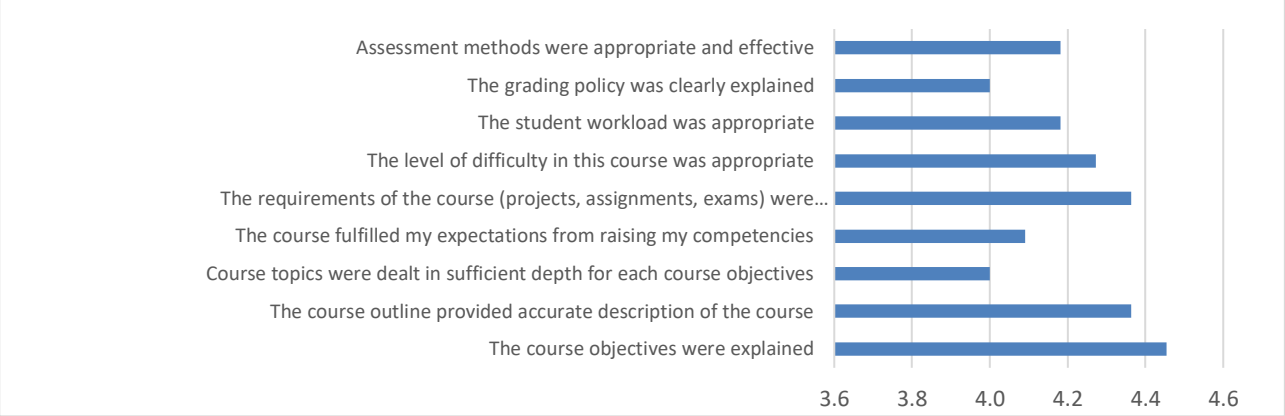

Figure 2. Smart Operations Management: evaluation results on Course Characteristics

Evaluation of course delivery, teaching methods and resource materials went also good. It shows the appropriateness on the level of teaching methods selection, timeliness of course materials, its organization and use of information technologies (Figure 3).

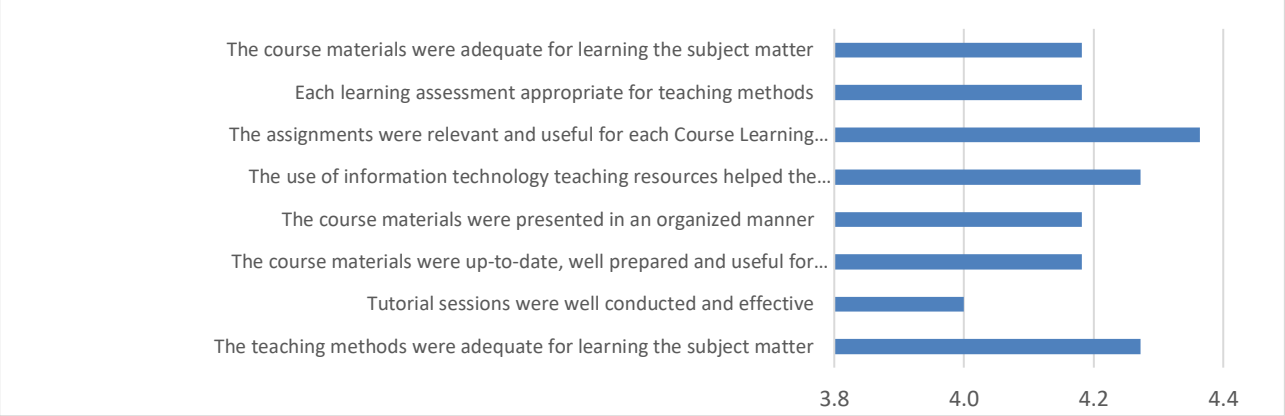

Figure 3. Smart Operations Management: evaluation results on Course Delivery/Teaching Methods/Resource Materials

Workshop sessions delivered within the course were evaluated positively. The positive evaluation mostly concerns the condition of equipment and allocated time to the sessions (Figure 4).

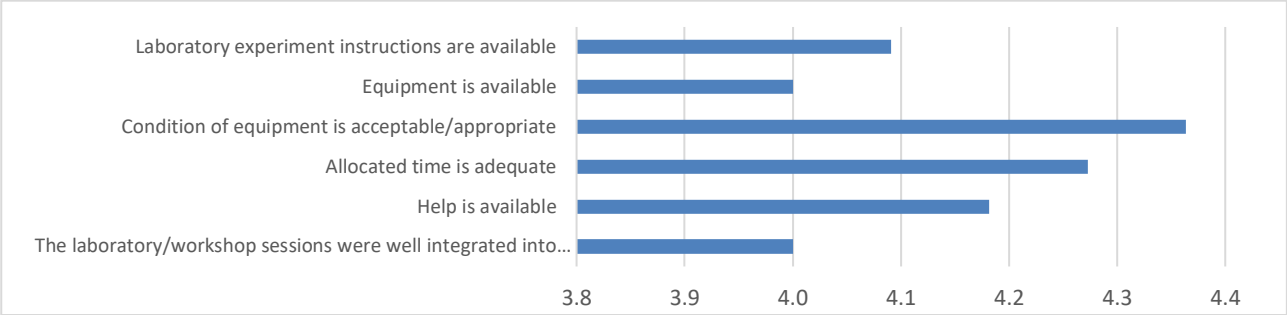

Figure 4. Smart Operations Management: evaluation results on Laboratory/Workshop Sessions

Overall assessment showed special appreciation to the conduct of the course and knowledge and competences gain from the course (Figure 5).

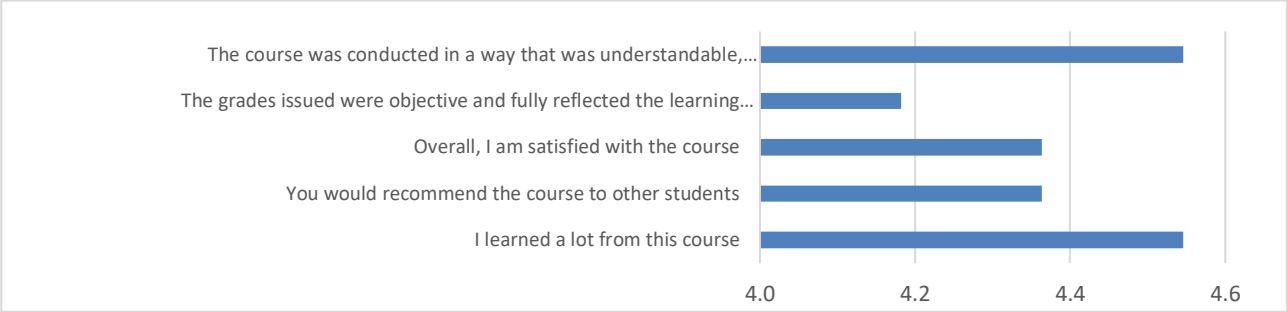

Figure 5. Smart Operations Management: Overall Assessment results

Students admit that their involvement into the course was quite high (Figure 6).

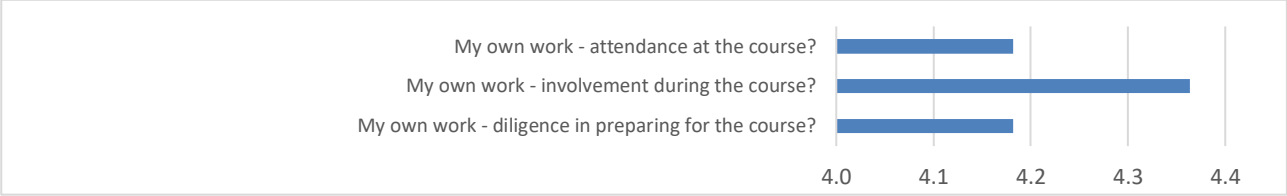

Figure 6. Smart Operations Management: Student self-assessment results

Open comments from students have been oriented on overall assessment as well. In general, the comments showed appreciation of teaching and learning methods applied

> "*Excellent in teaching and learning*",
>
> "*Group working and brain storming support student to work as a teamwork. I would like to thank all lecturers who conduct this course to let students to show his/her potential and knowledge in applying theory for real applications*" and
>
> "*Teaching methods of this course are very impressed comparing with other courses teaching as lecture-based. For me, I feel that I willing to spend more effort and more attention for this course because both teaching methods and lecturers. The teaching and learning methods of this course can help me in working on my thesis, as well.*")

or its motivating power

> "*Encourage students to have more participate in class*".

As for teachers assessment, all the important elements of course syllabus and teaching approach have been well designed and performed and played its roles in educational process (Figure 7). There are some specific

recommendations concerning the elements of course structure that were made by one of the teachers. The first one refers to CLOs:

> *"The CLOs should be more specific regarding each modules in the course.",*

And the second one refers to the relationship of the course with other courses within MSIE4.0 curriculum:

> *"As the core course in the curriculum, the smart operations management should provide and cover aspects or topics relating to other courses."*

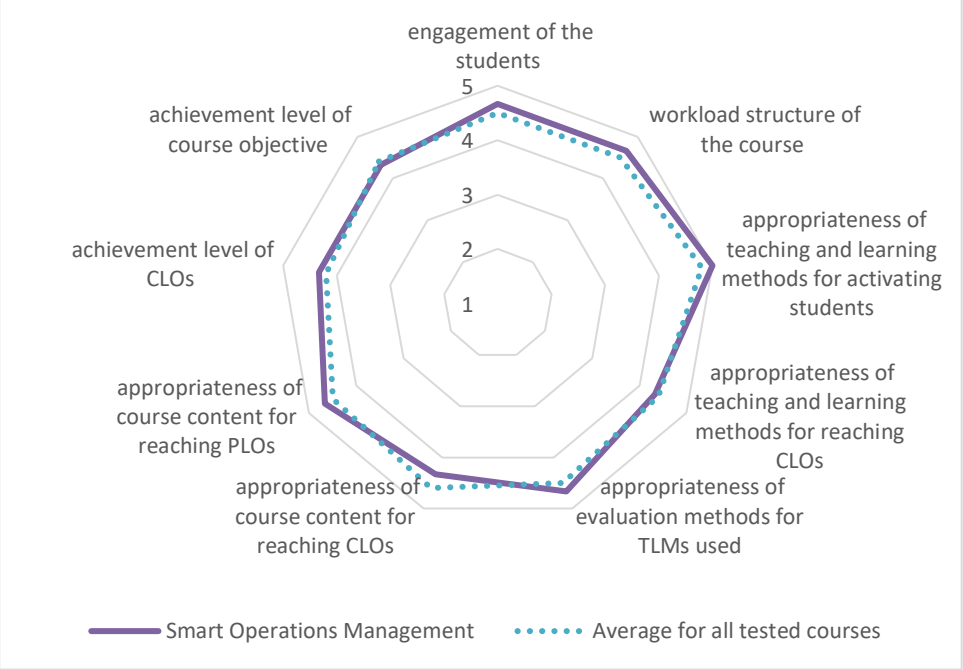

Figure 7. Smart Operations Management: course teacher perspective

3.3 Course 5: Sustainable Supply Chain Management

Sustainable Supply Chain Management (SSCM) course has been tested by Częstochowa University of Technology. Evaluation of the course has been made through the online survey of students twice, both, in autumn and spring semesters of 2019/2020. Since the course syllabus has been significantly changed during the winter break, only the spring semester evaluation is taken into account in this report.

Evaluation of course characteristics showed that the course is well prepared and organized, and have good potential in developing the competencies through reaching CLOs. The most appreciated categories by students are: the requirements, raising competencies and explanation of course objectives (Figure 8).

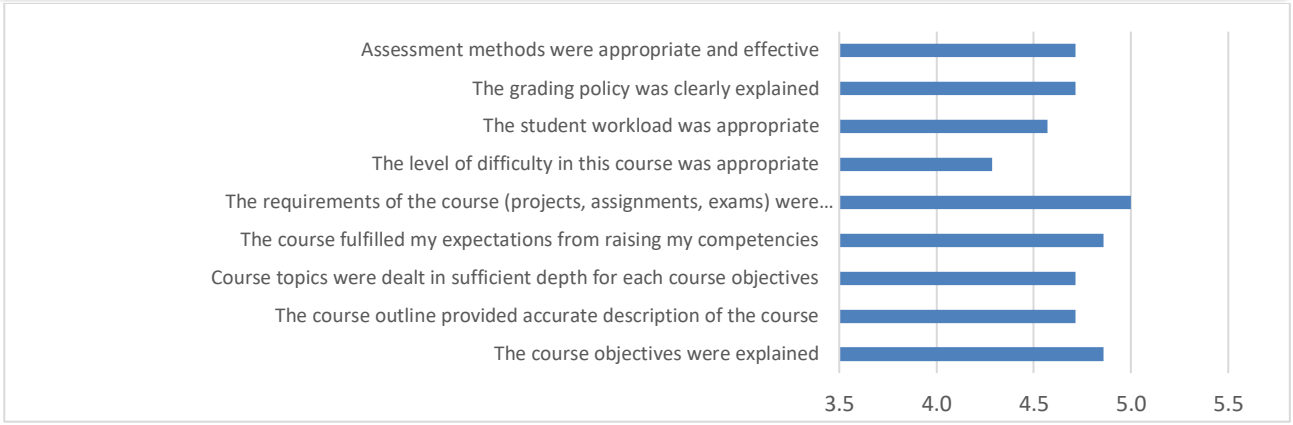

Figure 8. Sustainable Supply Chain Management: evaluation results on Course Characteristics

Evaluation of course delivery, teaching methods and resource materials went also good. It shows the appropriateness on course materials for learning the subject matter, timeliness of course materials, and use of information technologies (Figure 9).

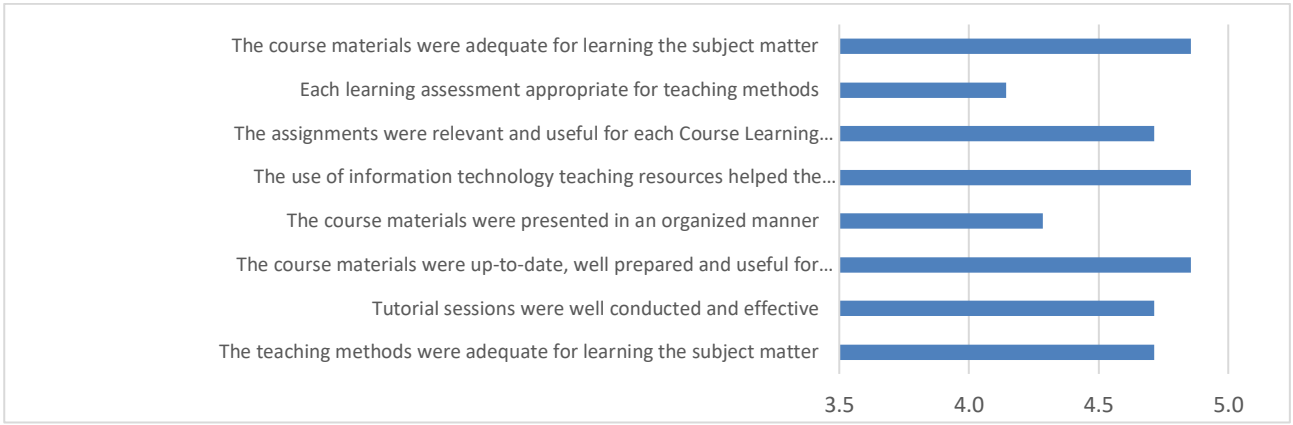

Figure 9. Sustainable Supply Chain Management: evaluation results on Course Delivery/Teaching Methods/Resource Materials

Workshop sessions delivered within the course were evaluated positively. The positive evaluation mostly concerns the condition of equipment, its accessibility, allocated time to the sessions and good integration of workshops into course (Figure 10).

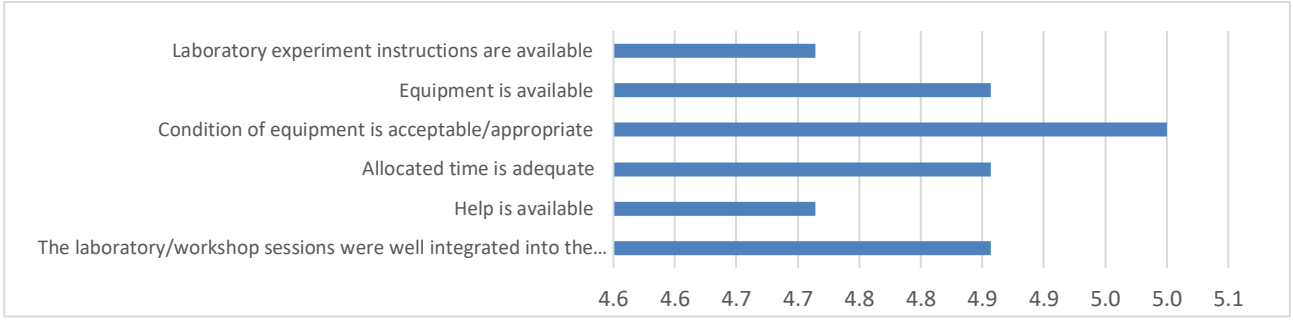

Figure 10. Sustainable Supply Chain Management: evaluation results on Laboratory/Workshop Sessions

Overall assessment showed special appreciation to the conduct of the course, objectivity of the grading and knowledge and competences gain from the course (Figure 11).

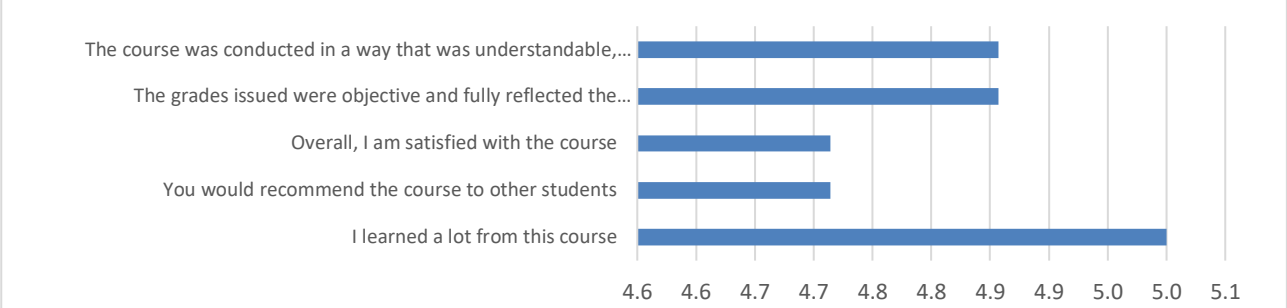

Figure 11. Sustainable Supply Chain Management: Overall Assessment results

Students admitted that their involvement into the course and diligence in preparing for the classes was quite high. The course seemed to be run with full presents of students (Figure 12).

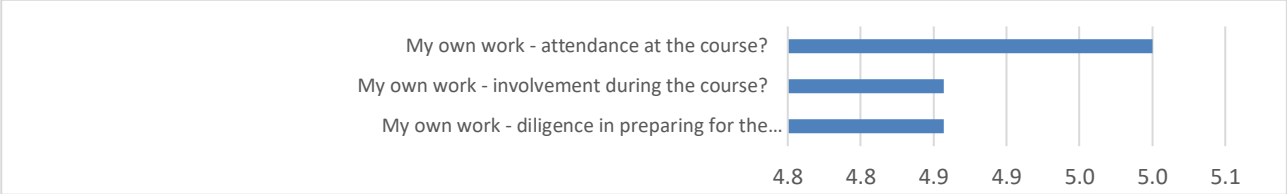

Figure 12. Sustainable Supply Chain Management: Student self-assessment results

Open comments from students have been oriented on overall assessment as well. In general, the comments showed appreciation of teaching and learning methods applied:

> *"expanding knowledge on sustainable development, acquiring knowledge of good practices that lead companies that want to develop sustainably"*

And group work

> *"Ability to work in a group"*
>
> *"creativity, group work"*

As for the proposals to enrich the course the students vowed for including more integrated managerial perspective:

> *"the ability to search for solutions that help streamline, modernize or help, e.g. in various processes, deepening management knowledge"*

and more focus also on creative thinking approach.

As for teachers assessment, all the important elements of course syllabus and teaching approach have been well designed and performed and played efficiently its roles in educational process (Figure 13). There are no specific recommendations concerning the elements of course structure. There is one general remark though that refers to the course implementation within curriculum:

> *"Effects should be updated prior to each course starting cycle"*

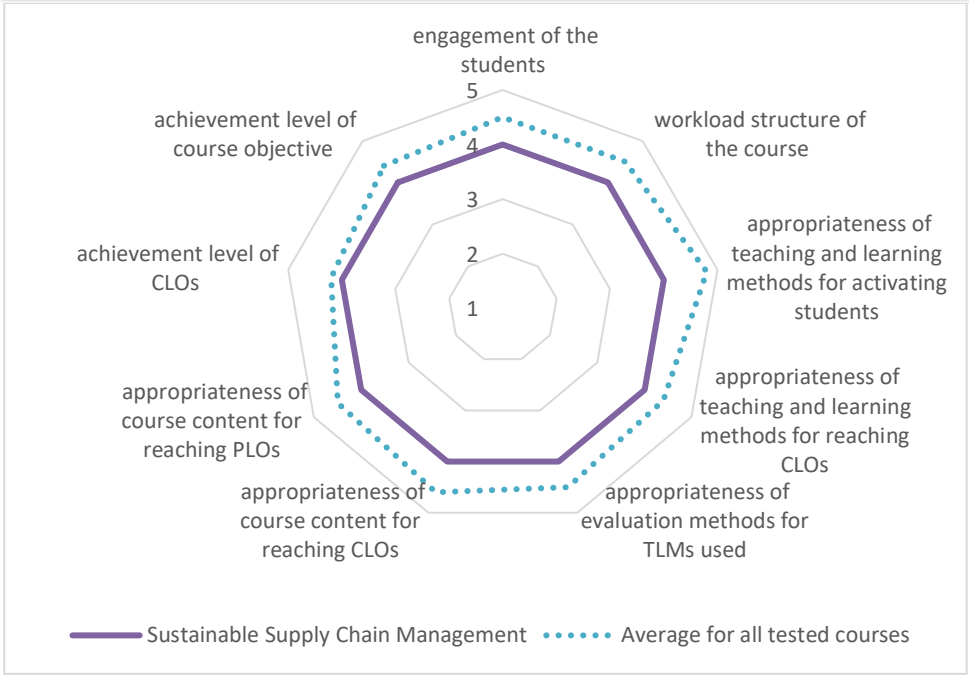

Figure 13. Sustainable Supply Chain Management: course teacher perspective

3.4 Course 6: Digital Factory

Digital Factory (DF) course has been tested by King Mongkut's University of Technology North Bangkok. Evaluation of the course has been made through the online survey of students. The results of course testing and evaluation were partially presented on PAEE/ALE'20 Conference (Chanchittakarn, Buakaew, & Kengpol, 2020; Kengpol, Koohathongsumrit, & Meethom, 2020).

Evaluation results of course characteristics showed that the course is well described, the grading policy and CLOs were well explained, assessment methods were appropriate, requirements of the course were just (Figure 14).

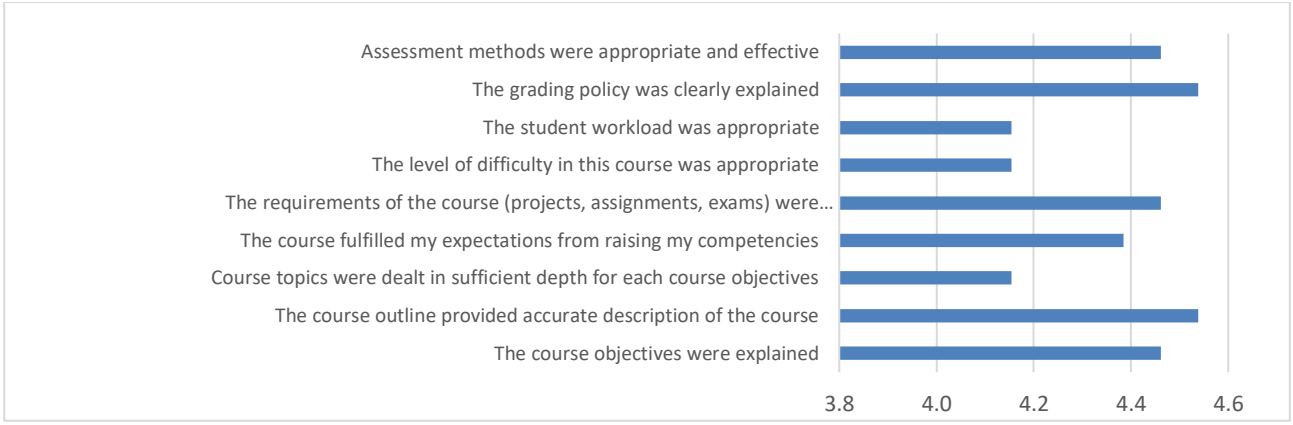

Figure 14. Digital Factory: evaluation results on Course Characteristics

Evaluation of course delivery, teaching methods and resource materials went also good. It shows the appropriateness especially on the level of teaching methods selection, and use of information technologies and relevance of assignments (Figure 15).

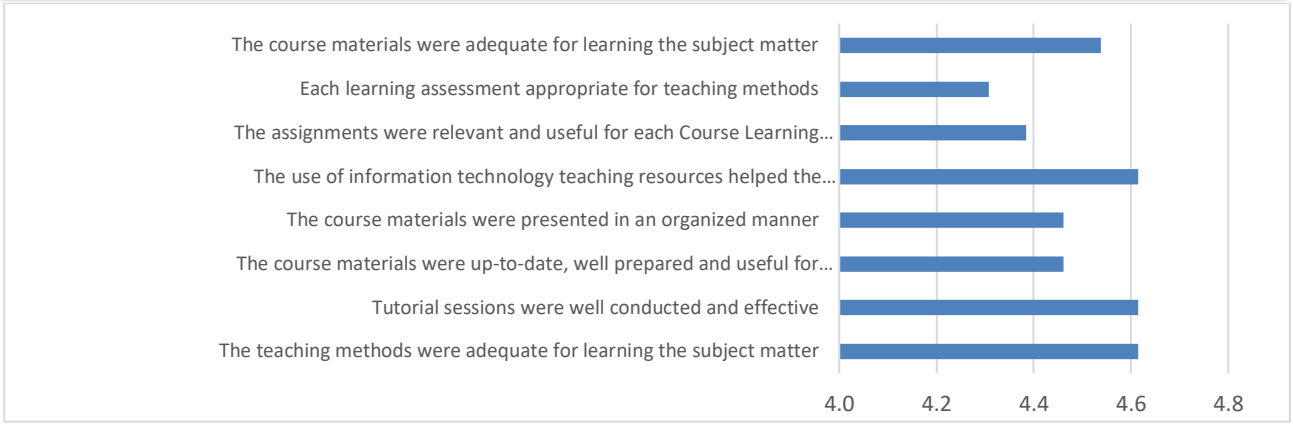

Figure 15. Digital Factory: evaluation results on Course Delivery/Teaching Methods/Resource Materials

Laboratory sessions delivered within the course were evaluated positively. The positive evaluation mostly concerns the availability of support from the teachers, time allocation and integration of (Figure 16). There are no significant negative assessments in any of the categories.

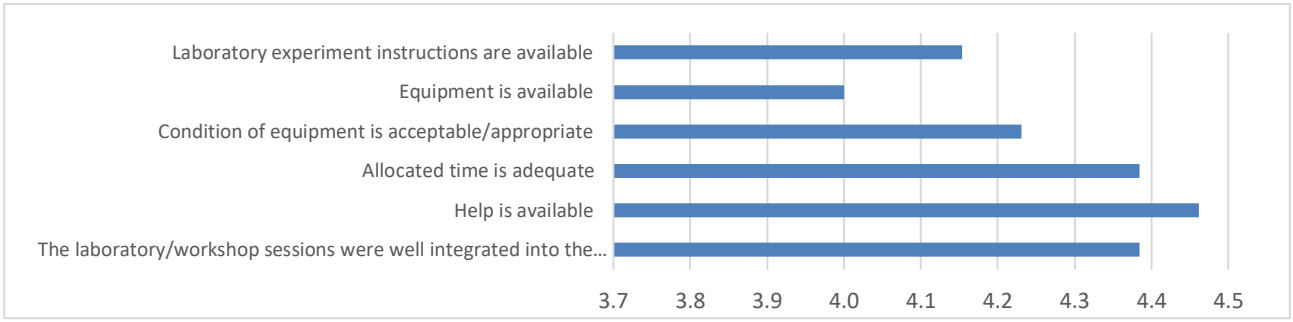

Figure 16. Digital Factory: evaluation results on Laboratory/Workshop Sessions

Overall assessment showed that the course is satisfactory for the students and willingness to recommend the course further (Figure 17).

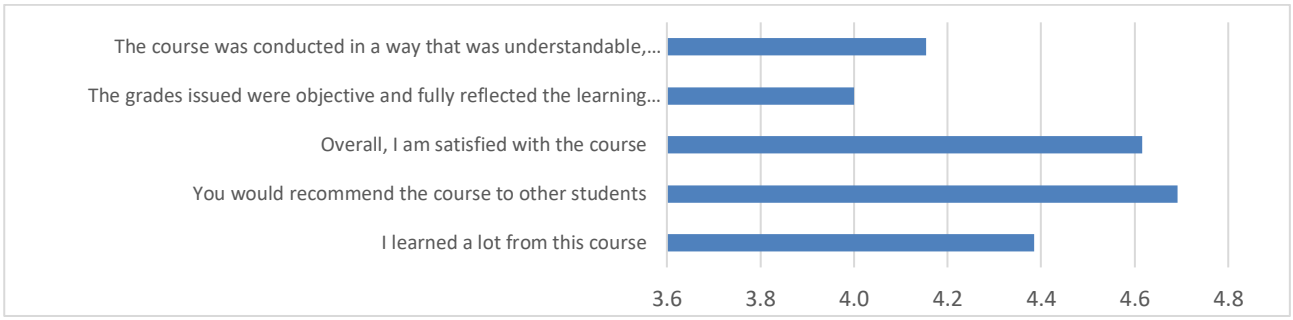

Figure 17. Digital Factory: Overall Assessment results

The assessment of the course have been made with high involvement of students (Figure 18).

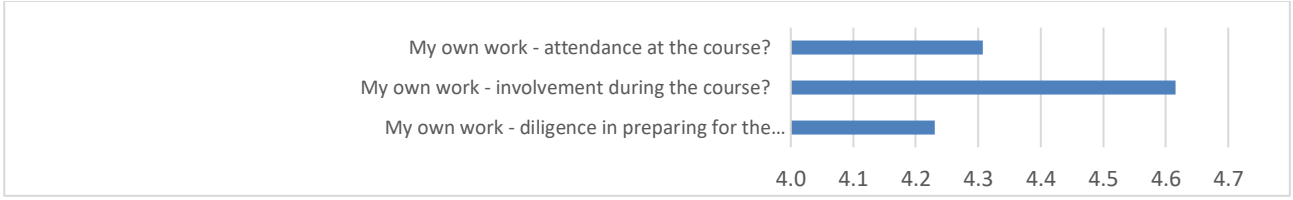

Figure 18. Digital Factory: Student self-assessment results

Open comments from students in general, showed appreciation of teaching and learning methods applied, with a special focus on: communication and leadership skills, factory visits, presentation skills and data analysis reference. Selected comments appreciating the course are shown below:

> *"The experiment method should be noted because the students can learn the causes and the results in this method, so they can prepare a lot for their works",*
>
> *"Developing your own potential is to be a learned technician. And constantly seeking new knowledge",*
>
> *"Communication, Design Thinking Using gadgets, Data Analysis",*
>
> *"Students visit the factory and analyze what technologies are appropriate for the factory".*

As for the proposals to enrich the course the students vowed for inclusion of observation methods, creative and critical thinking, as well as some more coverage for digital factory technologies. Selected comments presenting the possible enrichment of the course are shown below:

> *"The observation method should be noted because the successfully innovations are the results of good observations",*
>
> *"using the technology to work", "Programming, AI, Practice" and "Critical thinking skills and Creative problem solving"*

As for teachers assessment, all the important elements of course syllabus and teaching approach have been well designed and performed and played its roles in educational process (Figure 19). There are no specific recommendations concerning the elements of course structure. There is one remark though, concerning the visiting type of experience for course students:

> *"If possible, due to Covid 19, visiting to factories, virtual visit plus real video visit should have been effectively possible."*

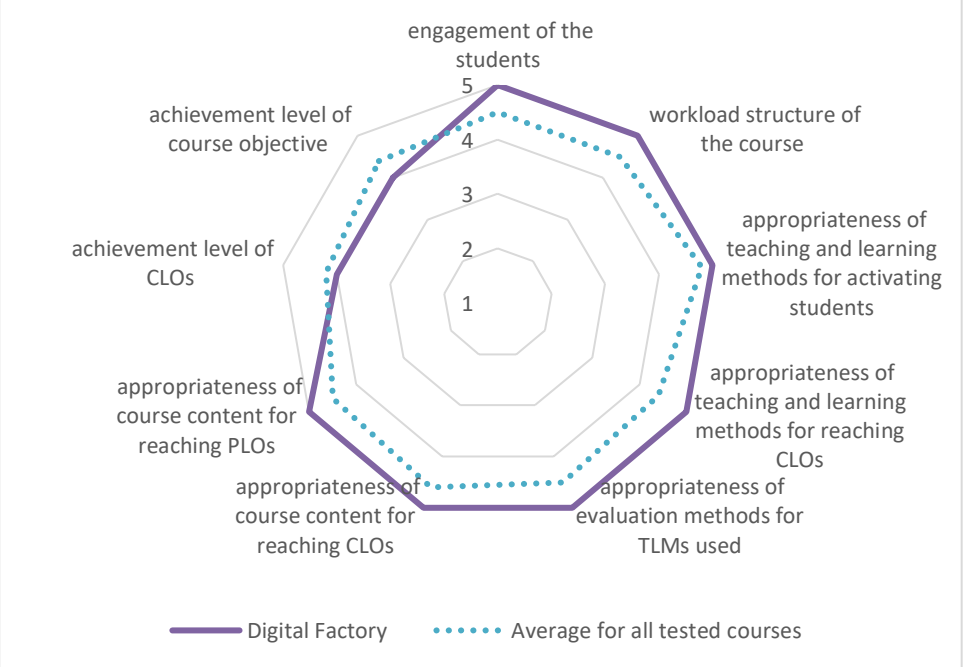

Figure 19. Digital Factory: course teacher perspective

3.5 Course 7: Advanced Optimization: Techniques and Industrial Applications

Advanced Optimization: Techniques and Industrial Applications (AOTIAT) course has been tested by Khon Kaen University. Evaluation of the course has been made through the online survey of students in spring

semester 2019/2020. Evaluation of course characteristics showed that the course is well outlined and its requirements are well defined and appropriate (Figure 20).

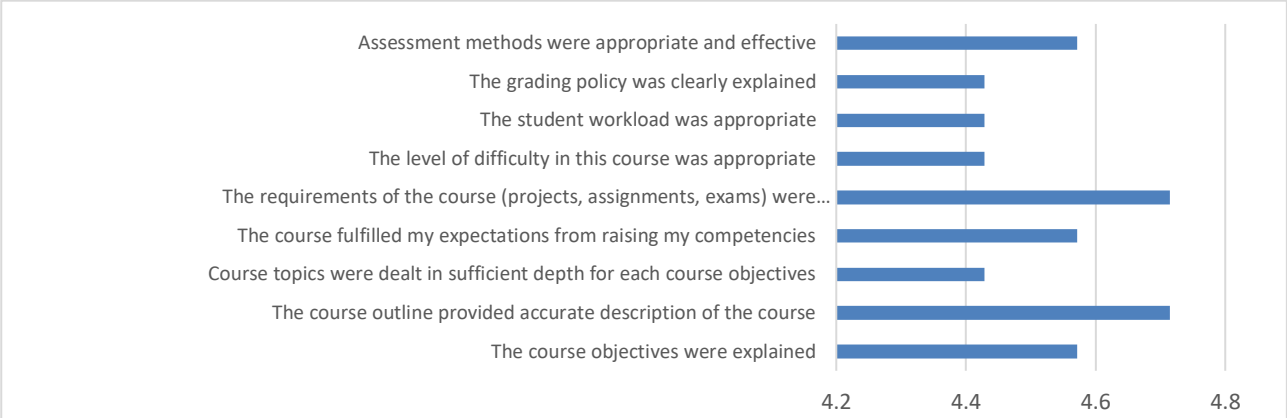

Figure 20. Advanced Optimization: Techniques and Industrial Applications: evaluation results on Course Characteristics

Evaluation of course delivery, teaching methods and resource materials went also good. It shows the appropriateness on course materials for learning the subject matter, timeliness of course materials delivery, and relevance of teaching methods and course assignments (Figure 21).

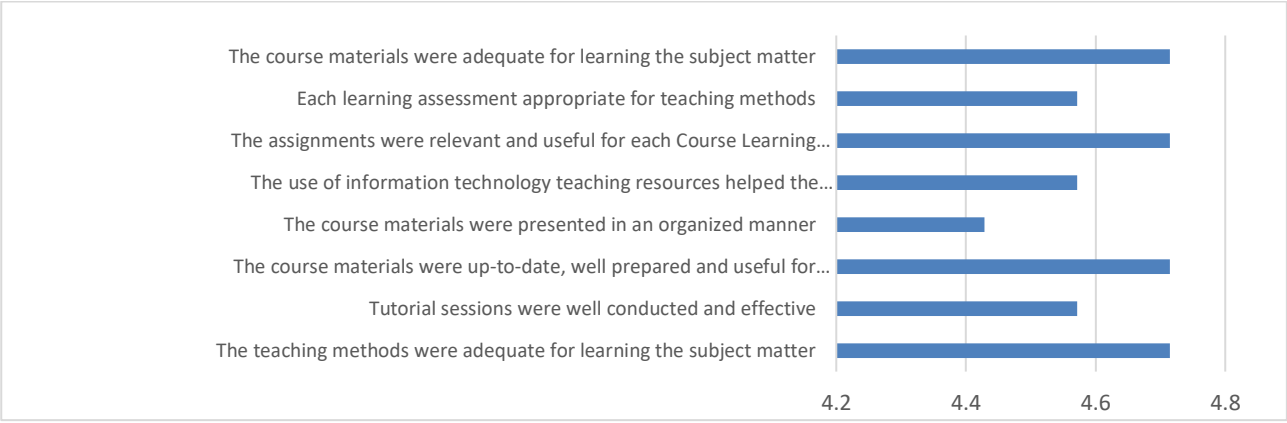

Figure 21. Advanced Optimization: Techniques and Industrial Applications: evaluation results on Course Delivery/Teaching Methods/Resource Materials

The course workload is structured in lecture, project and self-studying hours only, so the feedback to workshop and lab sessions should be considered as overall assessment of technical and organizational issues. The positive evaluation mostly concerns the condition of equipment, its accessibility, allocated time to the sessions and good integration of project and individual work into course (Figure 22).

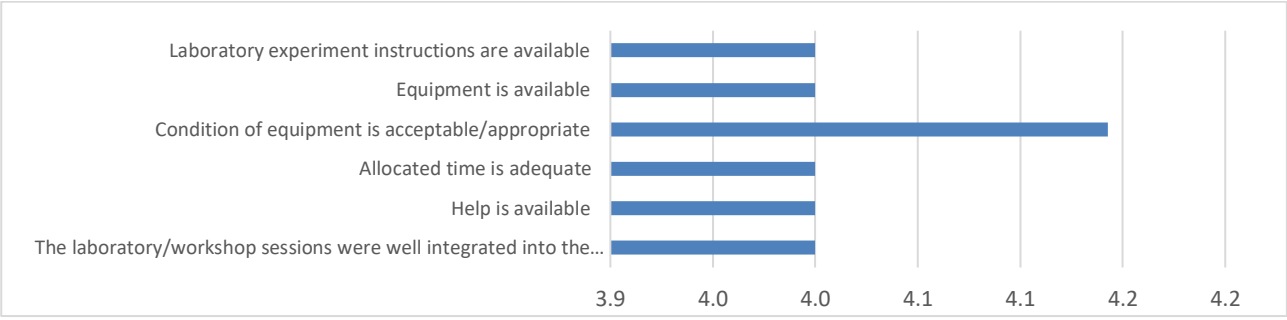

Figure 22. Advanced Optimization: Techniques and Industrial Applications: evaluation results on Laboratory/Workshop Sessions

Overall assessment showed special appreciation to the conduct of the course, and knowledge and competences gain from the course (Figure 23).

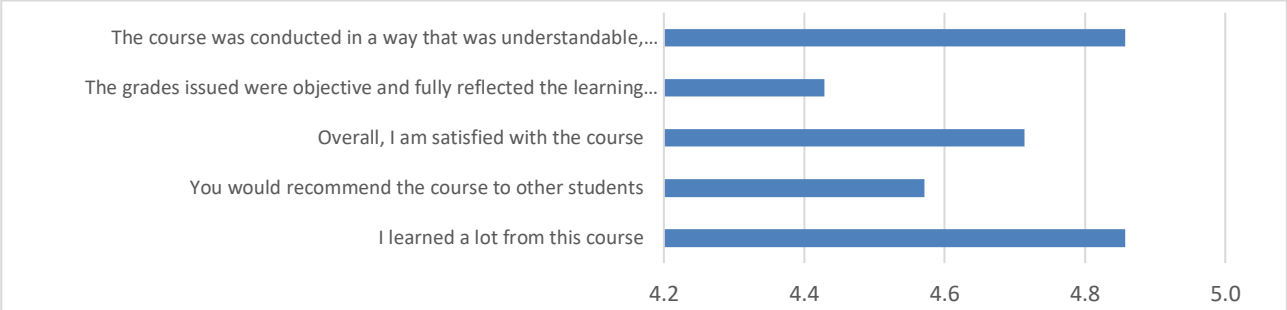

Figure 23. Advanced Optimization: Techniques and Industrial Applications: Overall Assessment results

Students admitted that their involvement into the course was quite high (Figure 24).

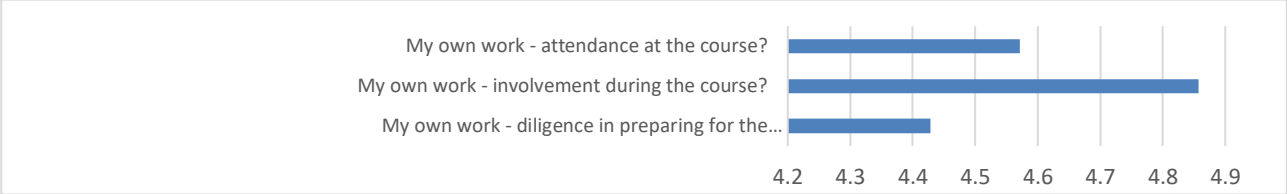

Figure 24. Advanced Optimization: Techniques and Industrial Applications: Student self-assessment results

Open comments from students in general showed appreciation to the following elements applied within the course:

"AI Technology and simulator programming",

"Analytical thinking / Planning / Organizing"

"Critical thinking, Management, System thinking"

"Simulation optimization skill"

As for the proposals to enrich the course the students vowed for including the following elements:

"Adaptability and flexibility",

"Understand process of each module, update knowledge."

"Automation" and "Application".

As for teachers assessment, all the important elements of course syllabus and teaching approach have been well designed and performed and played its roles in educational process (Figure 25). There are no specific recommendations concerning the elements of course structure. The need of changing the workload structure and course content are signalled.

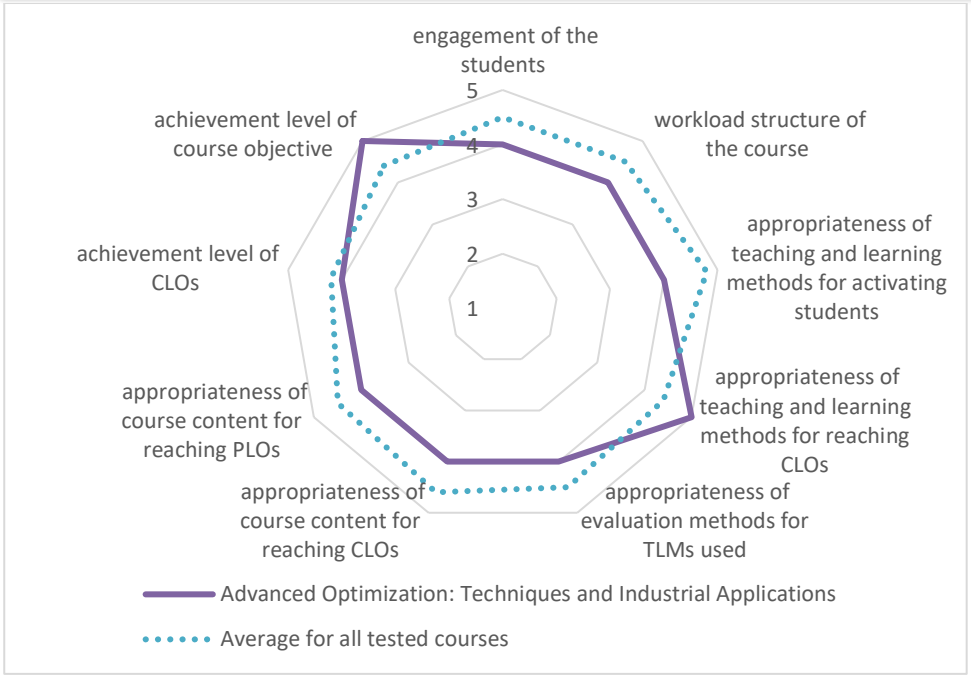

Figure 25. Advanced Optimization: Techniques and Industrial Applications: course teacher perspective

3.6 Course 8: Intelligent Decision Support Systems

Intelligent Decision Support Systems (IDSS) course has been tested by Prince of Songkla University. Evaluation of the course has been made through the online survey of students during spring semester 2019/2020. Evaluation of course characteristics is quite good, with underlining appropriateness of assessment methods, good definition of requirements and raising competencies. On the other hand, students have complained on structure of course workload (Figure 26). As for the explanation, the term project within the course was oriented on programming, while some of the students has no appropriate preparation for that.

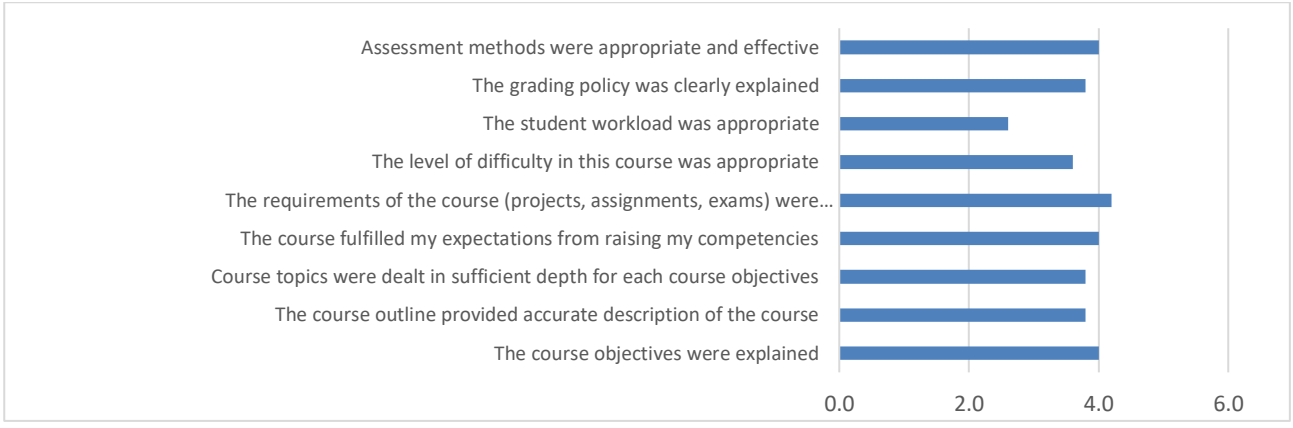

Figure 26. Intelligent Decision Support Systems: evaluation results on Course Characteristics

Evaluation of course delivery, teaching methods and resource materials went also quite good. It shows the appropriateness of course materials and its timeliness, the way they were presented as well as the conduct of tutorial sessions. Students complained on some discord between teaching and assessment methods and little relevance between the assignments and CLOs (Figure 27).

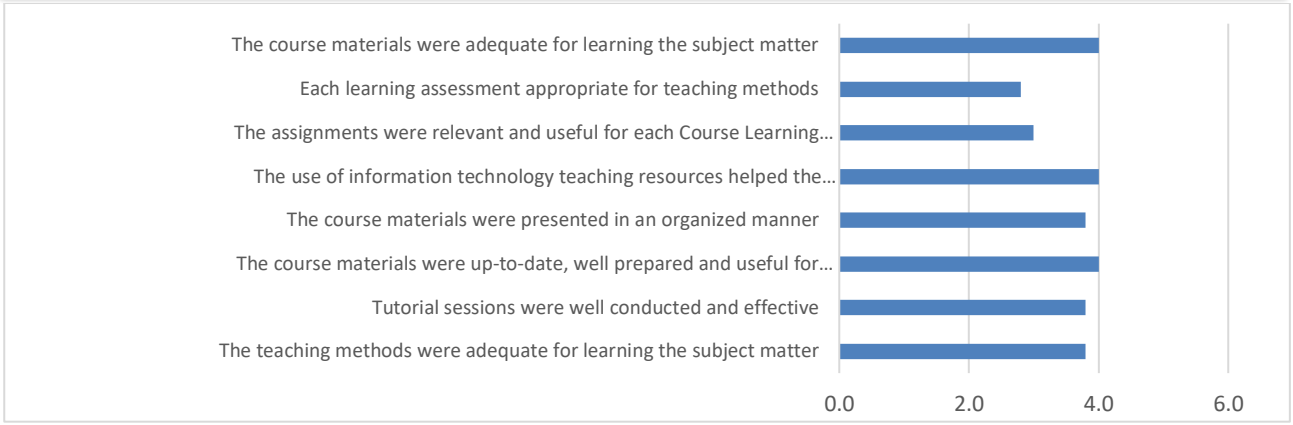

Figure 27. Intelligent Decision Support Systems: evaluation results on Course Delivery/Teaching Methods/Resource Materials

Workshop sessions delivered within the course were evaluated quite positively. The positive evaluation mostly concerns the integration of workshop sessions within the course workload. The complaints of the students referred to the availability of the equipment (Figure 28).

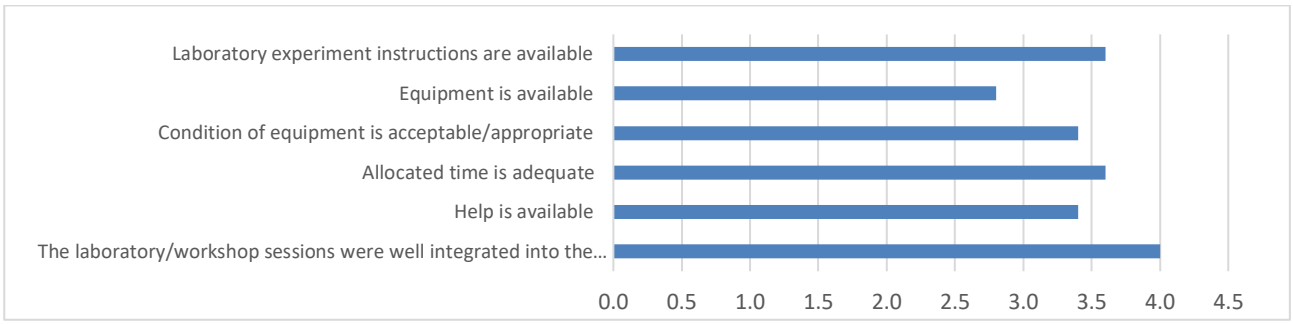

Figure 28. Intelligent Decision Support Systems: evaluation results on Laboratory/Workshop Sessions

Overall assessment went pretty good and showed special appreciation to the conduct of the course, objectivity of grading, and knowledge and competences gain from the course (Figure 29).

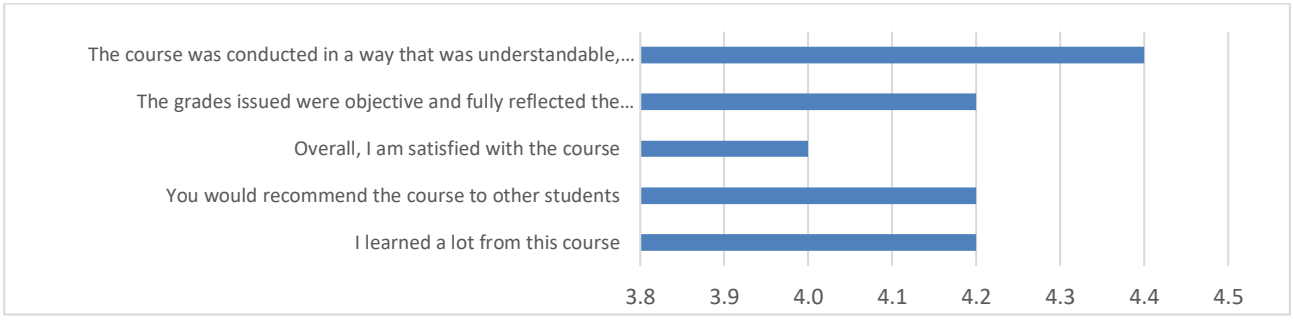

Figure 29. Intelligent Decision Support Systems: Overall Assessment results

Students admit that their attendance in the course was quite high (Figure 30).

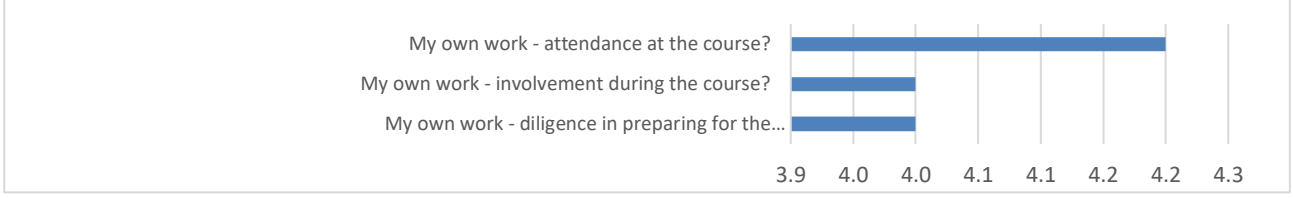

Figure 30. Intelligent Decision Support Systems: Student self-assessment results

Open comments from students, in general, showed appreciation of course specific skills, what is confirmed by the following comments:

"Skills in management and problem solving skills" and

"Data analytics and data engineering".

As for the proposals to enrich the course the students vowed for including the following issues:

"Machine Learning"

"technological knowledge, and integration with the era".

As for teachers assessment, all the important elements of course syllabus and teaching approach there has been some problem concerning the TLMs and evaluation methods that has impacted the achievement of CLOs and course objective (Figure 31). According to the teacher, the problem was related to the lack of programming competencies that were crucial for finishing term project.

General recommendations from course teacher concerning possible changes in the course content are:

"Add more contents related to industry 4.0" and

"Laboratory to support smart industry".

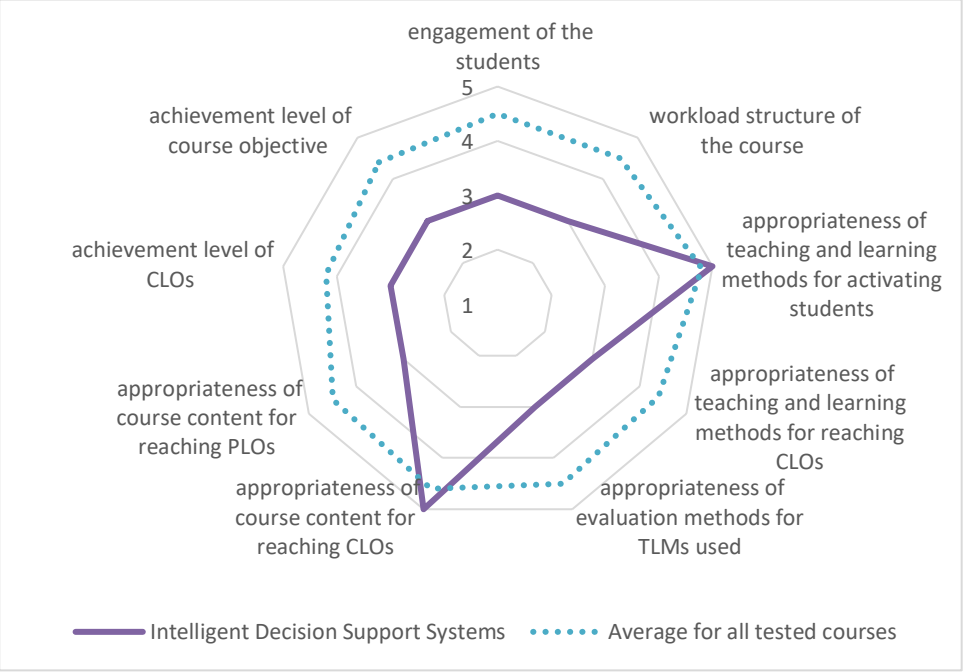

Figure 31. Intelligent Decision Support Systems: course teacher perspective

3.7 Course 9: Applied Data Analytics

Applied Data Analytics (ADA) course has been tested by Asian Institute of Technology in spring semester 2019//2020. Evaluation of the course has been made through the online survey of students. Evaluation results of course characteristics showed that the course was well outlined, assessment methods and course workload were appropriate, requirements of the course were just and topics treated with sufficient depth (Figure 32).

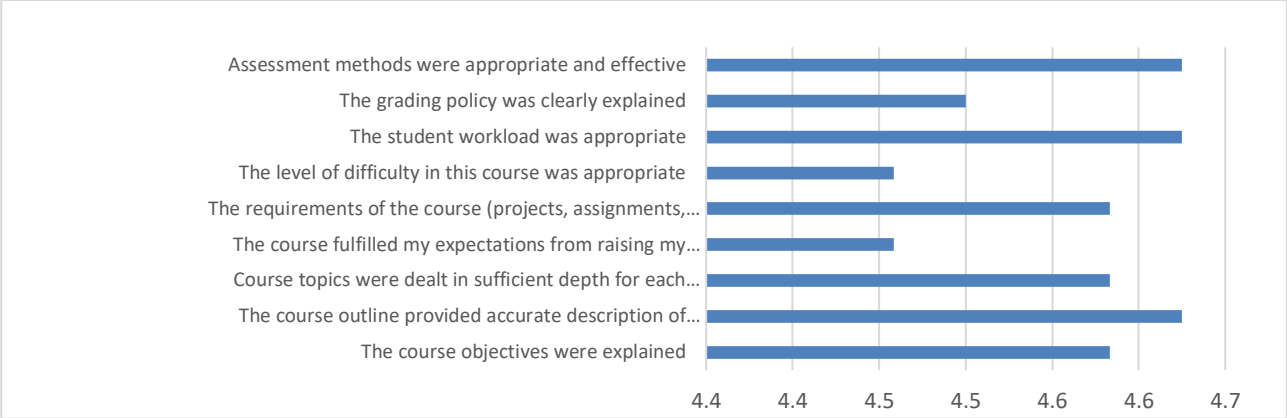

Figure 32. Applied Data Analytics: evaluation results on Course Characteristics

Evaluation of course delivery, teaching methods and resource materials went also good. It shows the appropriateness especially on the level of teaching methods selection, relevance of teaching methods to the assessment criteria and timeliness of course materials (Figure 33).

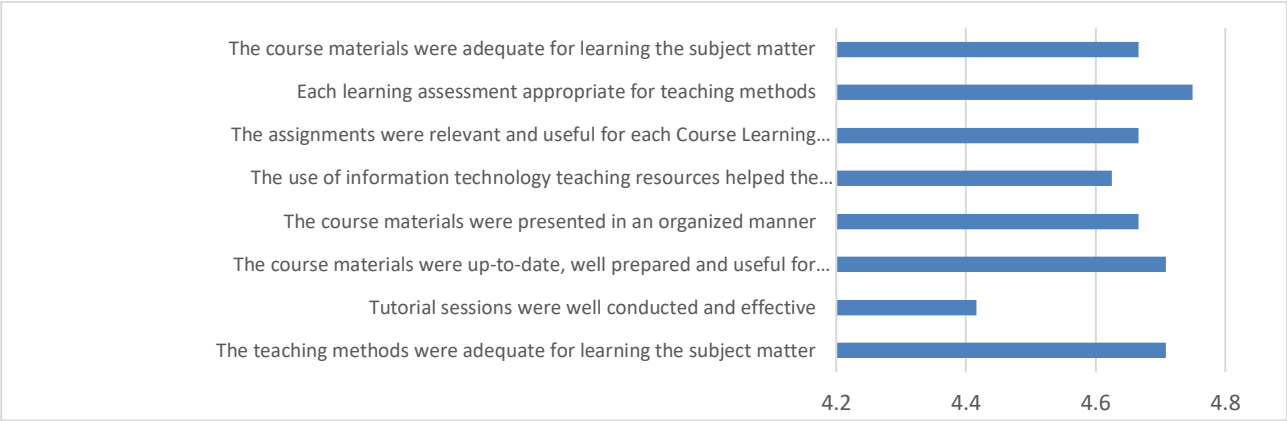

Figure 33. Applied Data Analytics: evaluation results on Course Delivery/Teaching Methods/Resource Materials

Workshop sessions delivered within the course were evaluated positively. The positive evaluation mostly concerns the availability of support from the teachers (Figure 34). There are no significant negative assessments in any of the categories.

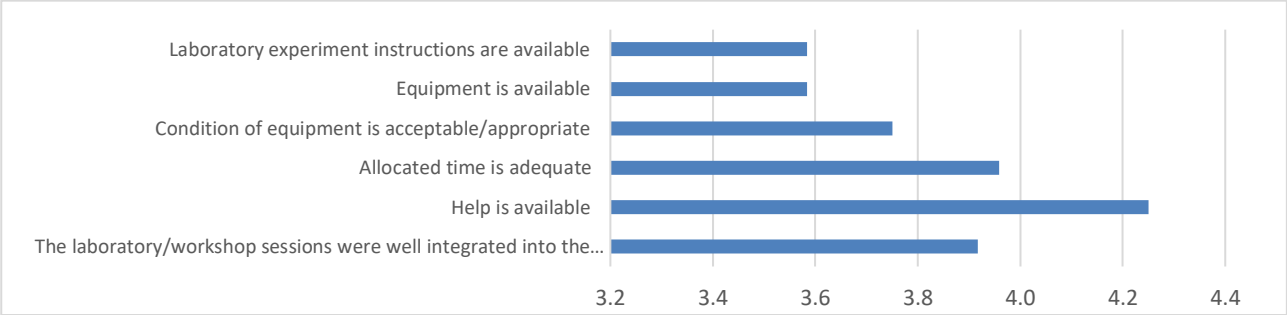

Figure 34. Applied Data Analytics: evaluation results on Laboratory/Workshop Sessions

Overall assessment showed that the course is satisfactory for the students, there is a strong willingness to recommend the course further and appreciation of knowledge and competences gained from the course (Figure 35).

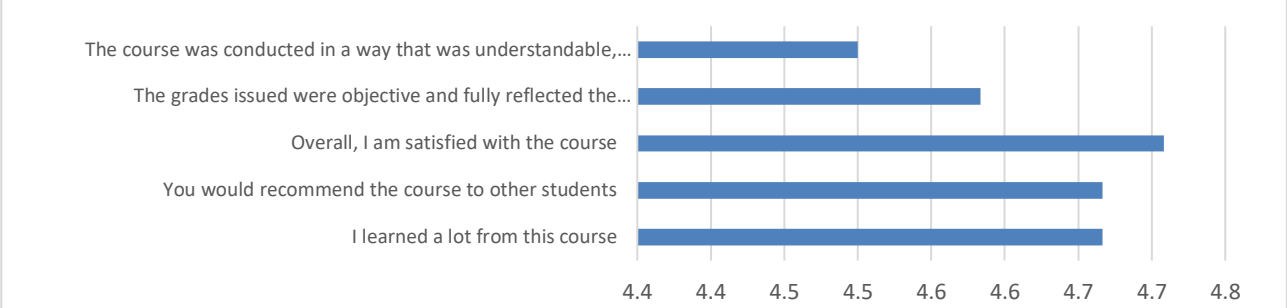

Figure 35. Applied Data Analytics: Overall Assessment results

The assessment of the course have been made with high attendance and involvement of students (Figure 36).

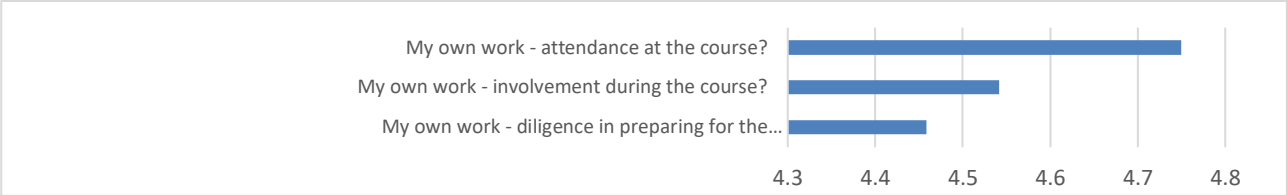

Figure 36. Applied Data Analytics: Student self-assessment results

Open comments from students in general, showed appreciation of several course elements including the following:

> *"Attention to details in the lectures and assignments. Explanation in simpler terms in lectures. Assignments should compare to the actual industry problems. Video recordings of lectures are a lifeline."*
>
> *"Analytical thinking, interpersonal skills and digital literacy", "Model analysis", "Decision making skills in real life situations", "R , Data analysis in details", "Problem-solving skills"*
>
> *"More practical based teaching of relevant course topics should be implemented."*
>
> *"Precise analysis, communication skill, and leadership."*
>
> *"I think strong basic fundamentals behind every section relevant to the course should be the primary focus for a teacher to educate their students and for making it a clear understanding practical hands on exercise should be given. In my opinion, learning tools and software's without knowing the true value generated from the tools and software is meaning less and can lead to totally wrong conclusion. "*
>
> *"Ethics and responsibility", "Social Awareness and self-awareness should be noted".*

As for the proposals to enrich the course the students vowed for the following issues:

> *"The practical work should be practiced with the on-going market trends.",*
>
> *"Wider vision and teamwork",*
>
> *"Attention to details in the lectures and assignments. Explanation in simpler terms in lectures. Assignments should compare to the actual industry problems. Video recordings of lectures are a lifeline.",*
>
> *"Utilization of available technological resources in efficient manner.",*
>
> *"Communication and problem-solving skills",*
>
> *"As data is being more and more accessible. Personally, students should be educated and at least made familiar with basic concept on working with data. Within AI, machine learning and deep*

learning are gaining extremely attraction and they have been proved useful as well. So, basic algorithm behind it or the basic concept behind them should somehow be shared with even students apart from the relevant field because sooner or later a lot of industry will seek people who are familiar and proficient with these concepts.",

"The using of various software and precise analysis.",

"I think social skills like project management, communication skills should be noted in process of educating students in preparing them to work in a Industry 4.0 market".

As for teachers assessment, all the important elements of course syllabus and teaching approach have been well designed and performed and played its roles in educational process (Figure 37). There are no specific recommendations concerning the elements of course structure.

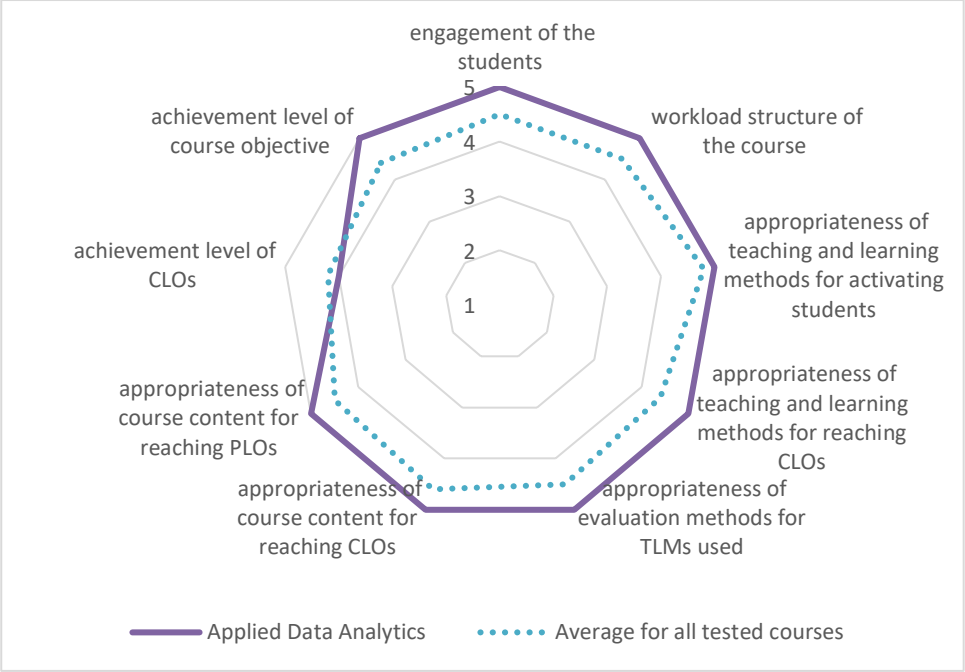

Figure 37. Applied Data Analytics: course teacher perspective

3.8 Course 10: Cyber-Physical Industrial Systems

Cyber-Physical Industrial Systems (CPIS) course has been tested by University Politehnica of Bucharest. The course has been tested within existing program partially replacing content of Experimental Research course. The course was tested in autumn semester 2019/2020. Evaluation results of course characteristics showed that the course in general fulfilled students' expectations, requirements and course workload were appropriate (Figure 38).

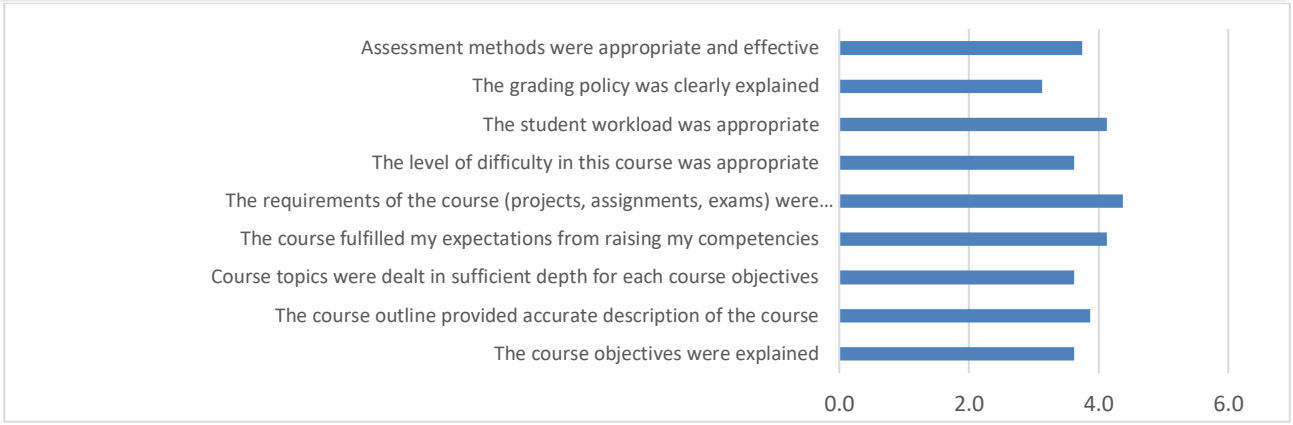

Figure 38. Cyber-Physical Industrial Systems: evaluation results on Course Characteristics

Evaluation of course delivery, teaching methods and resource materials went quite good. It shows the appropriateness especially on the level of teaching methods selection (Figure 39).

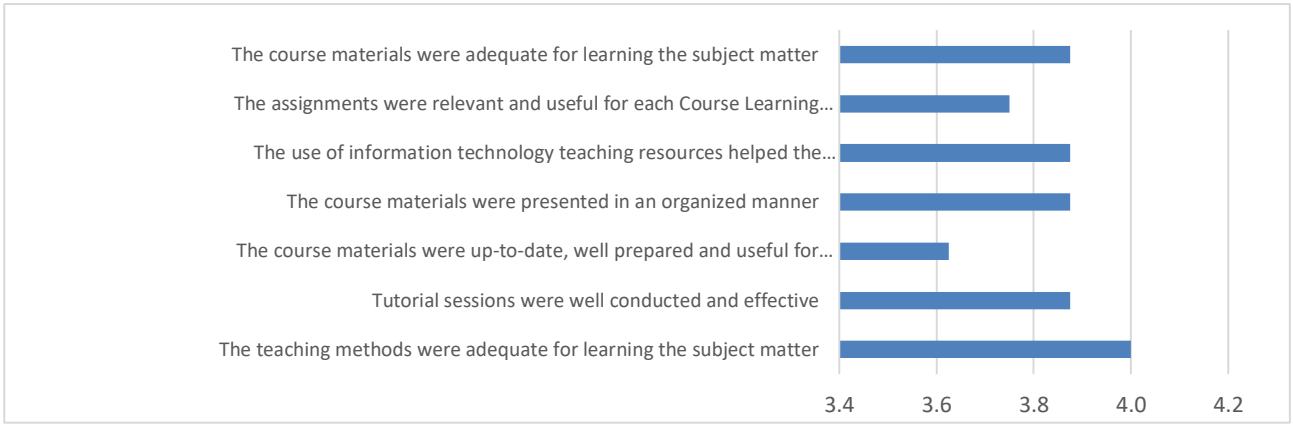

Figure 39. Cyber-Physical Industrial Systems: evaluation results on Course Delivery/Teaching Methods/Resource Materials

Laboratory sessions delivered within the course were evaluated positively. The positive evaluation mostly concerns the availability of support from the teachers, availability of equipment and experiment instructions (Figure 40).

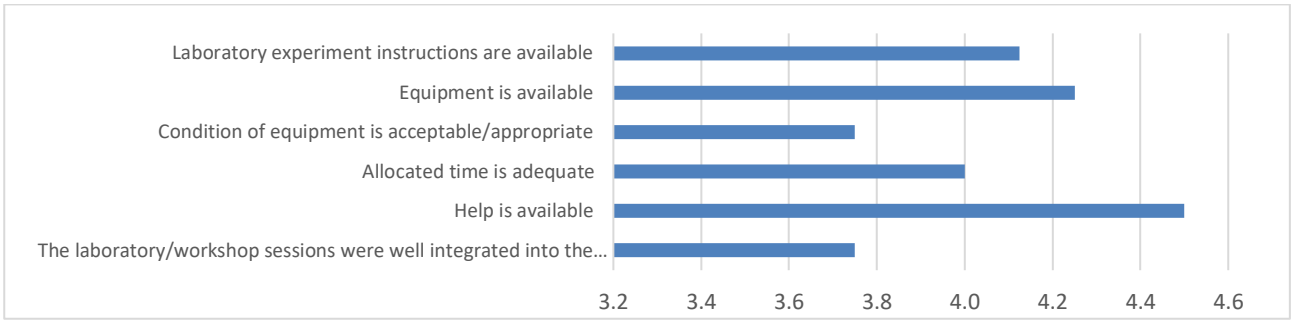

Figure 40. Cyber-Physical Industrial Systems: evaluation results on Laboratory/Workshop Sessions

Overall assessment showed that the course is satisfactory for the students (Figure 41).

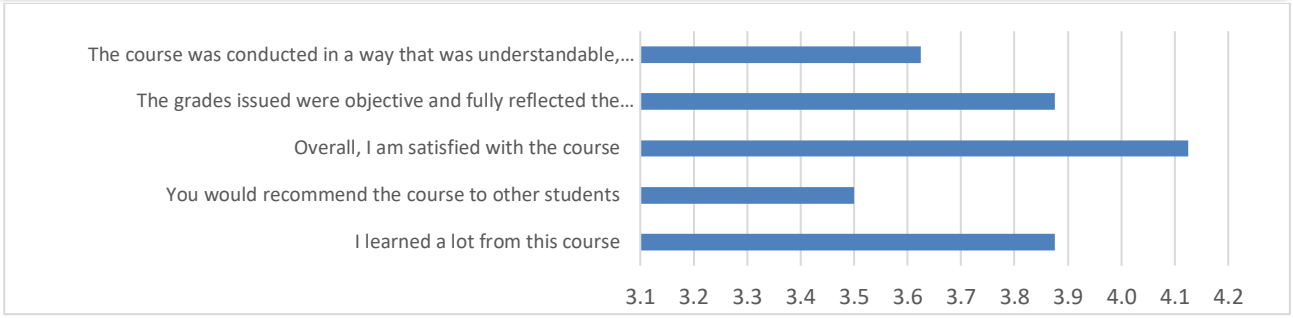

Figure 41. Cyber-Physical Industrial Systems: Overall Assessment results

The assessment of the course have been made with high attendance of students (Figure 42).

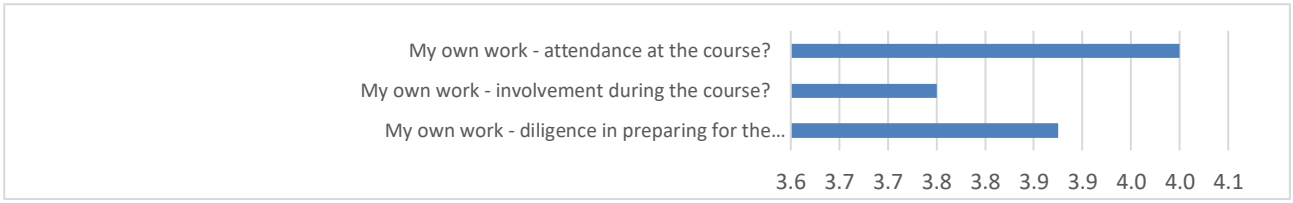

Figure 42. Cyber-Physical Industrial Systems: Student self-assessment results

As for teachers assessment, all the important elements of course syllabus and teaching approach have been well designed and performed and played its roles in educational process (Figure 43). There are no specific recommendations concerning the elements of course structure.

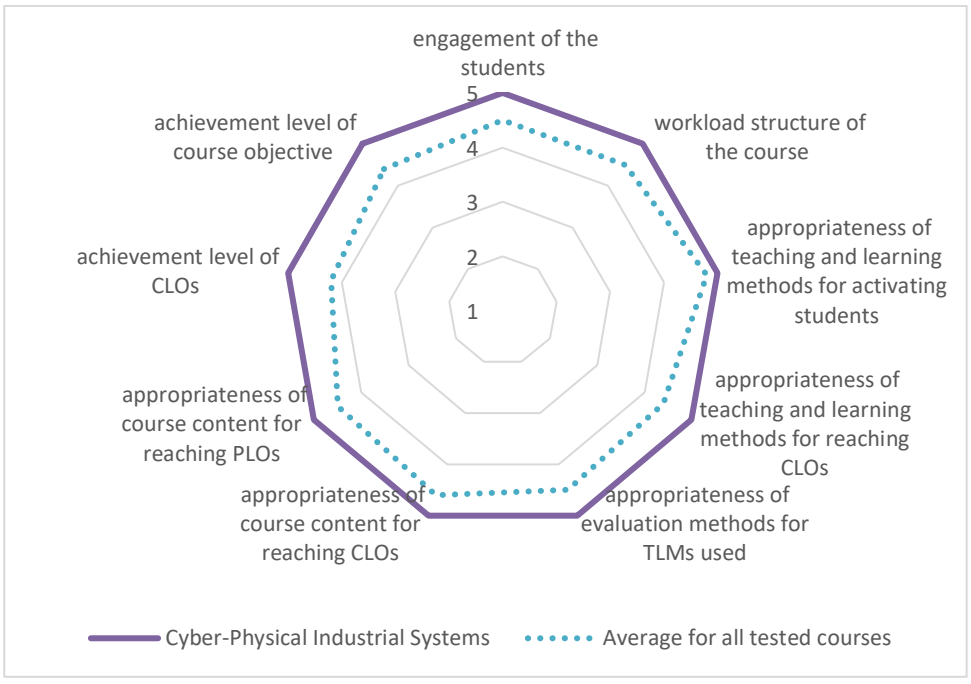

Figure 43. Cyber-Physical Industrial Systems: course teacher perspective

3.9 Course 14: Human-Centric Design for Operator 4.0

Human-Centric Design for Operator 4.0 (HCDO4) course has been tested by Thammasat University. Evaluation of the course has been made through the University specific online survey of students in spring semester 2019/2020. Since the evaluation was based on university specific questionnaire its content differs from the one used by other Partners. Despite the differences, several of similar evaluation categories are included here. Evaluation showed that the course materials were considered adequate, well organized and

timeliness. Students received sufficient support from the teachers and the course conduct was good (Figure 44).

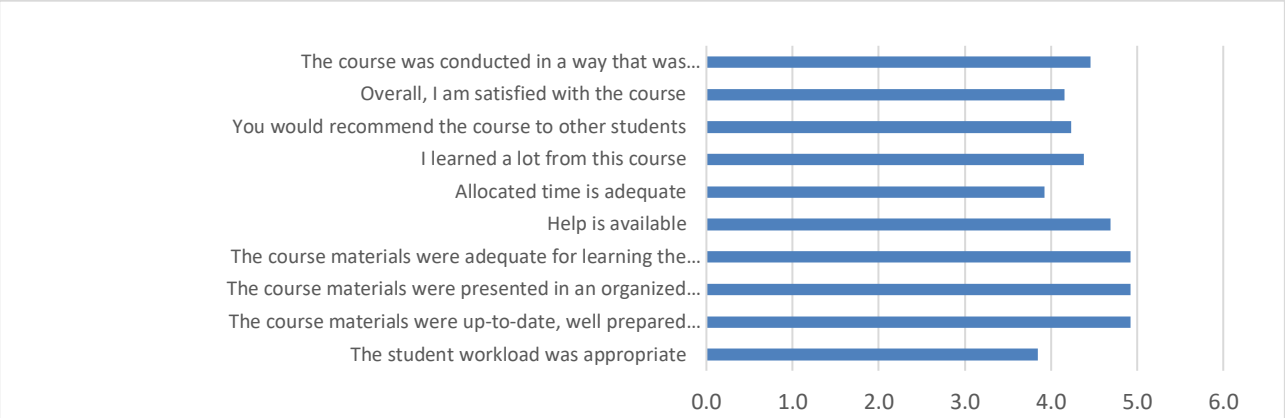

Figure 44. Human-Centric Design for Operator 4.0: evaluation results on selected issues

As for the proposals to enrich the course the students vowed for more practice oriented course conduct and inclusion of some Industry 4.0 technologies. Following comments indicate what features could be added to the course:

> *"3D print"*
>
> *"Putting the design into practice"*
>
> *"Real lab tests with the test instrument still not found (COVID-19)"*
>
> *"Sharing multiple workplace problems and exchanging deals."*

Students also expressed some critical comments towards the conduct of the course:

> *"The teachers teach well, understand the interesting content. But with no background in this matter and there are many workshops, so it is not suitable for a master's course That everyone works That is, if we had time to meet and discuss, the work would have been better."*
>
> *"Assignment too much work Should have decreased somewhat"*
>
> *"Reduce the number of drawing jobs in some parts. And change to present the problem that you want to solve in the work page that students want to solve"*

3.10 Course 16: Communications and People Skills Development for Engineering Leaders

Communications and People Skills Development for Engineering Leaders (CPS) course has been tested by Asian Institute of Technology in autumn semester and by King Mongkut's University of Technology North Bangkok in spring semester 2019//2020. Evaluation of the course has been made through the online survey of students. Evaluation results of course characteristics showed that the course was well outlined, assessment methods and course workload were appropriate, and CLOs well explained (Figure 45).

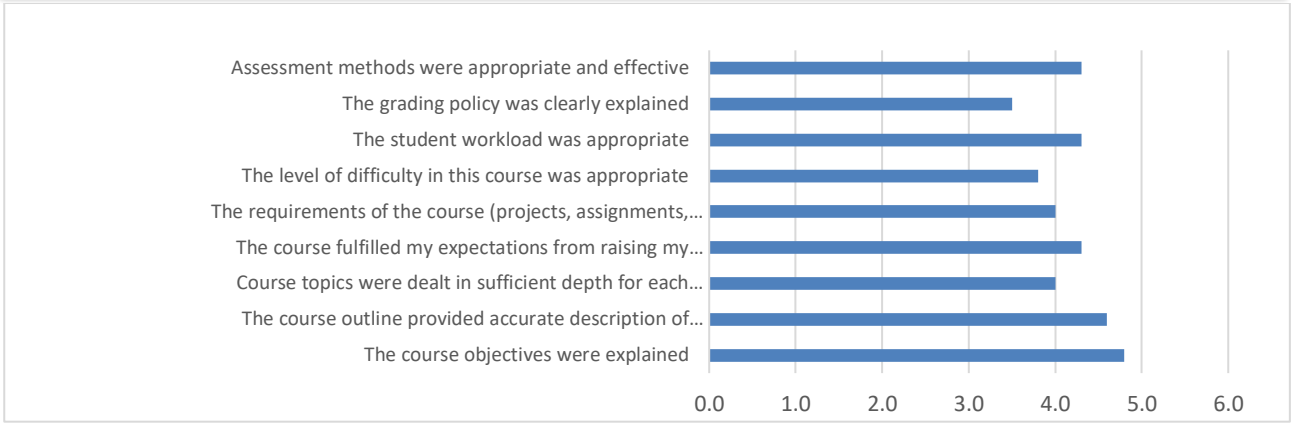

Figure 45. Communications and People Skills Development for Engineering Leaders: evaluation results on Course Characteristics

Evaluation of course delivery, teaching methods and resource materials went also good. The results shows the appropriateness especially on the use of information technologies and organization and timeliness of course materials (Figure 46).

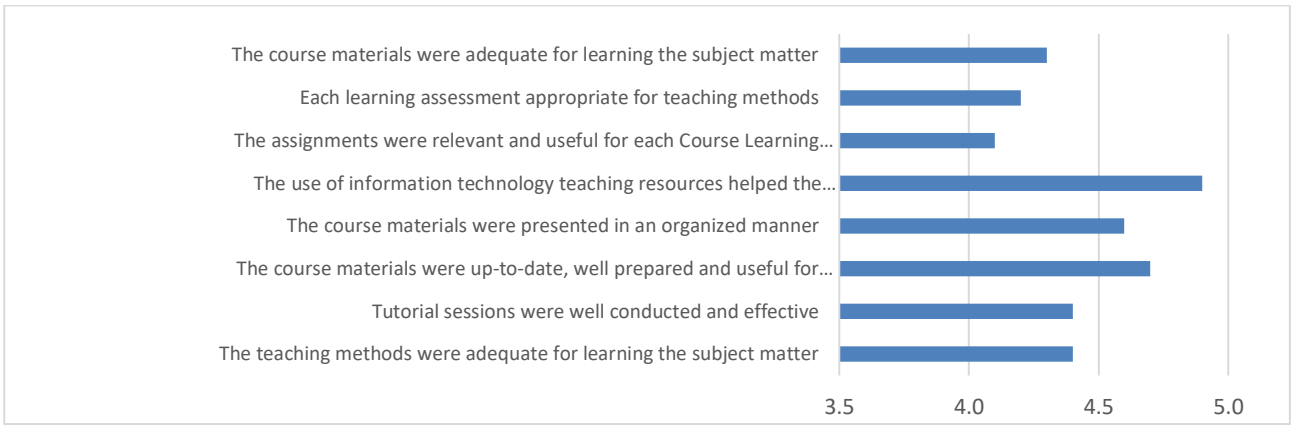

Figure 46. Communications and People Skills Development for Engineering Leaders: evaluation results on Course Delivery/Teaching Methods/Resource Materials

Workshop sessions delivered within the course were evaluated positively. The positive evaluation mostly concerns the availability of equipment, its condition and sufficient instructions (Figure 47). There are no significant negative assessments in any of the categories.

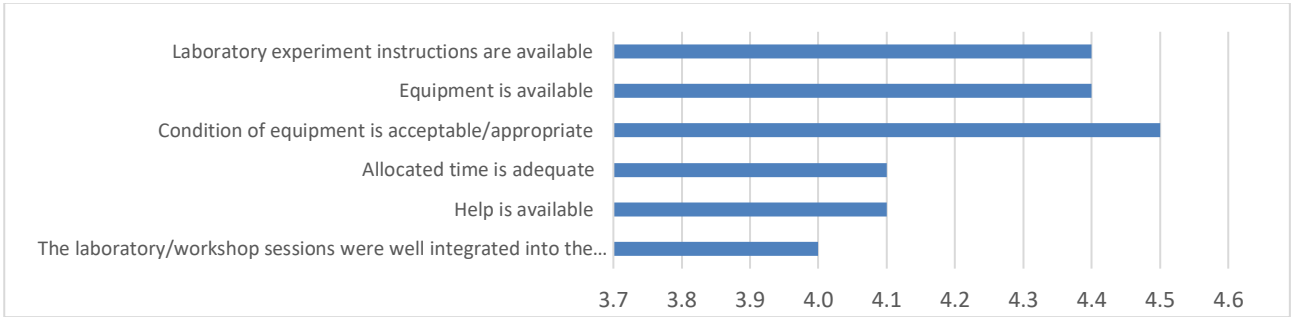

Figure 47. Communications and People Skills Development for Engineering Leaders: evaluation results on Laboratory/Workshop Sessions

Overall assessment showed that the course brings new knowledge and skills for the students and willingness to recommend the course further (Figure 48).

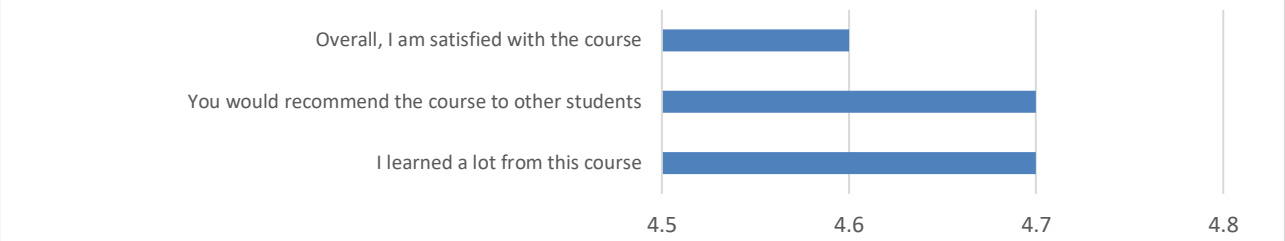

Figure 48. Communications and People Skills Development for Engineering Leaders: Overall Assessment results

As for the proposals to enrich the course the students vowed for some technical and organizational improvements. Following comments indicate what features could be revised in the course:

> *"Is it possible or not? --> 1.If we use online software for lecture, 2.It will be better if we can watch repeatedly, 3.Take time in classroom for practice and apply theory from online lectures."*
>
> *"I think lecture class and workshop class should separate the day of class because I want the time for review the lesson."*
>
> *"More practice time of students in classroom."*
>
> *"More in-depth study on topics like writing."*

They also showed some appreciation for the conduct of the course:

> *"In the very first time of this course, I think I am tried, but after that, this course becomes interesting and effective for our future. I am sure that I would recommend this course to my friends."*

As for teachers assessment, all the important elements of course syllabus and teaching approach have been well designed and performed and played its roles in educational process (Figure 49). There are no specific recommendations concerning the elements of course structure.

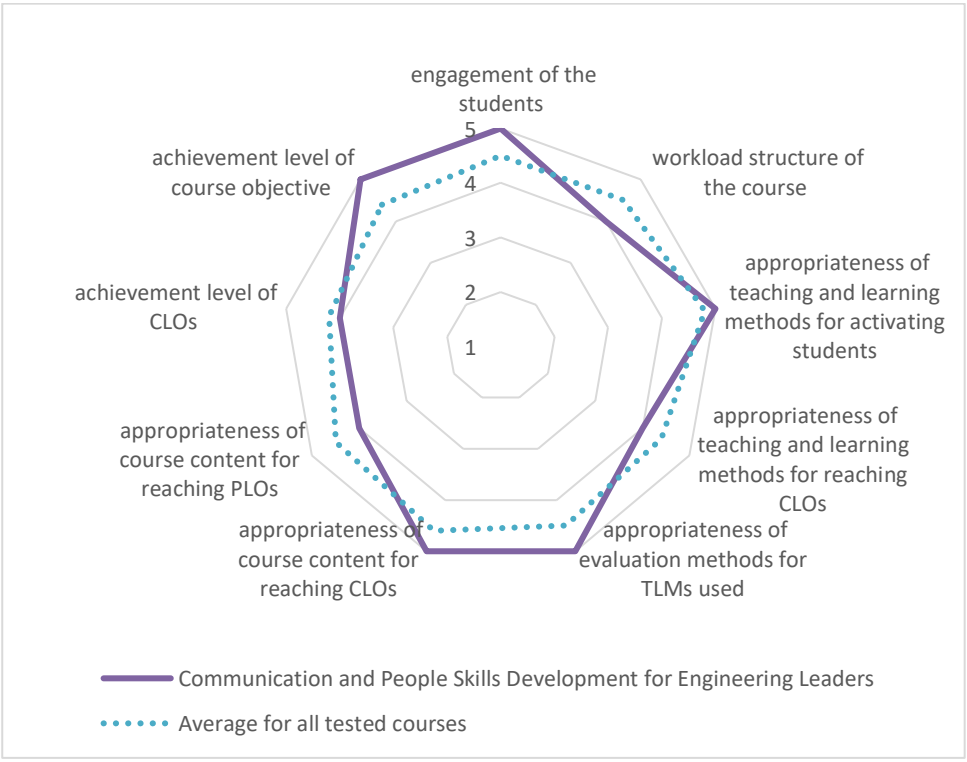

Figure 49. Communications and People Skills Development for Engineering Leaders: course teacher perspective

CPS course has a special status within MSIE4.0 curriculum. It is an obligatory course and brings special focus on soft and transversal skills that are becoming more and more important for IE graduates. As for the relation of CPS course to other courses the teacher notes that:

"It's a foundation for student active participation in other courses"

The achievement of its CLOs is not only important for the graduate and its skill set offered on the labor market but also for students and its learning process throughout the whole studying period. Providing CLOs to students early enough would encourage them and make them better prepared for active learning experiences.

4 Recommendations for MSIE4.0 curriculum from the pilot testing of selected courses

Student based assessment overall results should be discussed within the three categories: course characteristics, course delivery and laboratory/workshop sessions.

Concerning the students feedback on general course characteristics there is no significant issue that should be addressed with immediate changes within course syllabuses. Figure 50 presents the average assessment of general course characteristics from the perspective of students. The issues that could be problematic during the run of the MSIE4.0 curriculum rather refer to the depth of dealing with course objectives, the difficulty level and explaining grade policy, which are typical performance characteristics of a course. Course performance indicators depend individual on teachers and students perception and possible recommendations on them refer to the preparation of each one of course runs. The recommendations are to make effort to present the course content and use its TLMs in a way that supports the absorption and immersion of knowledge and skills by students. Additionally, the recommendation is to keep students informed and updated on grading policy and their performance throughout the course.

One of the issues that could be problematic while students perspective is considered is the course workload. The recommendation here is to make all contact hours meaningful for students and stimulate their learning processed within self-studying time. It is not an easy task, and perhaps needs several runs of each course until optimal learning approach and workload structure adoption is worked out. Therefore, the recommendation is to monitor the curriculum implementation process and enable course syllabus adjustments throughout the advancements of process. As EU higher education system practices shows, regular adoptions of syllabus helps in keeping its educational power in line with current industrial, educational and individual possibilities.

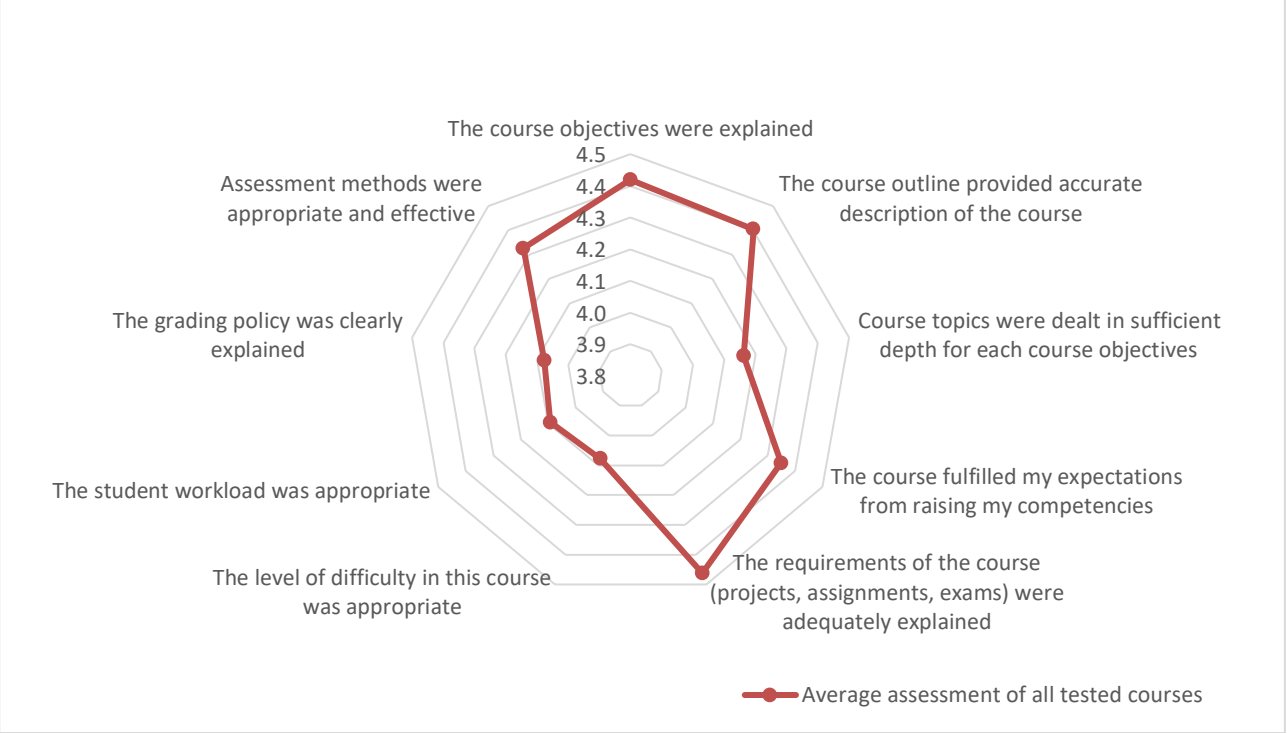

Figure 50. Average assessment of general course characteristics: perspective of students

As for students general feedback on course delivery there is no significant issue that should be addressed with immediate changes within course syllabuses, teaching approach or course content. Figure 51 presents the average assessment of general course delivery issues from the perspective of students. The only issue that could depreciate the educational efforts is related to the coherence between the assessment and teaching methods. Perhaps, this issue is one of the biggest challenges of educational process and needs careful and individual considerations before, during and after the educational process. Therefore, the recommendations for the organization of MSIE4.0 curriculum is to organize appropriate conditions and support for teachers to consider the coherence between the teaching methods and assessment strategy. In order to achieve that coherence, it is important to provide non-biased feedback streams from the students and peer evaluations of courses. Additionally, the institutional and program related framework should enable appropriate framework for revising the courses and optionally the program as well.

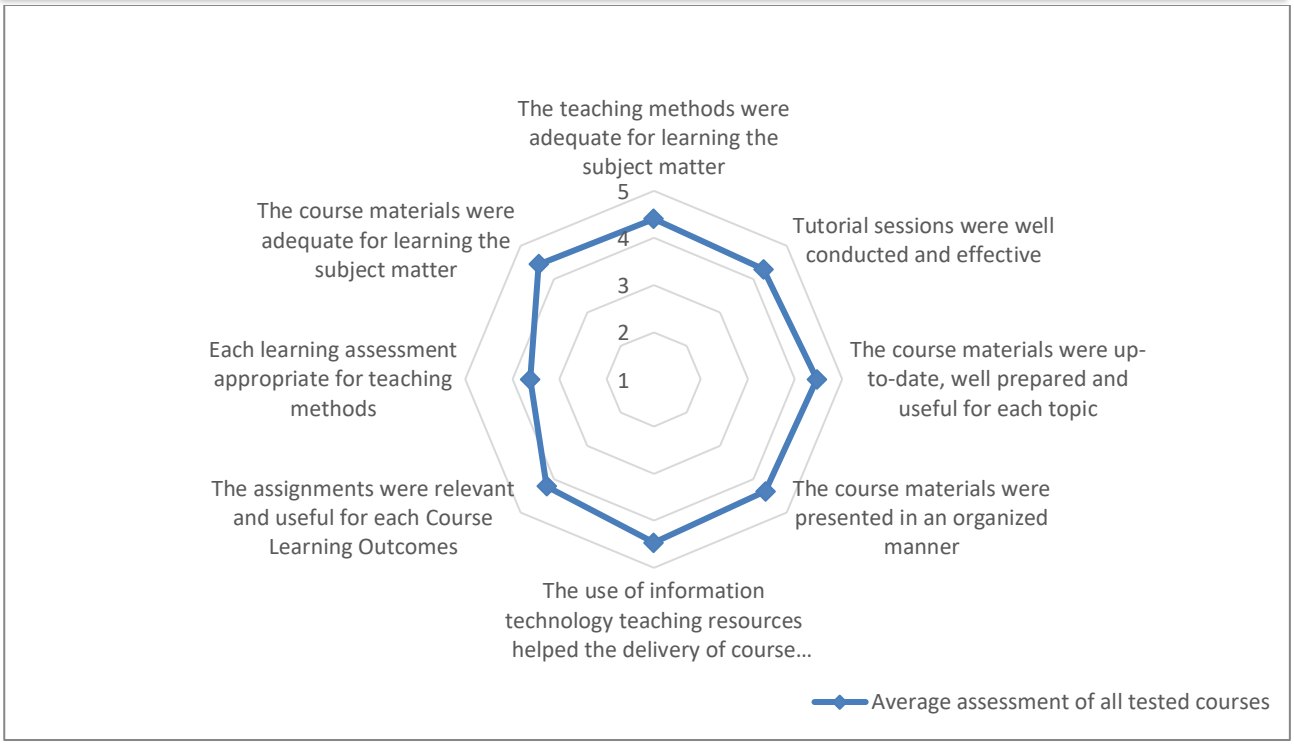

Figure 51. Average assessment of general course delivery categories: perspective of students

As for students general feedback on laboratory and workshop session there is no significant issue that should be addressed. Figure 52 presents the average assessment of general course delivery issues from the perspective of students. It seems, that all pilot tested course have been prepared well enough while laboratory and workshop sessions are considered. Therefore, there is no need to formulate any recommendations here basing of students feedback.

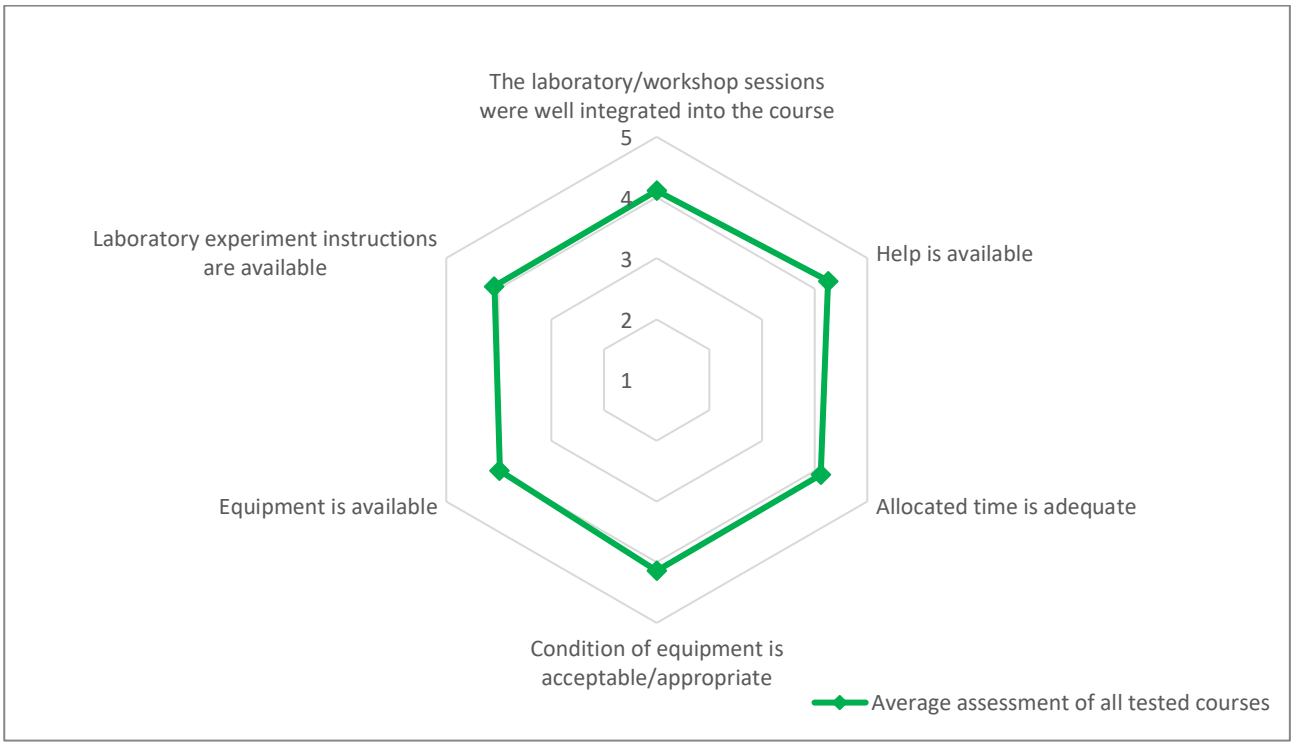

Figure 52. Average assessment of laboratory and workshop sessions: perspective of students

Figure 53 shows the overall average assessment of pilot tested courses. The feedback from students shows that participating in those courses has been meaningful and self-developing experience for them. If MSIE4.0 curriculum would stood up to keep it that way through its complex implementation on different Partner universities it will certainly become important milestone in building sustainable and smart industry.

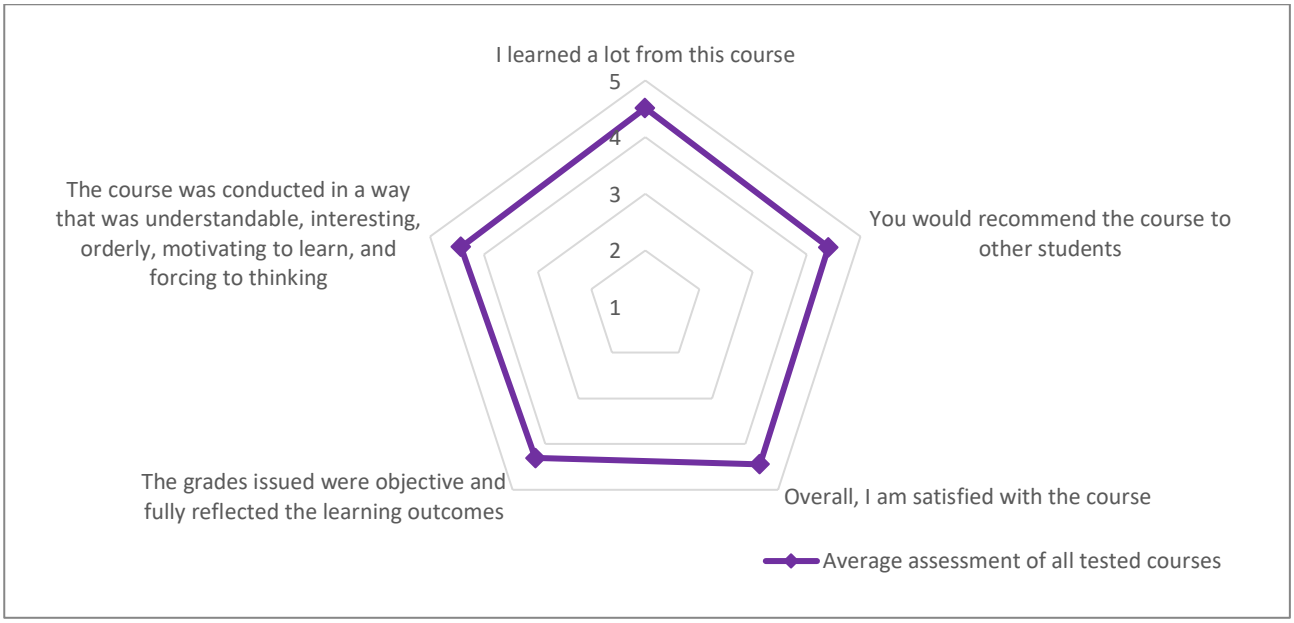

Figure 53. Average overall assessment: perspective of students

As for general recommendation from course teachers, there is no strong need for such changes observed. Table 3 shows the summary of these recommendations with reference to specific courses and its building blocks. Course content and course workload structure are the two categories that have multiple ticks on its recommended or possible changes.

The issue of workload structure was discussed from the beginning of MSIE4.0 curriculum development process and finally, it was agreed to define it to keep the standard amount of credits for each course. The solutions that was adopted here enabled the course development on the basis of pre-defined workload schemes. Those schemes combined number of contact hours and its structure, including lectures, workshops and laboratory sessions, in a way to get specific amount of credits for each combination. The process of developing courses was finalized in Outcome 2.2 but the internal rules within some Partner universities does not support the adopted credit system. It means that the credits for each course as calculated for its workload structure could be different in different Partner universities. Therefore, the recommendation that was already formulated in Outcome 2.1 on possible adjustments of MSIE4.0 curriculum in its implementation process, still holds and could impact curriculum as a whole and its courses as well.

The issue of course content was discussed mainly within Work package 3. Curriculum Development II: Modernisation of teaching methods and tools for innovative MSc programmes. There has been multiple verification stages on course materials including course material assessment within Task 3.1, Task 3.3 and Task 3.5. The criteria used within the aforementioned tasks have been oriented on different aspects including: the reference to course syllabus, its structure, formatting, originality, consistence with online learning conditions, inclusion of guidance for its future teachers, and etc. Since the course content, as prepared for the moment of writing this report, is the most susceptible element for the changing business environment, industrial practices and and market evolution, it should be updated in each year of offering the course and possibly adjusted to the specific conditions of each Partner introducing it. General recommendation therefore, concerning the course content is to keep it updated and matched to local conditions.

Table 3. Recommendations from teachers of tested courses with reference to main elements of course syllabus

	Would you recommend changes within:				
Tested Courses	**Course workload structure**	**CLOs**	**Course content**	**Assessment methods**	**Teaching and learning methods**
Project Management for Industry 4.0	No	No	No	No	Not sure
Smart Operations Management	No	No/Yes	No/Yes	No	No
Sustainable Supply Chain Management	No	No	No	No	No
Digital Factory	No	No	No	No	No
Advanced Optimization: Techniques and Industrial Applications	Yes	No	Yes	No	No
Intelligent Decision Support Systems	Yes	No	Yes	No	No
Applied Data Analytics	No	No	No	No	No
Cyber-Physical Industrial Systems	Not sure	No	Not sure	No	No
Human-Centric Design for Operator 4.0	n/a	n/a	n/a	n/a	n/a
Communications and People Skills Development for Engineering Leaders	No	No	No	No	No

Finally, the feedback from different internal and external stakeholders should be noted. Throughout the pilot testing of selected courses there is no consortium wide approach towards gathering such a feedback. There are some issues that make such a process difficult and time consuming. First of all, the best feedback would be if internal and external stakeholders could verify the knowledge, skills and competencies of students after they finish participating in tested courses. Unfortunately, due to time constrains it was not possible to gather such a feedback. Secondly, the educational process on higher education institution is not very often shared with external stakeholders. The exceptions from that rule include cooperation with business environment and study visits within the run of the course. Some examples, like business oriented projects within Project Management for Industry 4.0 course, or study visits within Digital Factory and Smart Operations Management courses, confirm that business environment accepts and supports approach adopted within MSIE4.0 curriculum.

5 References

Chanchittakarn, C., Buakaew, K., & Kengpol, A. (2020). Learning Experiences from Digital Factory Subject and Communications and People Skills Development for Engineering Leaders Subject. In R. M. Lima, V. Villas-Boas, P. Koomsap, & K. Sethanan (Eds.), *Proceedings of the PAEE/ALE'2020, International Conference on Active Learning in Engineering Education; Striving engineering education towards student competence development* (pp. 237–243). Retrieved from http://paee.dps.uminho.pt/proceedingsSCOPUS/PAEE_ALE_2020_PROCEEDINGS.pdf

Kengpol, A., Koohathongsumrit, N., & Meethom, W. (2020). Design, Implementation, and Improvement of the Course for Master's Degree Program in Industry 4.0: A Case Study in Digital Factory Subject. In R. M. Lima, V. Villas-Boas, P. Koomsap, & K. Sethanan (Eds.), *Proceedings of the PAEE/ALE'2020, International Conference on Active Learning in Engineering Education; Striving engineering education towards student competence development* (pp. 127–134). Retrieved from http://paee.dps.uminho.pt/proceedingsSCOPUS/PAEE_ALE_2020_PROCEEDINGS.pdf

Lima, R. M., Mesquita, D., Aquere, A. L., & Jesus, C. de. (2020). Evaluation of a Pilot Course of Project Management for Industry 4.0. In R. M. Lima, V. Villas-Boas, P. Koomsap, & K. Sethanan (Eds.), *Proceedings of the PAEE/ALE'2020, International Conference on Active Learning in Engineering Education; Striving engineering education towards student competence development* (pp. 271–277). Retrieved from http://paee.dps.uminho.pt/proceedingsSCOPUS/PAEE_ALE_2020_PROCEEDINGS.pdf

6 Annex I. Course evaluation form for students

COURSE EVALUATION FORM

Course Title:
Course Duration: From…….. To……
Instructor:

Please evaluate by ticking [X] on the appropriate degree (1-weak: 5-strong)

PART I:

Course Characteristics:	**1**	**2**	**3**	**4**	**5**
The course objectives were explained.					
The course outline provided accurate description of the course.					
Course topics were dealt in sufficient depth for each course objectives.					
The course fulfilled my expectations from raising my competencies					
The requirements of the course (projects, assignments, exams) were adequately explained.					
The level of difficulty in this course was appropriate.					
The student workload was appropriate.					
The grading policy was clearly explained.					
Assessment methods were appropriate and effective.					

Other Comments:

……...……

……...

PART II:

Course Delivery/Teaching Methods/Resource Materials:	**1**	**2**	**3**	**4**	**5**
The teaching methods were adequate for learning the subject matter.					
Tutorial sessions were well conducted and effective					
The course materials were up-to-date, well prepared and useful for each topic					
The course materials were presented in an organized manner.					
The use of information technology teaching resources helped the delivery of course material.					

The assignments were relevant and useful useful l for each Course Learning Outcomes.					
Each learning assessment appropriate for teaching methods.					
The course materials were adequate for learning the subject matter.					

Other Comments:

……...……

……...

PART III:

Laboratory/Workshop Sessions: (if applicable)	**1**	**2**	**3**	**4**	**5**
The laboratory/workshop sessions were well integrated into the course.					
Help is available.					
Allocated time is adequate.					
Condition of equipment is acceptable/appropriate.					
Equipment is available.					
Laboratory experiment instructions are available.					

Other Comments:

……...……

……...

OVERALL ASSESSMENT

Overall Assessment:	**1**	**2**	**3**	**4**	**5**
I learned a lot from this course.					
You would recommend the course to other students.					
Overall, I am satisfied with the course.					
The grades issued were objective and fully reflected the learning outcomes.					
The course was conducted in a way that was understandable, interesting, orderly, motivating to learn, and forcing to thinking.					

Other Comments:

……...……

……...

STUDENT SELF-ASSESSMENT

Overall Assessment:	**1**	**2**	**3**	**4**	**5**
My own work - diligence in preparing for the course?					
My own work - involvement during the course?					
My own work - attendance at the course?					

Other Comments:

……...……

……...

What skills and competencies do you think should be noted in the process of educating students in preparing them to work in a sustainable market?

……...……

……...……

What skills and competencies do you think should be noted in the process of educating students in preparing them to work in a Industry 4.0 market?

……...……

……...……

7 Annex II. Course evaluation form for teachers

COURSE SELF-EVALUATION FORM
Please evaluate your own course on the appropriate degree
* Required
1. Course title that you've taught during pilot testing *
Mark only one oval.
Smart Operations Management
Advanced Optimization: Techniques and Industrial Applications
Digital Factory
Communications and People Skills Development for Engineering Leaders
Sustainable Supply Chain Management
Intelligent Decision Support Systems
Human-Centric Design for Operator 4.0
Project Management for Industry 4.0
Cyber-Physical Industrial Systems (under the existing course on Experimental Research)
Communication and People Skills Development for Engineering Leaders
Applied Data Analytics

PART I
Course assessment
2. How do you assess the engagement of the students? *
Mark only one oval.
weak 1 2 3 4 5 strong
3. How do you assess the workload structure of the course? *
Mark only one oval.
not appropriate 1 2 3 4 5 appropriate
4. How do you assess the appropriateness of teaching and learning methods for activating students? *
Mark only one oval.
weak 1 2 3 4 5 strong
5. How do you assess the appropriateness of teaching and learning methods for reaching CLOs? *
Mark only one oval.
weak 1 2 3 4 5 strong
6. How do you assess the appropriateness of evaluation methods for TLMs used? *
Mark only one oval.
weak 1 2 3 4 5 strong
7. How do you assess the appropriateness of course content for reaching CLOs? *
Mark only one oval.
weak 1 2 3 4 5 strong
8. How do you assess the appropriateness of course content for reaching PLOs? *
Mark only one oval.
weak 1 2 3 4 5 strong
9. How do you assess the achievement level of CLOs? *
Mark only one oval.
weak 1 2 3 4 5 strong
10. How do you assess the achievement level of course objective? *
Mark only one oval.
weak 1 2 3 4 5 strong
11. Other Comments

PART II
Recommendations
12. Would you recommend changing course workload structure? *
Mark only one oval.
Yes
No
Not sure
13. Would you recommend changing existing CLOs? *
Mark only one oval.
Yes
No
Not sure
14. Would you recommend changing course content? *
Mark only one oval.
Yes
No
Not sure
15. Would you recommend changing assessment methods? *
Mark only one oval.
Yes
No
Not sure
16. Would you recommend changing teaching and learning methods? *
Mark only one oval.
Yes
No
Not sure
17. Would you recommend changing course objectives? *
Mark only one oval.
Yes
No
Not sure
18. If you recommended any changes please elaborate indicating what could be changed
19. Do you have any recommendations concerning the relationship of your course with other courses in MSIE4.0 curriculum?
20. Do you have any recommendations concerning the improvement of your course relevance to Industry 4.0 technologies?
21. Do you have any recommendations concerning the improvement of your course relevance to sustainability issue?
22. Do you have any recommendations concerning the improvement of your course relevance to smart industry concept?