WP 1 - Non-university capacity assessment

Outcome 1.3. An assessment report on non-university capacity

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1 Executive Summary

The ReCap4.0 project aims to develop competences for the non-university sector in Thailand in the context of Industry 4.0 (I4.0) and innovative teaching and learning approaches. Consequently, the potential target institutions are the 40 Rajabhat Universities and the 9 Rajamangala Universities of Technology. Considering the scope of the project, the target teaching staff consists of mainly teachers from Industrial Engineering or similar departments and programs.

This document constitutes the outcome 1.3 - An assessment report on non-university capacity, of the WP1 - Non-university capacity assessment. The assessment of the capacity of teaching staff from the non-university sector in Thailand was conducted through a self-perception questionnaire encompassing knowledge related to product, process and production in I4.0 Era, teaching skills enhancement and competence-based curriculum development.

The questionnaire was developed and validated during March, April and May 2021. The development and validation were based on: (i) think-aloud procedures with 6 teaching staff from Rajabhat and Rajamangala institutions, and (ii) test and retest statistics validation developed with approximately 30 teaching staff from the referred institutions. After validation, the questionnaire was applied, in June, to more than 200 teaching staff.

After the analysis of the collected results, the findings were reported and gave rise to a set of recommendations that will be part of the input information for the training design, the next work package. Two modules of Industry 4.0 part showed a lower level of self-perceived competence: Data Analytic and Digital Manufacturing. While it would not be possible to summarize all the results and recommendations, it is evident that there is a large number of Industry 4.0 themes proposed in the project that may benefit the development of competences of the target group. These include organizational, people management, methodologies, and techniques related to Industry 4.0.

Regarding the educational dimensions, the module “Learning experience-focused course design and development” shows a lower level of self-perceived competence, but in general the participants show higher self-perceived levels in the educational part. Nevertheless, there is room for improvement and also a high level of interest for training modules dedicated to the educational part.

2 Introduction

The fourth industrial revolution imposes/introduces new requirements for universities all around the world, relative to new knowledge and competences that must be included in the relevant curricula. Additionally, the evidence has shown that the development of competences is more effective if teachers from higher education institutions act as facilitators of active learning environments. These new requirements are demanding for all institutions, and Thai teaching staff may benefit from the ReCap 4.0 training, which aims to develop competences of the non-university sector in Thailand for Industry 4.0 (I4.0) and innovative teaching and learning approaches.

The first work package (WP1) of the ReCap 4.0 project aims to assess the capacity of a set of institutions of the non-university sector at the tertiary level in Thailand (Rajabhat Universities and Rajamangala Universities of Technology) and propose a set of recommendations for the training program (training needs) necessary to capacitate the teaching staff of those institutions. That capacitation involves I4.0 knowledge, innovative teaching/learning approaches and competence-based curriculum development.

After designing and validating the capacity assessment instrument, the WP1 team made its application. Finally, the team used the analysis of the collected data as the main evidence for the creation of a set of recommendations for the training program.

After the “executive summary” (i) and “introduction” (ii) sections, this assessment report is structured according to the following main sections: (iii) summary of methodology and procedure for collecting information and assessing the data, (iv) sample characterization with final list of assessed target non-university sector at tertiary education level, (v) summary of the survey results, (vi) assessment results, (vii) the recommendations, (viii) concluding remarks, followed by the references and the annexes of survey forms. The recommendations will focus on the areas on which the training program for industry 4.0 competence development should put more emphasis on in order to build the trainees’ competence level. Finally, it is important to note that despite the fact that this is a completely new report, some parts of it may be repeated or adapted from the WP1 plan report for the sake of clarification or continuity of the ideas.

3 Methodology

This section describes the methodology for the construction of the questionnaire for self-assessment of competences related to Industry 4.0 and educational aspects, and the procedure for collecting information and assessing the data. The design of the capacity assessment tool included four phases: (1) development and identification of critical knowledge; (2) development of items (questions) for each dimension; (3) improvement of the questionnaire using the think-aloud technique; (4) measurement of the reliability of the questionnaire using test and retest validation followed by an improvement of the items; (5) application of the questionnaire; (6) data analysis and reporting.

3.1 Development of items

The items should be relevant to the domain and purpose of the assessment and must be related and relevant to the dimension to be assessed. In other words, it is a matter of assessing the relevance, saturation, dimensionality or correspondence between the item and the characteristic to be assessed. With regard to the criterion of credibility, face validity or 'apparent validity', the item should not appear ridiculous, unreasonable or childish. As for the clarity of the item, as a rule, short sentences or simple expressions should be used. It also favours the item's clarity to report behaviours rather than abstractions [1]. Items are constructed to objectively assess a given latent reality, that is, dimensions or variables that may also be referred to as constructs [1]. Construct is the same as concept, however it has the additional attribute of being observable. Therefore, constructs are concepts that can be treated scientifically [2].

Considering the domain and purpose of the assessment it was necessary to make the acquisition of critical knowledge through bibliographic research on Industry 4.0 (part 1) and teaching skills and curriculum development (part 2), aiming to develop a two-part questionnaire to be applied among teaching staff of Rajabhat Universities and Rajamangala Universities in Thailand. Please note that from this point forward we will use teacher as “teaching staff” to simplify the text and data presentation.

For this purpose, the Acatech maturity model and courses developed in the MSIE4.0 project were used as theoretical foundations for item development. The theoretical foundations of the educational part of the questionnaire were active learning, communication, problem and project-based learning, coaching and mentoring, Curriculum Development processes, including assessment and evaluation, and Learning Experience-Focused Course Design and Development concepts. Thus, the questionnaire has the following main *content* related dimensions:

A Industry 4.0 Generic Items based on Acatech Elements
B Module 1.1: Industrial Management in Industry 4.0 Era
C Module 1.2: Applications of Optimization, and Technology in Value Chain
D Module 1.3: Digital Manufacturing
E Module 1.4: Innovative Product Design and Development
F Module 1.5: Data Analytic
G Module 2.1: Communication and people skills development

H Module 2.2: Innovative teaching and learning methods
I Module 2.3: Problem and Project-Based Learning (PBL)
J Module 2.4: Coaching and Mentoring Skills development
K Module 2.5: Learning experience-focused course design and development

During the development phase, the team carefully developed the items considering a simple way to write them. As much as possible, the items show a correspondence "one item - one task, one task - one idea".

Additionally, a Likert-type scale was defined to reinforce the objectivity of the items. As this questionnaire was aiming to self-assess the competences of teachers of Rajabhat Universities and Rajamangala Universities in Thailand, the chosen Likert scale was a 5-point agreement scale: strongly disagree, somewhat disagree, not sure, somewhat agree, and strongly agree.

Besides developing the items related to Industry 4.0 (part 1) and related to educational aspects (part 2), the questionnaire also included an initial part to characterize the participants (part 0) and a concluding part to collect the training preferences of the participants (part 3) and comments they could want to add.

The items of the assessment instrument were developed during the first phase of this work package, until April 6, 2021. The WP1 team gave feedback after that and this first version of the items was used for the validation phase. Annexes 1 to 3 show the results of the item development phases, by presenting the list of items for the questionnaire. These three versions were the result of the development and adjustments resultant from the validation phases.

3.2 Think-aloud – procedure

The think-aloud research procedure, also referred to as "cognitive interviewing" and "verbal protocols", aims to understand how respondents perceive and interpret questions, and to identify potential problems that may arise in questionnaires. It should be carried out during the pre-test phase, before application. Aspects such as attention span, word recognition, action, memory, language processing, problem solving and reasoning may be assessed, exploring how knowledge is organised in memory and how memory is retrieved in relation to completing questionnaires. The procedure is usually carried out in a controlled environment or in the setting where the proposed survey is to be administered with subjects who match the characteristics of the proposed sample and involves an interviewer asking a respondent to think aloud while they go through a questionnaire and tell them everything they are thinking, with the interviewer asking probing questions of the respondent to discover their thoughts. There are two main types of interviews: concurrent and retrospective. In the concurrent interview the respondent must give a verbal account of their thoughts as they answer the questionnaire and in the retrospective the answer is given after they have answered all the questions [4].

The think aloud procedure was implemented on April 22, 2021, in 6 virtual sessions, organized as represented in Table 1. In each session one teacher, from a Rajabhat University, read and thought aloud about their interpretation of each item. These sessions were conducted by a WP1 team. Sessions B, C, E and F were dedicated to I4.0 part of the questionnaire and sessions A and D were dedicated to the educational part of the questionnaire.

Table 1. Think aloud organization of sessions.

One synchronous zoom meeting	Parallel sessions		
PART I4.0 (1,75H) (<40 items)	Session A – Teacher A	Session B – Teacher B	Session C – Teacher C
PART EDUC (1,75H) (<40 items)	Session D – Teacher D	Session E – Teacher E	Session F – Teacher F

3.3 Think-aloud - improvement of the questionnaire

Think-aloud was performed before the application of the questionnaire, in the pre-test phase. As stated above, the objective of this research procedure is to identify potential problems in the interpretation of the items. The participants had a profile equivalent to the target audience and read aloud each question, said what they understood of the question, presented their answer, and described how their mental processing was done.

The think aloud procedure was performed on April 22, 2021 in 6 virtual sessions, 10:00 Brussels Time or 15:00 Bangkok Time, and 12:00 Brussels Time or 17:00 Bangkok Time. The sessions were conducted by a WP1 team. Sessions B, C, E and F were dedicated to I4.0 part of the questionnaire and sessions A and D were dedicated to the educational part of the questionnaire. The following list represent the participants:

10:00 Brussels Time or 15:00 Bangkok Time:

1. Udon Thani Rajabhat University (1 Lecturer)
2. Nakhon Sri Thammarat Rajabhat University (1 Lecturer)
3. Dhonburi Rajabhat University (1 Lecturer)

12:00 Brussels Time or 17:00 Bangkok Time:

1. Nakhon Sawan Rajabhat University (2 Lecturers)
2. Bansomdejchaopraya Rajabhat University (1 Lecturer)

The interviews were of the concurrent type, that is, the respondents gave verbal accounts of their thoughts as they answered the questionnaire. During the think-aloud procedure, the followed occurrences were identified:

- Comprehension difficulties
- Ambiguities in interpretation
- Errors in writing

After this step, the text was revised taking into account the reported problems. Based on the discussions, one item was eliminated, some items were simplified in the grammar, less usual words were changed for more accessible terms and the sentences were improved. In summary, from the 98 items, one was eliminated, and 34 were changed (34,7%). Table 2 presents examples of the revised items.

Table 2. Initial items and revised items after the Think aloud procedure.

Version applied in Think-aloud	**Version revised**
Industry 4.0 Generic Items based on Acatech Elements	
I am able to understand that it is possible to apply the concept of maturity levels to classify companies in different Industry 4.0 stages.	I am able to understand that companies have different Industry 4.0 maturity levels.
Industry 4.0 Specific Items based on training modules	
Module 1.3: Digital Manufacturing	
I am able to apply concepts of smart production and product co-design in CPS.	I am able to apply concepts of smart production and product co-design in Cyber Physical System (CPS).
EDUCATIONAL PART	
Module 2.1: Communication and people skills development	
I am able to apply emotional intelligence concepts in different professional situations	I am able to apply emotional intelligence concepts in different contexts of the teaching practice.

3.4 Test and retest – procedure

Measuring the reliability of the questionnaire was performed using a test and retest technique. The test corresponded to the administration of the survey to a set of respondents (approximately 30) and then, after a predetermined period of time (one week), the administration of the same questionnaire was repeated. This procedure measures the stability of scores across time and can be affected by the length of time between administrations of the survey. Moreover, the sample of respondents should be as homogeneous as possible. Thus, the sample comprised teachers from the non-university sector at tertiary education level. The test was performed on May 6, 2021 and the retest on May 13, 2021.

If the scores from test and retest are highly correlated with stable scores and error variability across time, then reliability can be assumed. Correlations and t-student tests will be used to infer about reliability. Statistically significant correlations which correlation coefficients above 0.7 indicate reliability, otherwise, there is no evidence of reliability. The t-student tests allow to conclude about the existence of similar average scores between test and retest [5]. If necessary, the questionnaire will be revised taking into account the reliability analysis results.

3.5 Test and retest - consistency analysis

To measure the reliability in the questionnaire, the test and retest technique was applied. The goal is to identify discrepancies in the answers, which would point to possible problems in the items. This procedure was carried out by 43 people who have the same profile as the questionnaire's target audience. From this 43 people, just 31 participants both answered the questionnaire and, after a one-week interval, repeated the same procedure. The answers were analysed by the software SPSS – Statistical Package for the Social Sciences.

The sample comprised teachers from the non-university sector at tertiary education level. The distribution by institution is given in Figure 1.

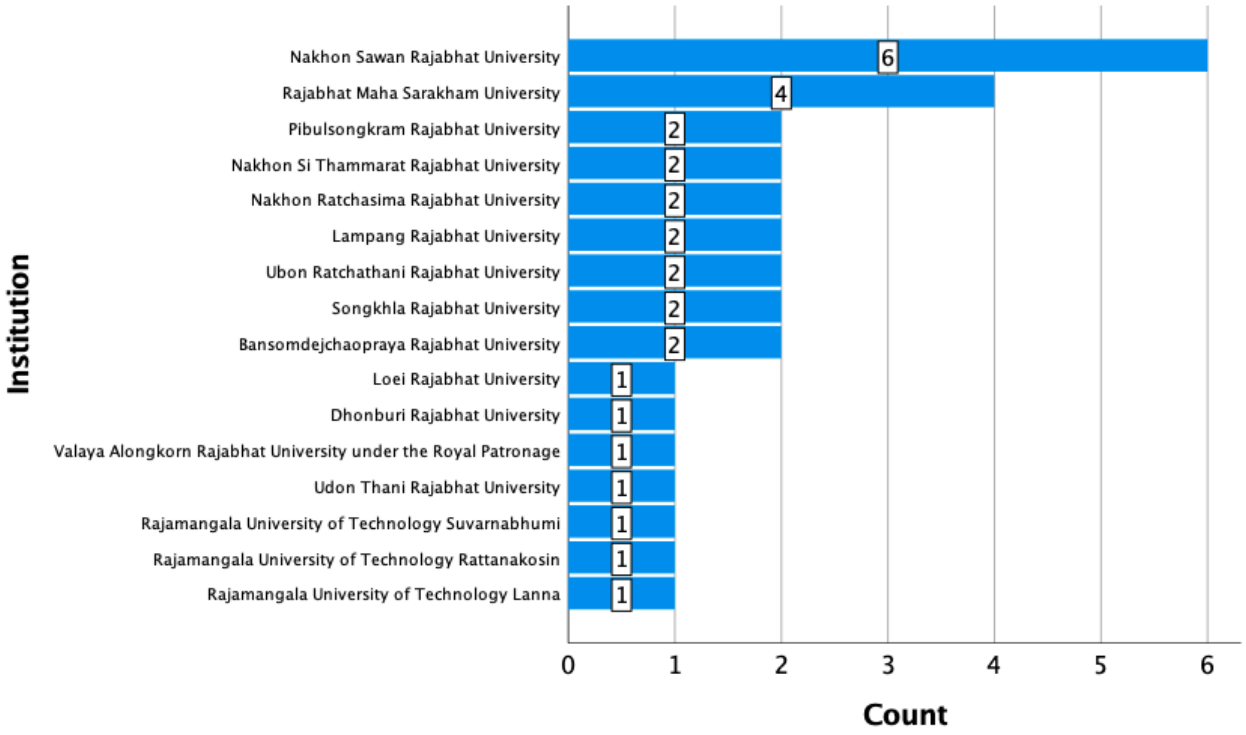

Figure 1. Teachers' distribution by Institution.

The average age is 39.9 with a standard deviation of 6.1 years. The histogram for the age shows that most teachers are 40 to 45 years old (Figure 2 - left).

The number of years of teaching experience is given by the following graph (Figure 2 - right). In this sample, it can be observed that the number of years of experience as teacher is almost uniform.

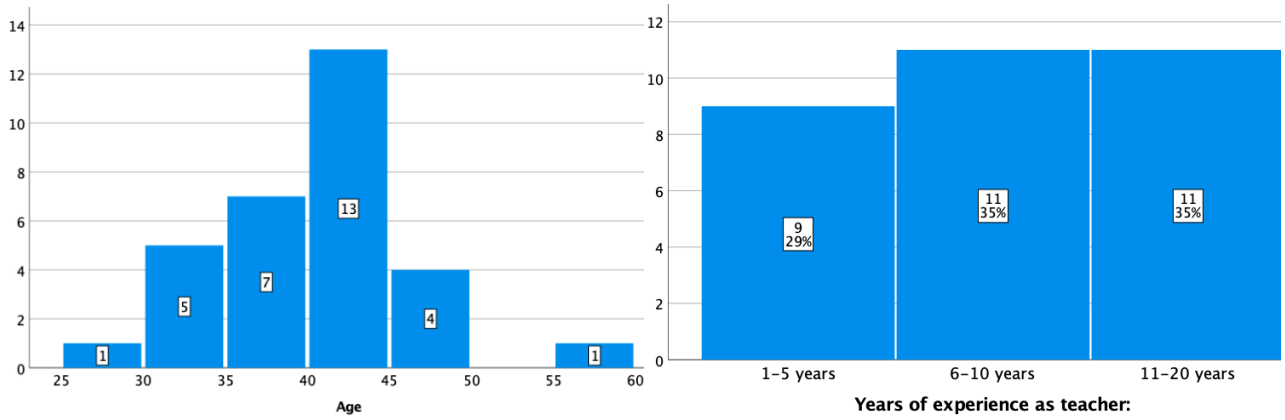

Figure 2. Teachers' age histogram and Teachers' years of experience.

The sample for the test-retest procedure was composed by 71% males and 29% females (Figure 3).

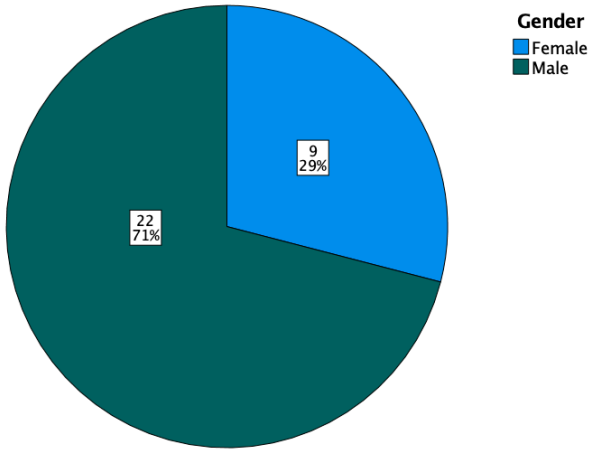

Figure 3. Teachers' gender.

Considering the highest academic degree (Figure 4), the majority of teachers has a Master's degree.

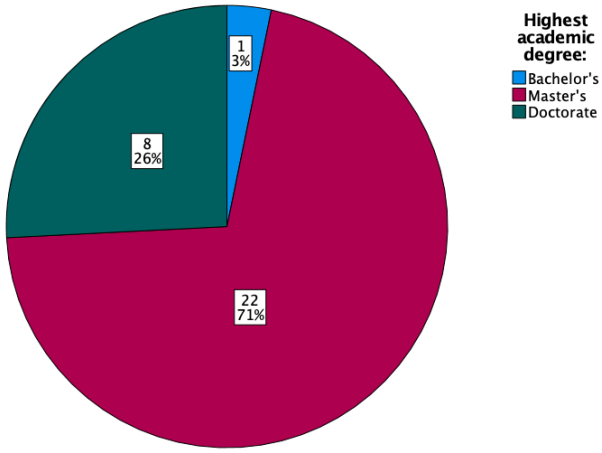

Figure 4. Teachers' highest academic degree.

The distribution of the English proficiency level is depicted in Figure 5. Most teachers have a low or high intermediate level.

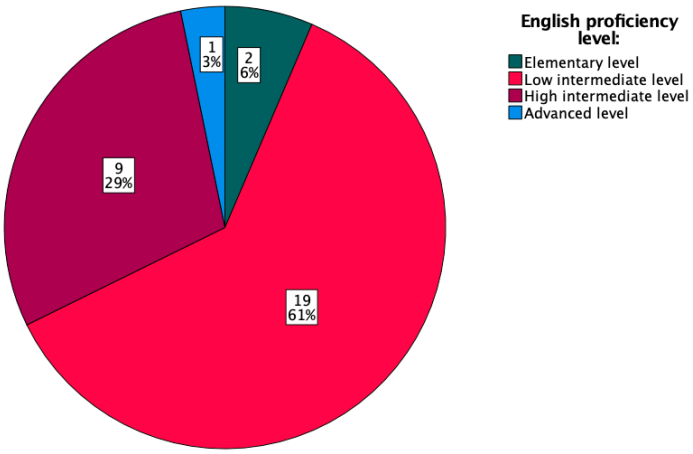

Figure 5. Teachers' english proficiency level.

Intraclass Correlation Coefficient (ICC) was computed to infer about reliability (Table 3). According to Koo (2016), ICC values less than 0.5 are indicative of poor reliability, values between 0.5 and 0.75 indicate moderate reliability, values between 0.75 and 0.9 indicate good reliability, and values greater than 0.90 indicate excellent reliability. ICC was computed for the original 5-classes Likert-type scale (ICC5) and a 3-classe Likert-type scale (ICC3). The 5 classes likert-type scale comprises the following classes: 1-"Strongly disagree", 2-"Somewhat disagree", 3-"Not sure", 4-"Somewhat agree" and 5-"Strongly agree". For the computation of ICC3, the previous classes were recoded as: 1-"Strongly or somewhat disagree", 2-"Not sure" and 3-"Somewhat or strongly agree". In the following tables, the ICC values that correspond to poor reliability, moderate reliability and good reliability are coloured in red or yellow, green, and black, respectively. The mean and standard deviation for the difference between the test and retest scores are also given. For a given item, a negative mean value indicates a higher average score in the retest. The results for the paired t-student test are also provided. A p-value inferior to 0.05 indicates the existence of significant differences between the average scores in the test and retest. This situation just occurred in the G1 item. For all other items there are no significant differences between the average scores in the test and retest.

Table 3. ICC and t-student test results.

A	Industry 4.0 Generic Items based on Acatech Elements						
	Intraclass correlation		Descriptive		Paired samples t-test (test-retest)		
	ICC5	ICC3	Mean	Std. Deviation	t	df	Sig. (2-tailed)
A1	0.544	0.591	-.097	1.012	-.533	30	.598
A2	0.452	0.447	-.065	1.031	-.349	30	.730
A3	0.472	0.472	-.161	1.036	-.867	30	.393
A4	0.224	0.362	-.129	1.147	-.626	30	.536
A5	0.363	0.291	-.129	1.258	-.571	30	.572
A6	0.404	0.432	-.161	1.241	-.724	30	.475
A7	0.284	0.349	-.065	1.289	-.279	30	.782
A8	0.474	0.45	-.258	1.154	-1.245	30	.223
A9	0.442	0.419	-.161	1.157	-.776	30	.444
A10	0.382	0.379	-.194	1.195	-.902	30	.374
A11	0.236	0.235	-.194	1.250	-.862	30	.395
A12	0.32	0.382	-.161	1.267	-.709	30	.484
A13	0.363	0.28	-.355	1.142	-1.731	30	.094
A14	0.185	0.309	.097	1.193	.452	30	.655

Table 3. ICC and t-student test results. (Continuation – parts B to E)

B	Module 1.1: Industrial Management in Industry 4.0 Era						
	Intraclass correlation		Descriptive		Paired samples t-test (test-retest)		
	ICC5	ICC3	Mean	Std. Deviation	t	df	Sig. (2-tailed)
B1	0.422	0.196	-.355	1.226	-1.611	30	.118
B2	0.535	0.448	-.097	1.012	-.533	30	.598
B3	0.526	0.294	-.194	1.078	-1.000	30	.325
B4	0.22	0.183	.129	1.231	.583	30	.564
B5	0.631	0.538	-.097	.944	-.571	30	.572
B6	0.38	-0.006	.065	1.181	.304	30	.763
B7	0.248	0.105	-.097	1.106	-.487	30	.630
B8	0.149	0.071	-.032	1.251	-.144	30	.887
B9	0.559	0.471	-.161	1.036	-.867	30	.393
B10	0.436	0.256	-.129	1.024	-.701	30	.489
B11	0.408	0.39	-.161	1.036	-.867	30	.393
B12	0.284	0.278	.000	1.211	.000	30	1.000
B13	0.317	0.231	-.161	1.098	-.818	30	.420
B14	0.295	0.213	-.161	1.098	-.818	30	.420
B15	0.189	0.076	-.097	1.248	-.432	30	.669
B16	0.28	0.184	-.323	1.166	-1.541	30	.134
C	Module 1.2: Applications of Optimization, and Technology in Value Chain						
	Intraclass correlation		Descriptive		Paired samples t-test (test-retest)		
	ICC5	ICC3	Mean	Std. Deviation	t	df	Sig. (2-tailed)
C1	0.324	0.177	-.097	1.221	-.441	30	.662
C2	0.423	0.399	-.290	1.270	-1.273	30	.213
C3	0.473	0.258	-.290	1.270	-1.273	30	.213
C4	0.332	0.15	-.194	1.276	-.845	30	.405
C5	0.367	0.279	-.129	1.258	-.571	30	.572
C6	0.473	0.323	-.355	1.253	-1.577	30	.125
C7	0.284	0.055	-.290	1.371	-1.179	30	.248
C8	0.506	0.288	-.194	1.167	-.924	30	.363
D	Module 1.3: Digital Manufacturing						
	Intraclass correlation		Descriptive		Paired samples t-test (test-retest)		
	ICC5	ICC3	Mean	Std. Deviation	t	df	Sig. (2-tailed)
D1	0.396	0.316	.032	1.110	.162	30	.873
D2	0.289	0.138	.000	1.155	.000	30	1.000
D3	0.403	0.453	.032	.912	.197	30	.845
D4	0.272	0.291	.000	1.000	.000	30	1.000
D5	0.275	0.363	.161	1.186	.757	30	.455
D6	0.074	0.145	.065	1.340	.268	30	.790
D7	0.632	0.538	-.194	1.014	-1.063	30	.296
D8	0.377	0.433	-.161	1.098	-.818	30	.420
D9	0.305	0.405	-.161	1.068	-.841	30	.407
D10	0.424	0.275	-.129	.957	-.751	30	.459
D11	0.263	0.13	-.065	1.181	-.304	30	.763
D12	0.47	0.416	-.032	.912	-.197	30	.845
D13	0.408	0.419	.065	1.063	.338	30	.738
E	Module 1.4: Innovative Product Design and Development						
	Intraclass correlation		Descriptive		Paired samples t-test (test-retest)		
	ICC5	ICC3	Mean	Std. Deviation	t	df	Sig. (2-tailed)
E1	0.528	0.5	-.290	1.131	-1.429	30	.163
E2	0.414	0.411	-.161	1.128	-.796	30	.432
E3	0.396	0.279	-.194	1.138	-.947	30	.351
E4	0.352	0.152	-.097	1.300	-.414	30	.682
E5	0.415	0.399	-.065	1.124	-.320	30	.751
E6	0.037	0.022	-.097	1.248	-.432	30	.669

Table 3. ICC and t-student test results. (Continuation – parts F to K)

F	**Module 1.5: Data Analytic**						
	Intraclass correlation		Descriptive		Paired samples t-test (test-retest)		
	ICC5	ICC3	Mean	Std. Deviation	t	df	Sig. (2-tailed)
F1	0.266	0.368	.161	1.128	.796	30	.432
F2	0.373	0.421	-.097	1.136	-.474	30	.639
F3	0.34	0.437	.161	1.098	.818	30	.420
F4	0.355	0.434	.000	1.125	.000	30	1.000
F5	0.612	0.464	-.161	1.036	-.867	30	.393
F6	0.496	0.508	-.065	1.063	-.338	30	.738
F7	0.497	0.513	-.226	1.087	-1.157	30	.256
F8	0.507	0.512	-.032	1.080	-.166	30	.869
F9	0.39	0.339	-.129	1.204	-.597	30	.555
G	**Module 2.1: Communication and people skills development**						
	Intraclass correlation		Descriptive		Paired samples t-test (test-retest)		
	ICC5	ICC3	Mean	Std. Deviation	t	df	Sig. (2-tailed)
G1	0.556	0.628	-.323	.871	-2.061	30	**.048**
G2	0.645	0.619	-.226	.956	-1.315	30	.198
G3	0.493	0.63	-.290	.864	-1.871	30	.071
G4	0.405	0.471	-.129	1.147	-.626	30	.536
G5	0.453	0.464	-.323	1.107	-1.622	30	.115
G6	0.509	0.588	-.290	1.006	-1.606	30	.119
H	**Module 2.2: Innovative teaching and learning methods**						
	Intraclass correlation		Descriptive		Paired samples t-test (test-retest)		
	ICC5	ICC3	Mean	Std. Deviation	t	df	Sig. (2-tailed)
H1	0.651	0.566	-.097	.978	-.551	30	.586
H2	0.56	0.648	-.194	.910	-1.184	30	.246
H3	0.394	0.305	-.419	1.205	-1.938	30	.062
H4	0.581	0.53	-.258	.965	-1.489	30	.147
H5	0.296	0.407	-.355	1.082	-1.827	30	.078
H6	0.249	0.281	-.323	1.107	-1.622	30	.115
H7	0.526	0.565	-.097	1.012	-.533	30	.598
I	**Module 2.3: Problem and Project-Based Learning (PBL)**						
	Intraclass correlation		Descriptive		Paired samples t-test (test-retest)		
	ICC5	ICC3	Mean	Std. Deviation	t	df	Sig. (2-tailed)
I1	0.579	0.5	-.129	1.056	-.680	30	.502
I2	0.474	0.395	-.129	.922	-.779	30	.442
I3	0.659	0.471	-.194	1.046	-1.030	30	.311
I4	0.507	0.388	-.097	1.076	-.501	30	.620
I5	0.556	0.357	-.065	1.063	-.338	30	.738
J	**Module 2.4: Coaching and Mentoring Skills development**						
	Intraclass correlation		Descriptive		Paired samples t-test (test-retest)		
	ICC5	ICC3	Mean	Std. Deviation	t	df	Sig. (2-tailed)
J1	0.609	0.582	-.129	1.024	-.701	30	.489
J2	0.775	0.661	-.226	.884	-1.423	30	.165
J3	0.582	0.624	-.161	.934	-.961	30	.344
J4	0.663	0.677	-.290	.824	-1.961	30	.059
J5	0.703	0.595	-.226	.845	-1.488	30	.147
J6	0.557	0.481	-.194	1.078	-1.000	30	.325
K	**Module 2.5: Learning experience-focused course design and development**						
	Intraclass correlation		Descriptive		Paired samples t-test (test-retest)		
	ICC5	ICC3	Mean	Std. Deviation	t	df	Sig. (2-tailed)
K1	0.455	0.309	-.161	1.186	-.757	30	.455
K2	0.517	0.351	-.194	1.138	-.947	30	.351
K3	0.403	0.205	-.194	1.167	-.924	30	.363
K4	0.36	0.432	.065	1.093	.329	30	.745
K5	0.462	0.548	-.065	.964	-.373	30	.712
K6	0.513	0.501	-.226	1.055	-1.191	30	.243
K7	0.36	0.345	-.194	1.046	-1.030	30	.311

3.6 Test and retest – improvement of the questionnaire

Based on the correlation values presented in the previous section, 68 out of 97 (70%) of the items of the questionnaire have poor reliability, thus requiring further revision. Thus, the 68 unreliable items were analysed and, whenever possible, were revised, in order to make them less susceptible to ambiguities in interpretation. During this process we revised 51 out of 68 unreliable items (75%).

Table 4 includes examples of initial items (version applied in the test-retest procedure) and the revised items.

Table 4. Examples of the initial items and the revised items after the test-retest procedure.

	Version applied in test-retest procedure	Version revised
A	**Industry 4.0 Generic Items based on Acatech Elements**	
A12	I am able to understand that Industry 4.0 focuses on customer benefits enabled by transparent collaboration networking inside (intra) the company and between (inter) companies.	I am able to understand that Industry 4.0 is focused on the customer benefits enabled by networked collaboration inside the company (i.e. intra-company) and between different companies (i.e. inter-companies).
	Industry 4.0 Specific Items based on training modules	
B	**Module 1.1: Industrial management in Industry 4.0 Era**	
B7	I am able to model industrial processes considering smart production concepts.	I am able to use a modelling tool (e.g. BPMN, VSM) to represent industrial processes considering smart production concepts.
H	**Module 2.2: Innovative teaching and learning methods**	
H3	I am able to use online learning management systems.	I am able to use online learning management systems (e.g. Moodle, Blackboard).

In general terms, the items of the first part of the questionnaire (Industry 4.0) required more attention than those of the second part (educational part). In particular, the module A - Industry 4.0 Generic Items based on Acatech Elements, required the revision of 13 of its 14 items. By contrast, the module J - Coaching and Mentoring Skills development, from the second part, required no changes. The module that needed a higher number of changes in this second part was the module H - Innovative teaching and learning methods, requiring the revision of 3 out 7 items. In the first part of the questionnaire, the module E - Innovative Product design and development, required the revision of a single item, being thus the module with the lower number of changes in this part.

Part 3 of the questionnaire, related to the interest in Training Modules, was completely changed. Before the test-retest procedure, this part demanded the participants to rank all modules, from the most important to the least important. The result showed that the participants were not able to make a clear choice because most of the answers showed the same pattern, which could be explained because it was the simplest pattern to choose. Thus, this part was changed, and was split in two questions. In the first, the participants have to choose the two most important training modules related to Industry 4.0 from the 5 offered. In the second, the participants have to choose the two most important training modules related to educational aspects from the 5 offered.

3.7 Synthesis of the Procedure for Items Development

The interviews conducted as part of the think-aloud procedure revealed problems such as difficulties in understanding the factors under evaluation, ambiguities in the interpretation of the questions and lack of understanding of the text. We observed the process of reading and interpreting the questions, and in addition to language-related challenges we also identified the conditions experienced by respondents such as the digital format of the questionnaire, the online availability of the questionnaire, the demand for attention and the time required to complete the answers. The results of the think-aloud procedure indicated that some items needed to be revised for simplification. Items that in their construction contained more than one question although corresponding to only one question were rewritten to gain more objectivity, items that referred to generic and conceptual notions were also reconstructed to refer to actions, and finally, items that

were formulated with unusual words and grammatical constructions were remade with more common words and grammatical constructions closer to those used in most people's daily lives. In addition, considering that the questionnaires would not be answered in a controlled environment, the objectives of the survey were presented in an introductory text.

The results of the test-retest procedure revealed that the changes made to the items as done in the think-aloud procedure were not sufficient to eliminate comprehension difficulties. The participating respondents were asked to answer on two occasions and in 70% of the cases the coherence of the answers remained low, that is, although the questions were the same, the answers did not remain the same in large part of the cases. The correlation test indicated questions that could be considered problematic, which were submitted to a new revision for simplification, elimination of ambiguities and reduction of the level of abstraction.

The item revision efforts were very successful because in the consistency analysis, the Cronbach's alpha index that assesses the internal consistency and reliability of the items was greater than 0.9 in all items. The standard recommends that this index should be greater than 0.8.

4 Sample characterization

This section presents a characterization of the sample related to the survey results. The analysis of the answers may be based on a view integrating both institutions, or if there are significant differences, it is important to make separate analysis by Rajabhat and Rajamangala institutions. Thus, data from both types of institutions were analysed. For each item, the existence of significant differences between the types of institution was tested using independent samples t-student tests or chi square tests depending on the nature of the data.

4.1 Institutions

The capacity assessment was conducted through a questionnaire sent to Rajabhat Universities and Rajamangala Universities of Technology. There are 40 Rajabhat University institutions and 9 Rajamangala Universities of Technology institutions. Considering the scope of this project, the main target group are Rajabhat Universities institutions with Industrial Engineering or similar departments and programs. Rajamangala Universities of Technology will also be included in this study. Table 5 (also included in a previous outcome for WP1.1) presents the complete list of institutions with this type of programs.

The application of the questionnaire was developed during a one-month period, in June 2021. The responses were confidential, but login was required to guarantee a one-to-one relation between answers and respondents.

The questionnaire was distributed to the Rajabhat Universities and Rajamangala Universities of Technology around the Northern, North-eastern, Central, and Southern Part of Thailand through research collaboration among King Mongkut's University of North Bangkok, Khon Kaen University, Mahidol University and Prince of Songkhla University. Lecturers from Rajabhat Universities and Rajamangala Universities of Technology were willing to fill the questionnaire.

Table 5. List of Rajabhat Universities and Rajamangala Universities of Technology institutions.

#	University	Faculty	Program
	North Eastern Part		
1	Udon Thani Rajabhat University	Technology	Industrial Management
2	Rajabhat Maha Sarakham University	Engineering	Industrial Management Engineering
3	Loei Rajabhat University	Industrial Technology	Industrial Management Engineering, Production Engineering
4	Nakhon Ratchasima Rajabhat University	Industrial Technology	Industrial Management Engineering
5	Buriram Rajabhat University	Industrial Technology	Industrial Management Engineering
6	Surindra Rajabhat University	Industrial Technology	Production Technology, Engineering and Technology Management

#	University	Faculty	Program
7	Ubon Ratchathani Rajabhat University	Industrial Technology	Industrial Management Technology, Logistics Management
8	Chaiyaphum Rajabhat University	Engineering and Industrial Technology	Production Engineering
9	Kalasin Rajabhat University (since 2016 combined to Kalasin University)	Engineering and Industrial Technology	Industrial Engineering
10	Sakon Nakhon Rajabhat University	Industrial Technology	Industrial and Production
11	Roi Et Rajabhat University	No	No
12	Sisaket Rajabhat University	No	No
13	***Rajamangala University of Technology isan***	Engineering	Industrial Engineering, Logistics Engineering
	Northern Part		
14	ChiangMai Rajabhat University	Science and Technology	Product design
15	Chiang Rai Rajabhat University	Industrial Technology	Logistics Engineering and Management
16	Lampang Rajabhat University	Industrial Technology	ProductionTechnology
17	Uttaradit Rajabhat University	Industrial Technology	Industrial Technology, Logistics Engineering
18	Pibulsongkram Rajabhat University	Industrial Technology	Industrial Technology, Logistics Engineering
19	Kamphaeng Phet Rajabhat University	Industrial Technology	Logistics Management
20	Nakhon Sawan Rajabhat University	Agricultural Technology and Industrial Technology	Engineering Management, Industrial Technology
21	Phetchabun Rajabhat University	Agricultural and Industrial Technology	Production Engineering and Management, Production Technology
22	***Rajamangala University of Technology Lanna***	Engineering	Industrial Engineering
	Central Part		
23	Kanchanaburi Rajabhat University	Industrial Technology	Industrial Technology
24	Chandrakasem Rajabhat University	Science	Production engineering and energy management
25	Thepsatri Rajabhat University	Industrial Technology	Industrial Technology
26	Dhonburi Rajabhat University	Science and Technology	Industrial Management
27	Nakhon Pathom Rajabhat University	Science and Technology	Industrial Computer Technology
28	Bansomdejchaopraya Rajabhat University	Industrial Technology	Production and Logistics Engineering Management
29	Phranakhon Rajabhat University	Industrial Technology	Industrial Technology
30	Phranakhon Si Ayutthaya Rajabhat University	Science and Technology	Engineering Management
31	Phetchaburi Rajabhat University	Engineering and Industrial Technology	Industrial Engineering, Industrial Technology
32	Rajabhat Rajanagarindra University	Industrial Technology	Industrial Management Engineering, Industrial Technology
33	Rambhai Barni Rajabhat University	Industrial Technology	Logistics Engineering, Industrial Technology (Continuing Program)
34	Valaya Alongkorn Rajabhat University under the Royal Patronage	Industrial Technology	Industrial Engineering Management
35	Suan Sunandha Rajabhat University	Industrial Technology	Industrial Management
36	Muban Chombueng Rajabhat University	Industrial Technology	Production in Industrial Technology
37	***Rajamangala University of Technology Tawan-ok***	Agro-Industrial Technology	Industrial Engineering
38	***Rajamangala University of Technology Krungthep***	Engineering	Industrial Engineering
39	***Rajamangala University of Technology Thanyaburi***	Engineering	Industrial Engineering
40	***Rajamangala University of Technology Phra Nakhon***	Engineering	Industrial Engineering
41	***Rajamangala University of Technology Rattanakosin***	Engineering	Industrial Engineering
42	***Rajamangala University of Technology Suvarnabhumi***	Engineering and Architecture	Industrial Engineering
	Southern Part		
43	Suratthani Rajabhat University	Science and Technology	Industrial Management Technology
44	Nakhon Si Thammarat Rajabhat University	Industrial Technology	Industrial Technology, Industrial Management and Logistics
45	Phuket Rajabhat University	Science and Technology	Industrial Technology
46	Songkhla Rajabhat University	Industrial Technology	Industrial Technology
47	Yala Rajabhat University	No	No
48	Princess of Naradhiwas	Engineering	Industrial Engineering
49	***Rajamangala University of Technology Srivijaya***	Engineering	Industrial Engineering

Table 6 presents the relative number of institutions with the included faculties, according to the scope of the project.

Table 6. Relative number of institutions.

Faculty	Amount	%
Industrial Technology	22	47.83
Engineering	9	19.57
Science and Technology	6	13.04
Engineering and Industrial Technology	3	6.52
Agricultural and Industrial Technology	1	2.17
Agricultural Technology and Industrial Technology	1	2.17
Agro-Industrial Technology	1	2.17
Science	1	2.17
Technology	1	2.17
Engineering and Architecture	1	2.17
Total	**46**	**100.00**

Table 7 presents the relative number of included programmes, according to the scope of the project.

Table 7. Relative number of programmes in the included areas, according to the scope of the project.

Program	Amount	%
Industrial Technology	13	22.41
Industrial Engineering	12	20.69
Industrial Management Engineering	6	10.34
Logistics Engineering	4	6.90
Industrial Management	3	5.17
Production Technology	3	5.17
Engineering Management	2	3.45
Industrial Management Technology	2	3.45
Logistics Management	2	3.45
Industrial Computer Technology	1	1.72
Logistics Engineering and Management	1	1.72
Industrial Management and Logistics	1	1.72
Production and Logistics Engineering Management	1	1.72
Production Engineering	1	1.72
Production engineering and energy management	1	1.72
Production Engineering and Management	1	1.72
Production in Industrial Technology	1	1.72
Engineering and Technology Management	1	1.72
Industrial and Production	1	1.72
Product design	1	1.72
Total	**58**	**100.00**

4.2 Participants

The questionnaire was applied during a one-month period, in June 2021. There were 211 answers, and 9 were considered not valid because the respondents were from public and private universities, not included in our target group. Thus, a total of 202 valid answers were obtained. The distribution of respondents by institution is shown in Figure 6.

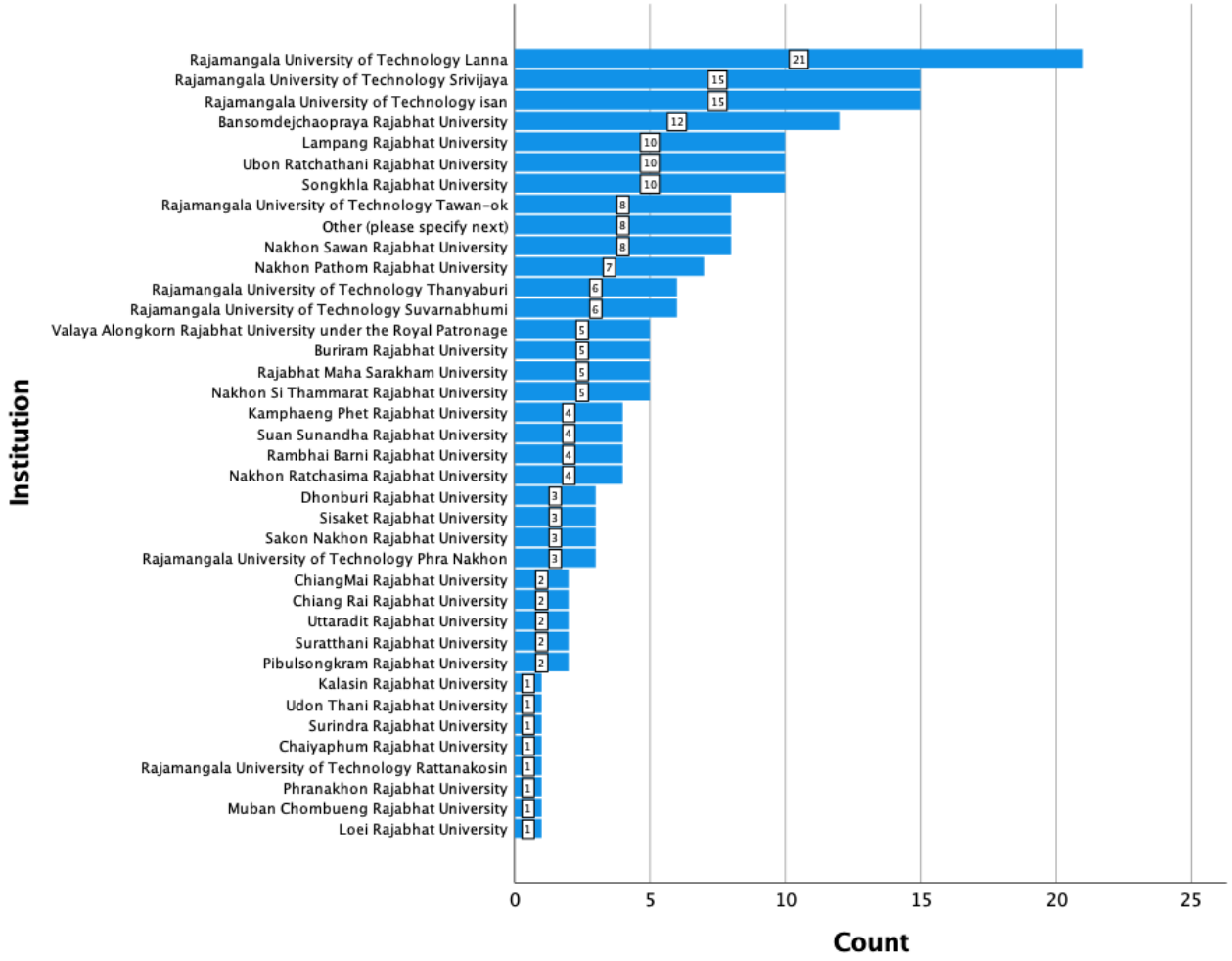

Figure 6. Distribution by institutions

The distribution of participants by type of institutions is given in Figure 7, representing 126 answers from Rajabhat institutions and 76 from Rajamangala institutions.

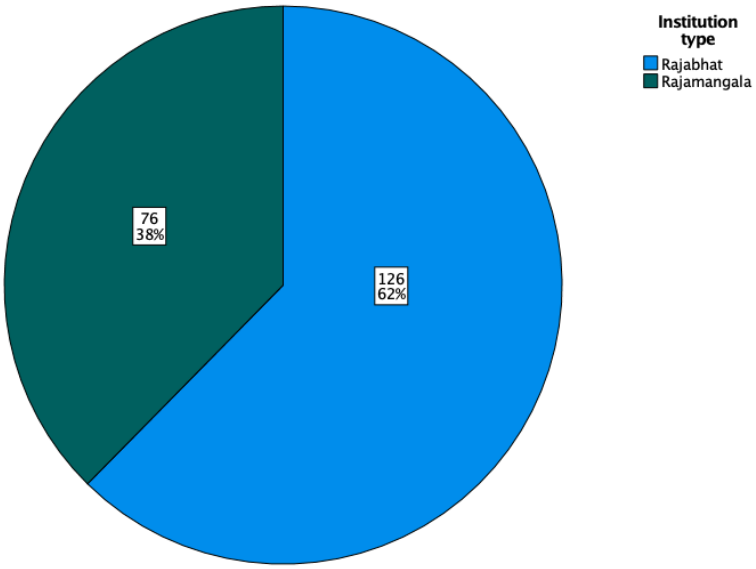

Figure 7. Distribution by type of institution

The distribution of the number of years of experience as teacher is presented in Figure 8, separated by type of institution because there is a significant difference between the respondents from the two type of institutions. The teachers that participated in this survey from Rajabhat institutions are in general less experienced than the teachers from Rajamangala institutions. Considering the way this information was collected in the questionnaire, the category with an higher number of answers from teachers of the Rajabhat institutions is the category of 6 to 10 years of experience, and the category with an higher number of answers from teachers of the Rajamangala institutions is the category of 11 to 20 years of experience.

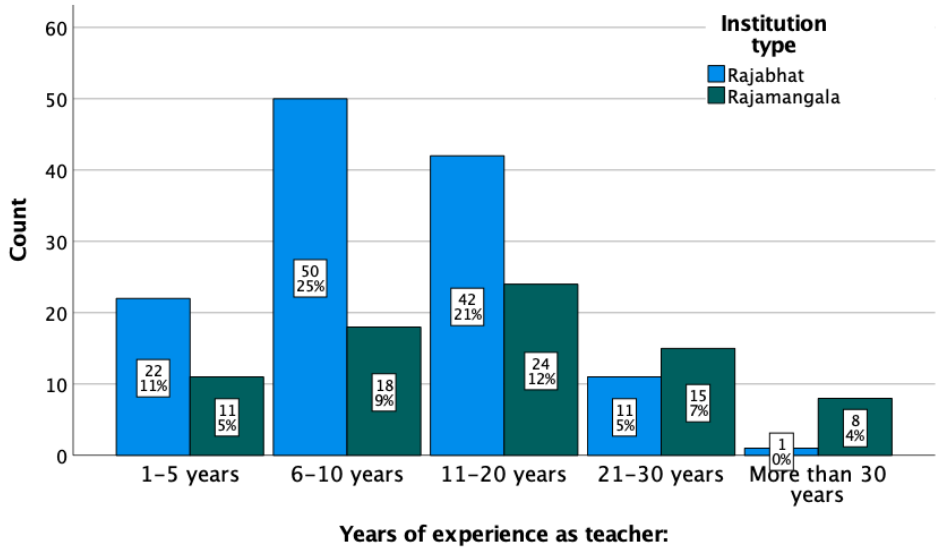

Figure 8. Teachers' years of experience.

The distribution of the highest academic degree was tested against the type of institution and a significant difference was identified. The teachers from Rajabhat institutions that answered to the questionnaire have in general lower levels of academic degrees. Figure 9 highlight this difference as it is clear that the majority of the respondents from this type of institution have master's degrees, while the majority of the respondents from Rajamangala institutions have doctorate degrees.

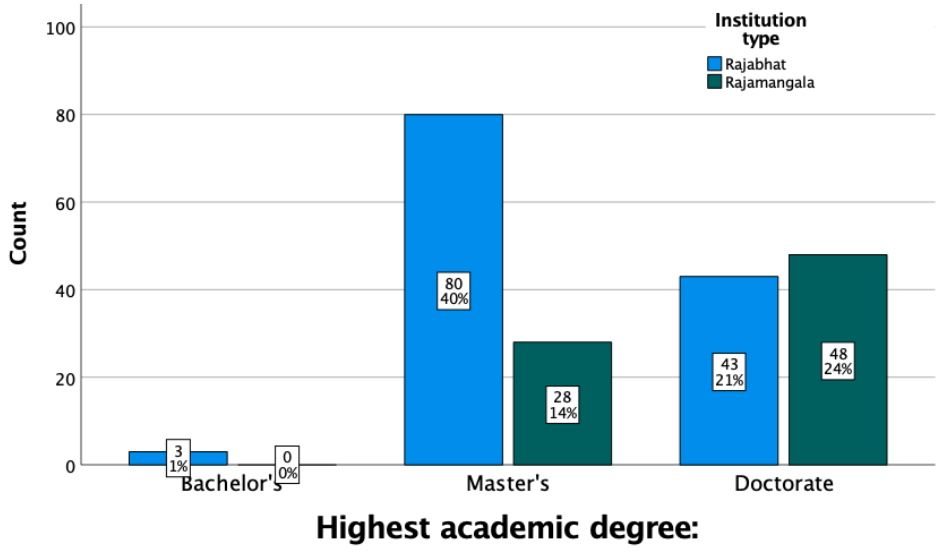

Figure 9. Teachers' highest academic degree.

The majority of the participants in this survey has low or high intermediate level of English proficiency level (Figure 10).

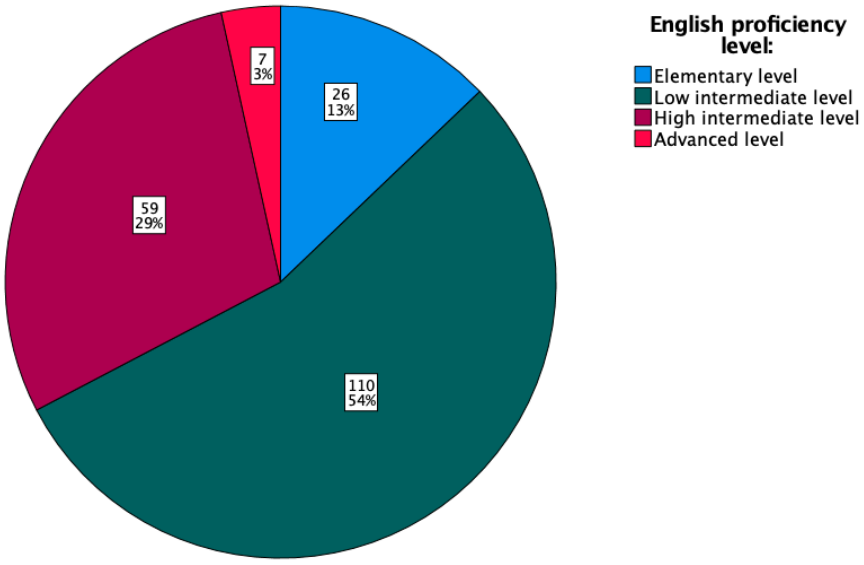

Figure 10. Teachers' English proficiency level.

Figure 11 presents the distribution of the respondents by gender. The sample comprises 131 male (65%) and 71 female (35%).

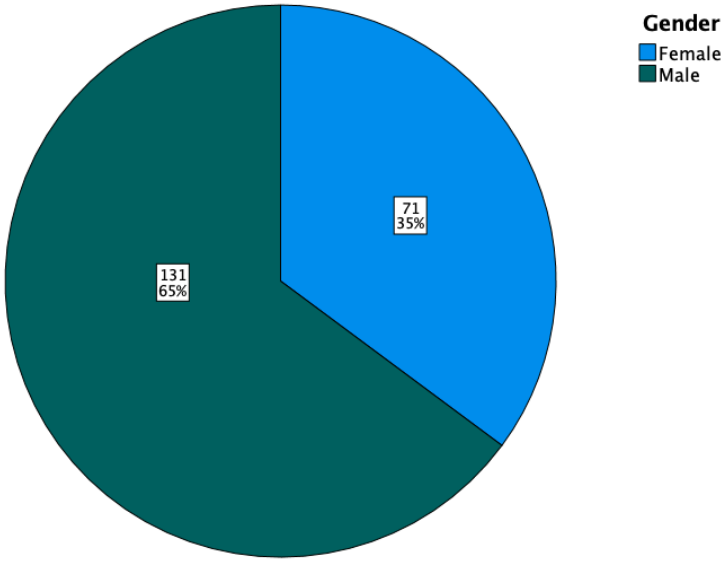

Figure 11. Teachers' gender.

The distribution of the age is presented in Figure 12, separated by type of institution because there is a significant difference between the respondents from the two types of institutions. The teachers that participated in this survey from Rajabhat institutions are in general younger than the teachers from Rajamangala institutions. The mean ages for teachers from Rajabhat institutions and Rajamangala institutions are, respectively, 40.4 years and 43.6 years.

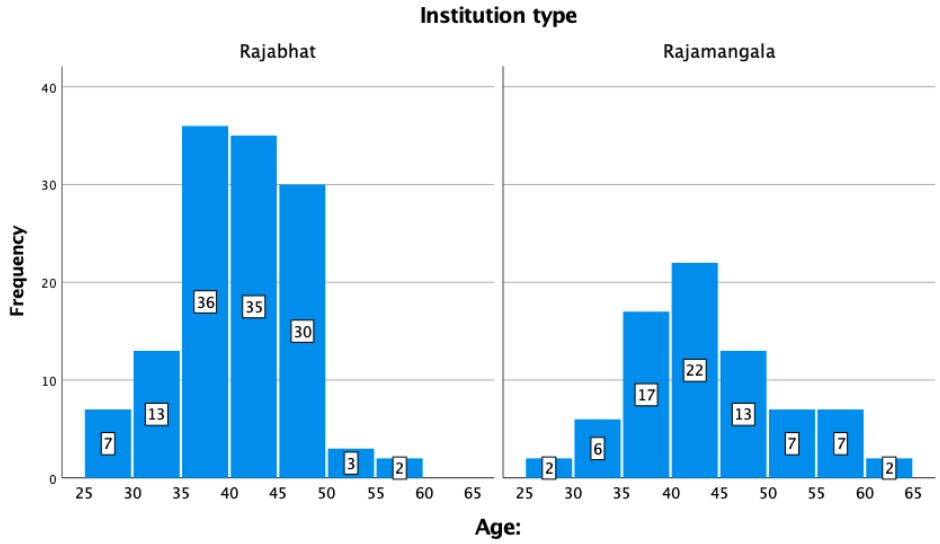

Figure 12. Teachers' age histogram.

5 Presentation of the survey results

This section presents the survey results, encompassing a consistency analysis using the Cronbach's alpha reliability coefficient (section 5.1), descriptive statistics (section 5.2) and the correlation between respondent characteristics and items (section 5.3).

The analysis of the answers may be based on a view integrating both institutions, or if there are significant differences, it is important to make separate analysis by Rajabhat and Rajamangala institutions. Thus, data from both types of institutions were analysed. For each item, the existence of significant differences between the types of institution was tested using independent samples t-student tests or chi square tests depending on the nature of the data.

Considering this analysis, the consistency section shows results related to aggregated and separated analysis. The interest in training modules is also different for each type of institution respondents and the corresponding results are shown. Additionally, for each item of the questionnaire, the existence of significant differences between the types of institution was tested using independent samples t-student tests. No significant differences were found in the item scores of the two types of institutions, except for items A10 and D11.

5.1 Consistency

Cronbach's alpha assesses internal the consistency or reliability of sets of items. It is recommended at least values superior to 0.8. The values obtained for Cronbach's alpha for the set of items of each module, the item means and the 95% Interval Confidence (IC) for the means of each module are given in Table 8. All Cronbach's alpha values are superior to 0.9 which correspond to excellent levels of internal consistency.

Table 8. Cronback's alpha and means for items modules.

		All			Rajabhat			Rajamangala		
	Number of items	Cronbach's alpha	Item Means	95% IC Item Means	Cronbach's alpha	Item Means	95% IC Item Means	Cronbach's alpha	Item Means	95% IC Item Means
A	14	0.976	3.265	[3.134, 3.396]	0.976	3.190	[3.024, 3.355]	0.974	3.390	[3.173, 3.607]
B	16	0.974	3.167	[3.049, 3.285]	0.973	3.128	[2.982, 3.275]	0.976	3.231	[3.028, 3.435]
C	8	0.956	3.008	[2.880, 3.136]	0.951	2.999	[2.848, 3.150]	0.961	3.023	[2.788, 3.258]
D	13	0.978	2.956	[2.822, 3.091]	0.981	2.869	[2.699, 3.038]	0.972	3.101	[2.878, 3.324]
E	6	0.958	3.090	[2.959, 3.221]	0.953	3.020	[2.860, 3.180]	0.963	3.206	[2.977, 3.436]
F	9	0.983	2.944	[2.799, 3.089]	0.984	2.883	[2.706, 3.059]	0.981	3.045	[2.792, 3.299]
G	6	0.966	3.587	[3.457, 3.716]	0.963	3.566	[3.410, 3.722]	0.971	3.621	[3.390, 3.852]
H	7	0.958	3.510	[3.380, 3.640]	0.960	3.537	[3.373, 3.702]	0.955	3.464	[3.246, 3.683]
I	5	0.975	3.443	[3.305, 3.580]	0.968	3.384	[3.226, 3.543]	0.982	3.539	[3.283, 3.796]
J	6	0.975	3.547	[3.414, 3.680]	0.975	3.495	[3.331, 3.659]	0.974	3.634	[3.403, 3.865]
K	7	0.958	3.231	[3.099, 3.364]	0.957	3.138	[2.976, 3.301]	0.959	3.385	[3.159, 3.611]

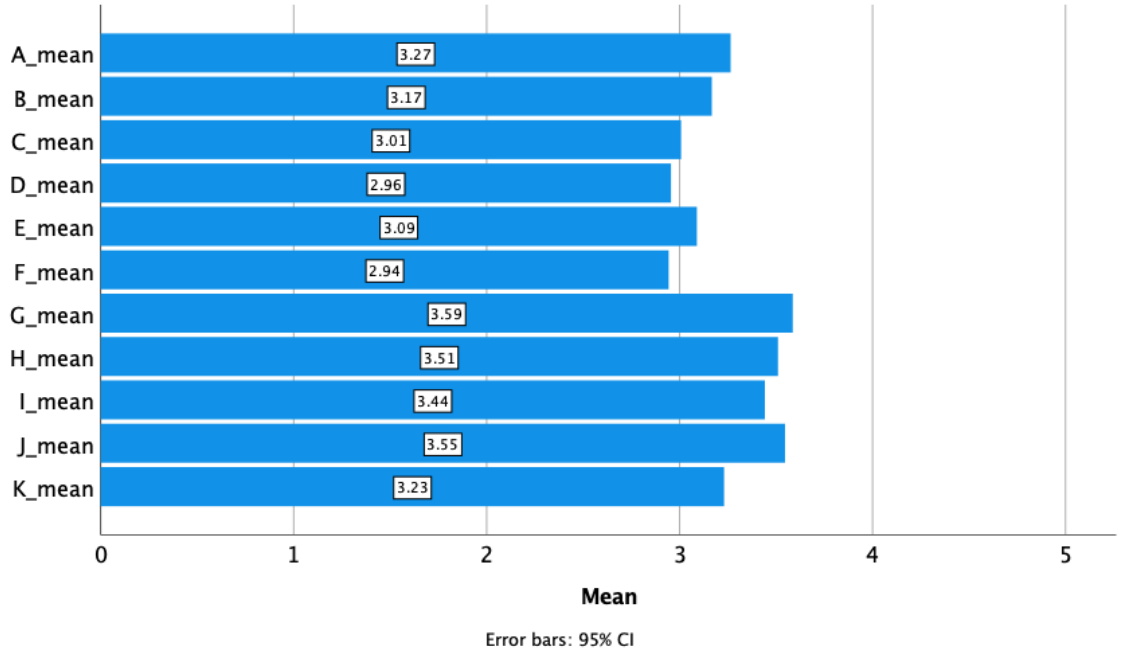

Figure 13. Average value of self-perceived competence level by module.

The mean scores of the items, in each module, range from 2.956 to 3.587 and the standard deviations are quite similar. Module F (Module 1.5: Data Analytic) and module D (Module 1.3: Digital Manufacturing) are the ones with lower scores. On the other hand, module G (Module 2.1: Communication and people skills development) attained the highest score, closely followed by module J (Module 2.4: Coaching and Mentoring Skills development) and module H (Module 2.2: Innovative teaching and learning methods). Taking into account the 95% confidence intervals for the mean, it can be observed that modules G, H, I and J have average scores significantly higher than modules B, C, D, E and F.

5.2 Descriptive statistics

The following tables and graphs present the results regarding each module of the questionnaire, accompanied by the respective descriptive statistics.

5.2.1 Generic Items based on Acatech Elements

The mean scores of the items of module A - Industry 4.0 Generic Items based on Acatech Elements, range from 3.18 to 3.56 and the standard deviations are quite similar. The mean value for the entire module is 3.265 (Figure 13) thus corresponding to a self-perceived competence level of 65.3%. Items A2 - I am able to evaluate the maturity level of a company in order to develop a project to evolve its Industry 4.0 stage, A6 - I am able to discuss the required learning and agile corporate culture, including willing to change, innovate, and develop employees' skills, in the context of Industry 4.0, and, A7 - I am able to understand the importance of digital capability for decentralized pre-processing of automated data acquisition through sensors and actuators, are the ones with the lowest (relative) scores. On the other hand, item A1 – I am able to understand that companies have different Industry 4.0 maturity levels, attained the highest score.

A significant statistical difference was identified for item A10 in which the mean score difference between Rajabhat institutions and Rajamangala institutions was -0.357 (t=-2.115, p-value=0.036). Thus, in this item, the average scores for teachers from Rajabhat institutions was inferior to those from Rajamangala institutions.

Table 9. Results for module A.

	Industry 4.0 Generic Items based on Acatech Elements	N	Mean	Std. Deviation
A1	I am able to understand that companies have different Industry 4.0 maturity levels.	202	3.56	1.078
A2	I am able to evaluate the maturity level of a company in order to develop a project to evolve its Industry 4.0 stage.	202	3.18	.998
A3	I am able to recognize a company required tangible, physical resources, including a company's workforce (human resources), facilities, machinery and equipment, tools, materials and the final product for Industry 4.0.	202	3.31	1.122
A4	I am able to discuss the required information systems for Industry 4.0, in which the information is provided by both people and "information and communication technology".	202	3.34	1.064
A5	I am able to recognize the required Industry 4.0 organisational structure, referring to both a company's internal organisation (structure and operational processes) and its position within the value network (value stream).	202	3.19	1.010
A6	I am able to discuss the required learning and agile corporate culture, including willing to change, innovate, and develop employees' skills, in the context of Industry 4.0.	202	3.18	1.070
A7	I am able to understand the importance of digital capability for decentralized pre-processing of automated data acquisition through sensors and actuators.	202	3.18	1.129
A8	I am able to understand that Industry 4.0 includes efficient communication between people and between people and machines through task-based interfaces.	202	3.27	1.096
A9	I am able to understand the importance of data and self-learning systems for delivering context-dependent data.	202	3.25	1.084
A10	I am able to understand that Industry 4.0 information systems must provide full integration between processes under governance policies and protected by data security systems.	202	3.28	1.173
A11	I am able to understand that in the context of Industry 4.0 the organization is a system enabled by a collective intelligence and agile management, i.e. involving motivation to change (problem solving, improvement), proper use of people skills and decentralized decision-making.	202	3.23	1.084
A12	I am able to understand that Industry 4.0 is focused on the customer benefits enabled by networked collaboration inside the company (i.e. intra-company) and between different companies (i.e. inter-companies).	202	3.28	1.076
A13	I am able to recognize that collaborative management is important in the context of Industry 4.0, i.e. including democratic leadership and transparent communication between people.	202	3.22	1.135
A14	I am able to discuss that in the context of Industry 4.0, people recognize the value of mistakes, are open to innovation, search for continuous professional development and are driven by knowledge databases and decision-making in a continuous process of change.	202	3.23	1.064

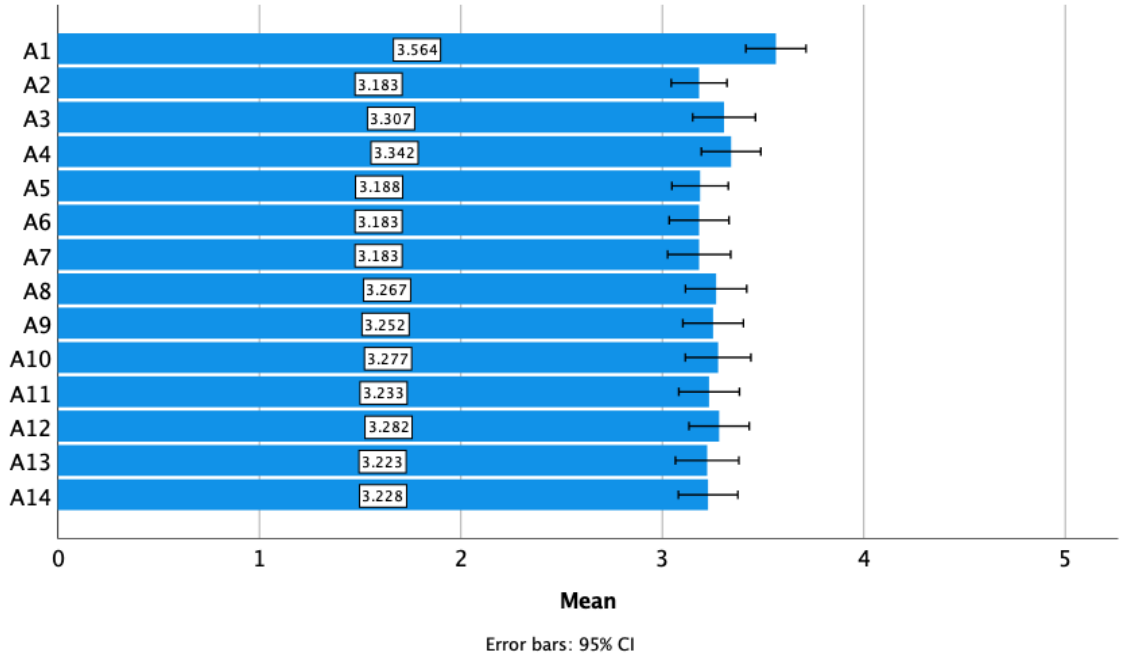

Figure 14. Results for module A

5.2.2 Module 1.1: Industrial Management in Industry 4.0 Era

The mean scores of the items of module B (1.1) - Industrial Management in Industry 4.0 Era, range from 2.99 to 3.31. The mean value for the entire module is 3.167 thus corresponding to a self-perceived competence level of 63.3%. Item B7 - I am able to use a modelling tool (e.g. BPMN, VSM) to represent industrial processes considering smart production concepts, is the one with the lowest (relative) score. On the other hand, item B5 – I am able to work effectively in a distributed team, attained the highest score.

Table 10. Results for module B.

Module 1.1: Industrial Management in Industry 4.0 Era		N	Mean	Std. Deviation
B1	I am able to discuss the relevance of agile project management in the context of Industry 4.0.	202	3.19	.990
B2	I am able to define the Industry 4.0 level of maturity of a company.	202	3.13	.929
B3	I am able to apply agile project management approaches in the context of Industry 4.0.	202	3.13	.960
B4	I am able to apply the team development phases (Forming, Storming, Norming, Performing, Adjourning) to support teamwork.	202	3.19	.995
B5	I am able to work effectively in a distributed team.	202	3.31	.990
B6	I am able to develop projects for the transformation of a company in the context of Industry 4.0.	202	3.18	.971
B7	I am able to use a modelling tool (e.g. BPMN, VSM) to represent industrial processes considering smart production concepts.	202	2.99	1.053
B8	I am able to use performance indicators of a company's operating efficiency in the context of Industry 4.0.	202	3.09	1.054
B9	I am able to recognize the role of customer service in the context of Industry 4.0.	202	3.23	1.011
B10	I am able to plan and control the company's operations considering smart production concepts.	202	3.16	.997
B11	I am able to design real time data analytics systems to support operations planning and control.	202	3.15	1.092
B12	I am able to discuss the impact of Industry 4.0 on quality management.	202	3.27	1.006
B13	I am able to identify performance indicators of quality management area in the context of Industry 4.0.	202	3.16	.985
B14	I am able to collect quality management data for Industry 4.0.	202	3.20	.998
B15	I am able to design a data visualization solution for quality management and productivity indicators.	202	3.17	1.005
B16	I am able to design a quality management system for Industry 4.0.	202	3.13	.984

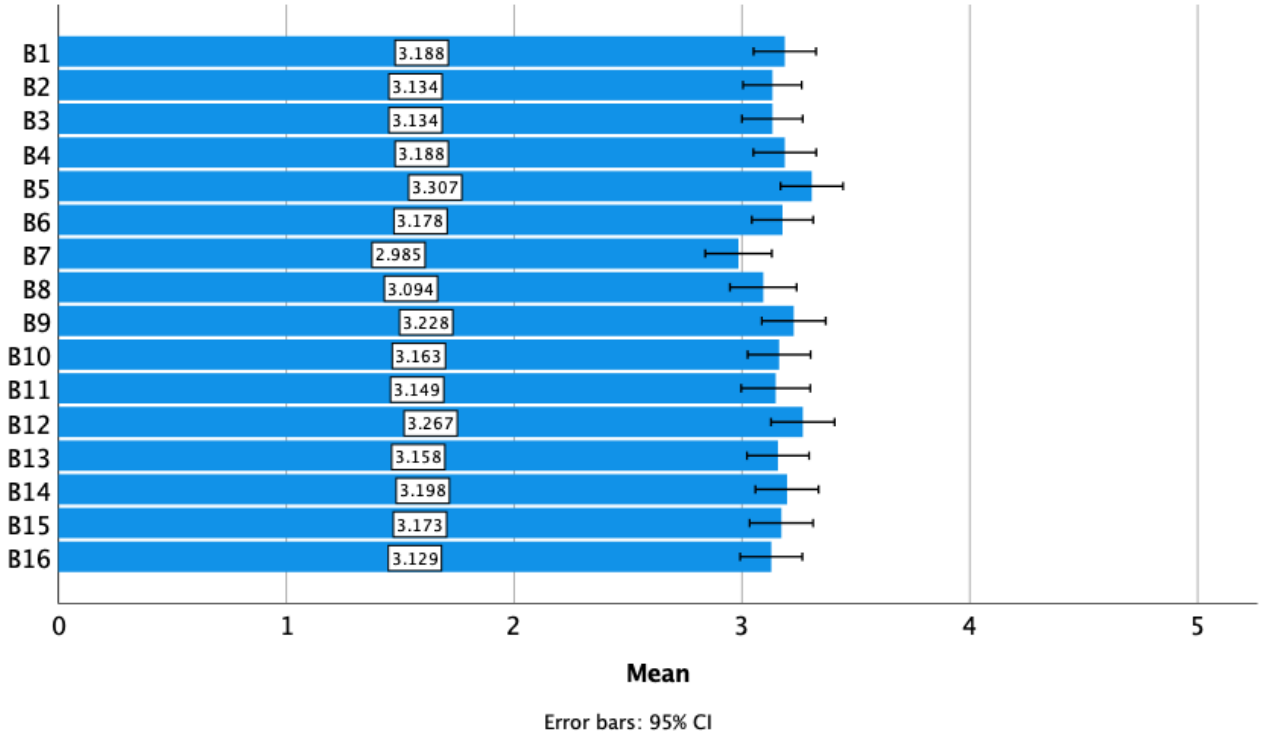

Figure 15. Results for module B

5.2.3 Module 1.2: Applications of Optimization, and Technology in Value Chain

The mean scores of the items of module C (1.2)- Applications of Optimization, and Technology in Value Chain, range from 2.94 to 3.10. The mean value for the entire module is 3.008 thus corresponding to a self-perceived competence level of 60.2%. Item C4 - I am able to conduct sensitivity analysis to examine solutions robustness, is the one with the lowest (relative) score. On the other hand, item C6 – I am able to describe Sustainable Supply Chain Management (SSCM) models, attained the highest score.

Table 11. Results for module C.

Module 1.2: Applications of Optimization, and Technology in Value Chain		N	Mean	Std. Deviation
C1	I am able to formulate mathematical optimization models for practical problems in industrial application.	202	2.97	1.043
C2	I am able to select appropriate optimization techniques to solve practical problems in industrial applications.	202	3.09	1.082
C3	I am able to use optimization software (e.g. MATLAB, LINGO, or MPL software) to solve practical problems in industrial applications.	202	2.95	1.096
C4	I am able to conduct sensitivity analysis to examine solutions robustness.	202	2.94	1.001
C5	I am able to develop real time optimization approaches for Industry 4.0.	202	2.99	1.032
C6	I am able to describe Sustainable Supply Chain Management (SSCM) models.	202	3.10	1.104
C7	I am able to manage a Sustainable Supply Chain Management (SSCM) network in the context of Industry 4.0.	202	2.99	1.017
C8	I am able to redesign a supply chain considering sustainability and Industry 4.0 requirements.	202	3.03	1.046

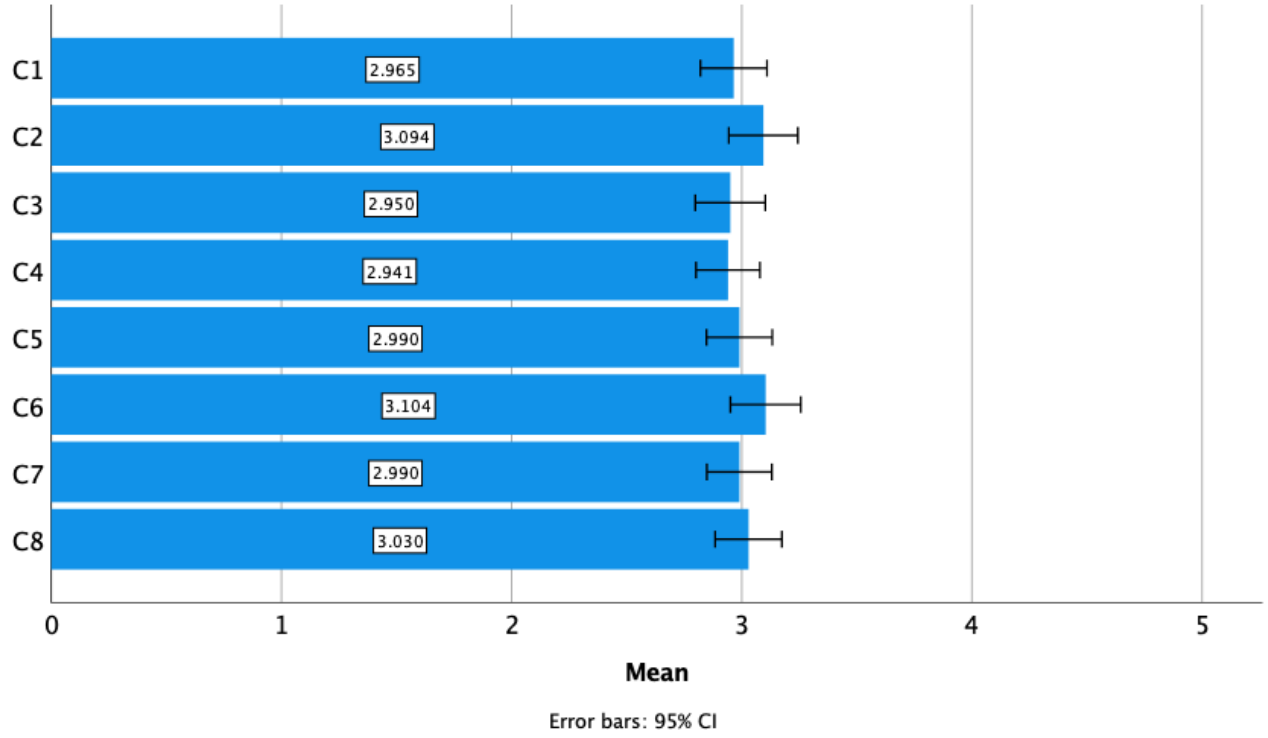

Figure 16. Results for module C

5.2.4 Module 1.3: Digital Manufacturing

The mean scores of the items of module D (1.3) - Digital Manufacturing, range from 2.80 to 3.14. The mean value for the entire module is 2.956 thus corresponding to a self-perceived competence level of 59.1%. Item D6 - I am able to implement concepts of Smart Production using Cyber Physical Systems (CPS), and, D8 - I am able to develop Cyber Physical System (CPS) projects to improve business performance, are the ones with the lowest (relative) score. On the other hand, item D1 – I am able to describe the concept of Digital Factory, attained the highest score.

A significant statistical difference was found for item D11 in which the mean score difference between Rajbhat institutions and Rajamangala institutions was -0.351 (t=-2.197, p-value=0.030). Thus, in this item, the average scores for teachers from Rajbhat institutions was inferior to those from Rajamangala institutions.

Table 12. Results for module D.

Module 1.3: Digital Manufacturing		N	Mean	Std. Deviation
D1	I am able to describe the concept of Digital Factory.	202	3.14	1.079
D2	I am able to understand the functionalities and limitations of current digital technologies.	202	3.13	1.071
D3	I am able to use simulation to analyse the performance of a production system.	202	3.07	1.126
D4	I am able to specify a digital transformation model for an industrial case study.	202	3.02	1.039
D5	I am able to describe the concept of Cyber Physical System (CPS).	202	2.83	1.080
D6	I am able to implement concepts of Smart Production using Cyber Physical Systems (CPS).	202	2.80	1.081
D7	I am able to use the Internet of Things (IoT) to collect real time data from sensors.	202	3.03	1.146
D8	I am able to develop Cyber Physical System (CPS) projects to improve business performance.	202	2.80	1.099

D9	I am able to describe principles of Additive Manufacturing.	202	2.94	1.098
D10	I am able to apply Reverse Engineering concepts in the context of Additive Manufacturing.	202	2.95	1.089
D11	I am able to choose process parameters for effective Additive Manufacturing.	202	2.89	1.103
D12	I am able to choose Additive Manufacturing technologies.	202	2.97	1.094
D13	I am able to develop products using the Design for Additive Manufacturing (DfAM) concept.	202	2.88	1.091

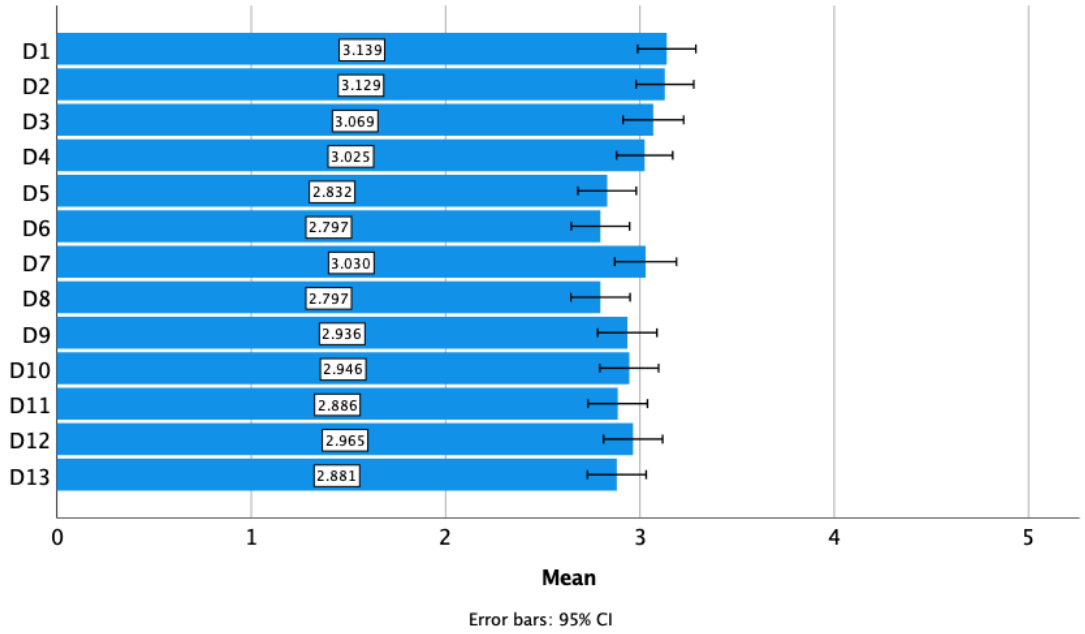

Figure 17. Results for module D

5.2.5 Module 1.4: Innovative Product Design and Development

The mean scores of the items of module E (1.4) - Innovative Product Design and Development, range from 2.94 to 3.29. The mean value for the entire module is 3.090 thus corresponding to a self-perceived competence level of 61.8%. Item E6 - I am able to valorise, capitalize and protect the original solutions obtained from the creative activity, is the one with the lowest (relative) score. On the other hand, item E1 – I am able to recognize the benefits of implementing innovations, attained the highest score.

Table 13. Results for module E.

Module 1.4: Innovative Product Design and Development		N	Mean	Std. Deviation
E1	I am able to recognize the benefits of implementing innovations.	202	3.29	1.073
E2	I am able to analyze strategic elements of new product innovation.	202	3.08	1.004
E3	I am able to identify ideas for innovative products in the context of Industry 4.0.	202	3.07	1.049
E4	I am able to apply methods for innovation (e.g. design thinking).	202	3.15	1.073
E5	I am able to propose marketing strategies for launching new products.	202	3.01	1.044
E6	I am able to valorize, capitalize and protect (e.g. using patents) the original solutions obtained from the creative activity.	202	2.94	1.011

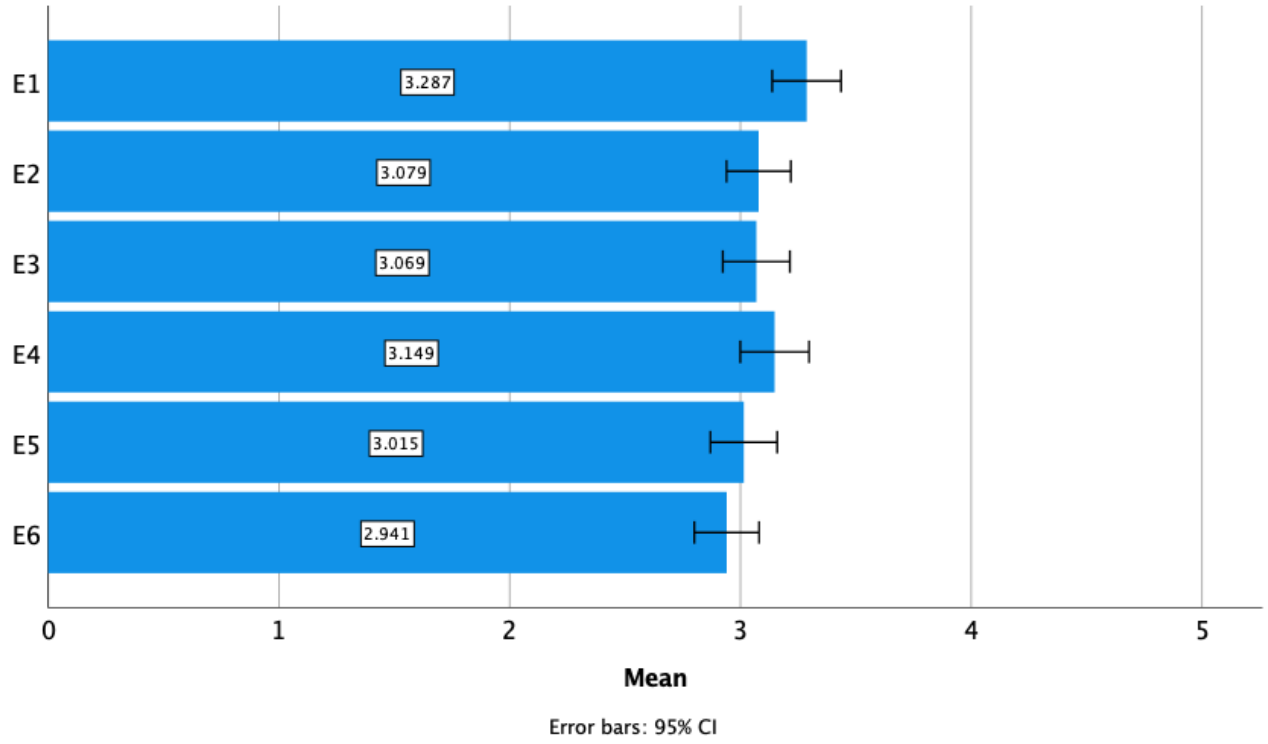

Figure 18. Results for module E

5.2.6 Module 1.5: Data Analytic

The mean scores of the items of module F (1.5) - Data Analytic, range from 2.86 to 3.07. The mean value for the entire module is 2.944 thus corresponding to a self-perceived competence level of 58.9%. Item F8 - I am able to develop data analytics algorithms for big data sets, is the one with the lowest (relative) score. On the other hand, item F5 – I am able to identify data analytics principles, attained the highest score.

Table 14. Results for module F.

Module 1.5: Data Analytic		N	Mean	Std. Deviation
F1	I am able to describe the concept of Intelligent Decision Support System (IDSS).	202	2.98	1.113
F2	I am able to apply techniques of Intelligent Decision Support Systems (e.g. artificial neural networks, machine learning or rule-based systems) to solve industrial problems.	202	2.94	1.136
F3	I am able to describe a framework of Intelligent Decision Support System (IDSS).	202	2.91	1.143
F4	I am able to design an Intelligent Decision Support System (IDSS) to support a smart production system.	202	2.89	1.103
F5	I am able to identify data analytics principles.	202	3.07	1.126
F6	I am able to apply data visualization techniques in dealing with big data sets.	202	2.95	1.069
F7	I am able to apply key data mining techniques (e.g. classification analysis, clustering analysis, regression analysis) in dealing with big data sets.	202	2.99	1.097
F8	I am able to develop data analytics algorithms for big data sets.	202	2.86	1.120
F9	I am able to develop data analytics projects in the context of Industry 4.0.	202	2.91	1.116

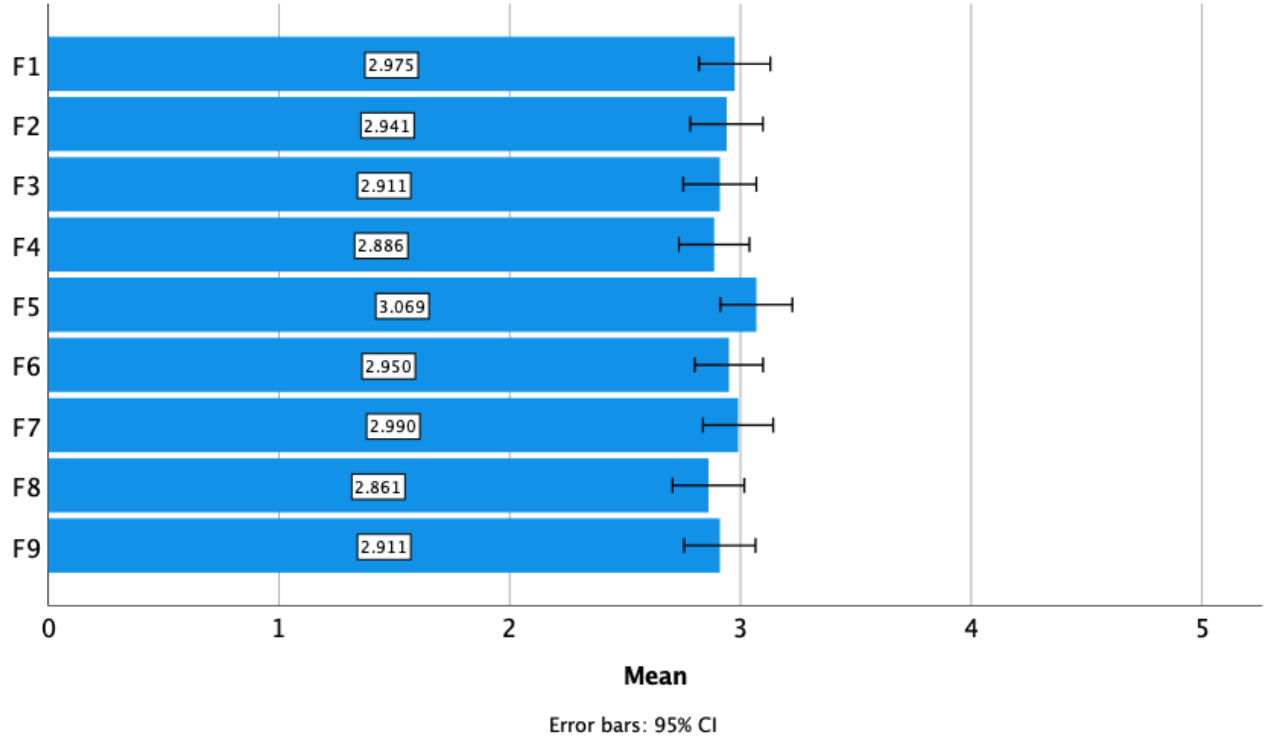

Figure 19. Results for module F

5.2.7 Module 2.1: Communication and people skills development

The mean scores of the items of module G (2.1) - Communication and people skills development, range from 3.41 to 3.71. The mean value for the entire module is 3,587 thus corresponding to a self-perceived competence level of 71.8%. Item G4 - I am able to apply emotional intelligence concepts in different contexts of the teaching practice, is the one with the lowest (relative) score. On the other hand, items G1 – I am able to make effective presentations to the students, and G5 - I am able to work in teams, collaborating with other teachers from the department or university, attained the highest score.

Table 15. Results for module G.

	Module 2.1: Communication and people skills development	N	Mean	Std. Deviation
G1	I am able to make effective presentations to the students.	202	3.71	1.055
G2	I am able to explain ideas effectively in a way that students understand.	202	3.62	.976
G3	I am able to understand the concept of emotional intelligence in different contexts of the teaching practice.	202	3.51	.948
G4	I am able to apply emotional intelligence concepts in different contexts of the teaching practice.	202	3.41	.959
G5	I am able to work in teams, collaborating with other teachers from the department or university.	202	3.71	1.074
G6	I am able to lead, persuade, motivate and inspire students to achieve goals	202	3.56	1.026

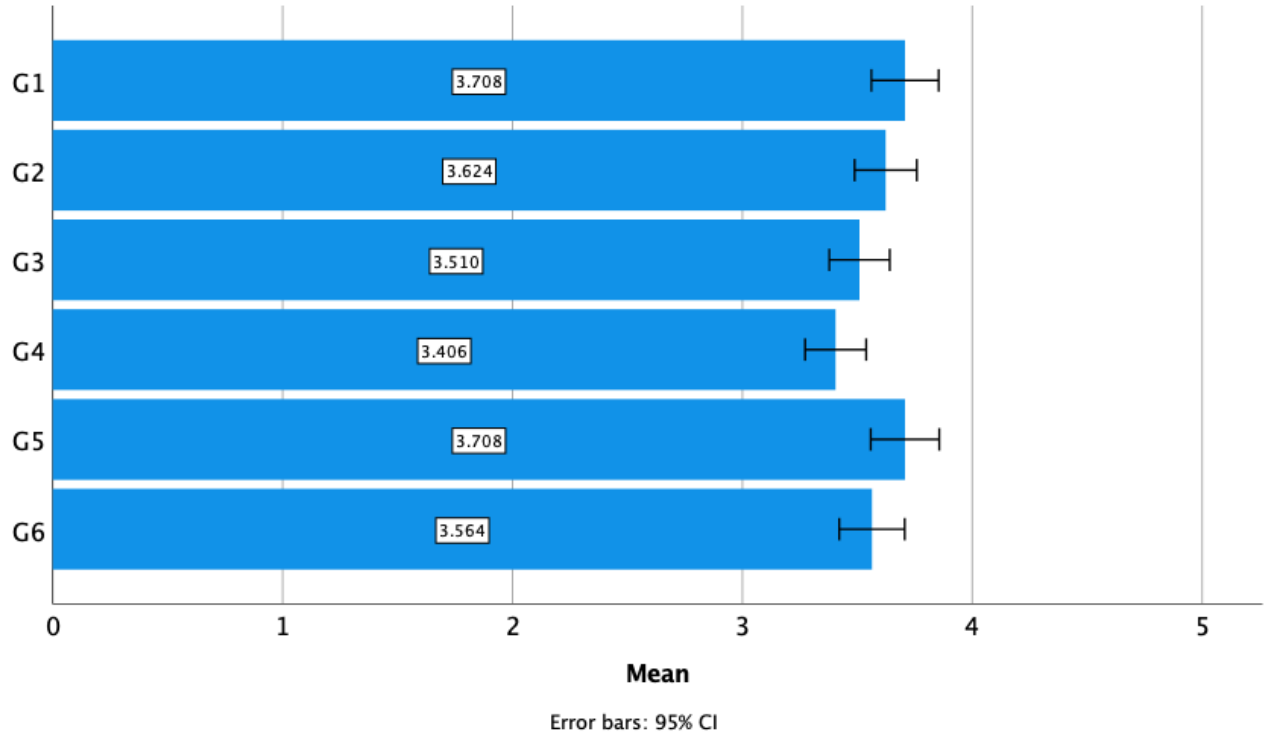

Figure *20*. Results for module G

5.2.8 Module 2.2: Innovative teaching and learning methods

The mean scores of the items of module H (2.2) - Innovative teaching and learning methods, range from 3.40 to 3.67. The mean value for the entire module is 3,510 thus corresponding to a self-perceived competence level of 70.2%. Item H6 - I am able to increase student engagement using a flipped classroom approach, is the one with the lowest (relative) score. On the other hand, item H2 – I am able to provide opportunities for students to collaborate, attained the highest score.

Table 16. Results for module H.

	Module 2.2: Innovative teaching and learning methods	N	Mean	Std. Deviation
H1	I am able to enhance teaching using different technology solutions (e.g. mentimeter, kahoot, miro, amongst others).	202	3.44	1.092
H2	I am able to provide opportunities for students to collaborate.	202	3.67	1.081
H3	I am able to use online learning management systems (e.g. Moodle, Blackboard).	202	3.54	1.027
H4	I am able to record videos for use by students later.	202	3.63	1.063
H5	I am able to plan and teach a class either on a synchronous or asynchronous mode.	202	3.42	1.063
H6	I am able to increase student engagement using a flipped classroom approach.	202	3.40	1.008
H7	I am able to incorporate the use of self-directed learning approaches.	202	3.48	1.018

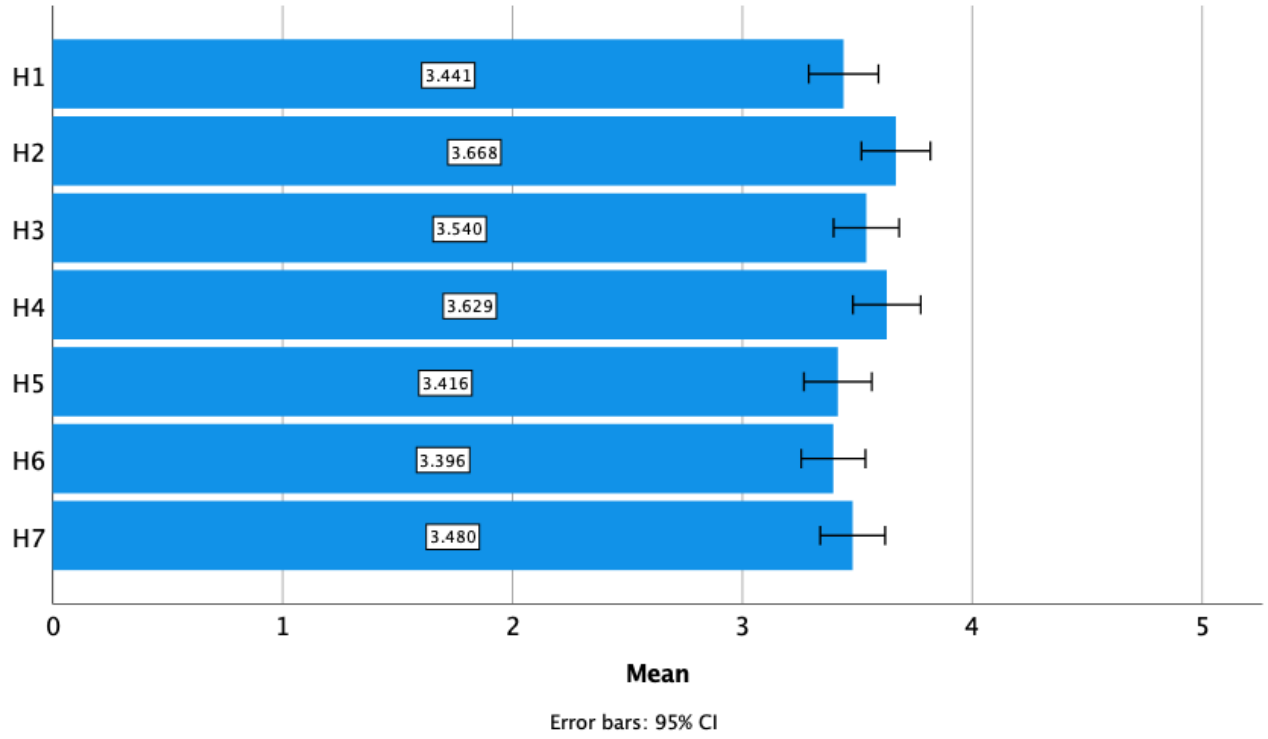

Figure 21. Results for module H

5.2.9 Module 2.3: Problem and Project-Based Learning (PBL)

The mean scores of the items of module I (2.3) - Problem and Project-Based Learning (PBL), range from 3.37 to 3.53. The mean value for the entire module is 3.443 thus corresponding to a self-perceived competence level of 68.9%. Item I4 - I am able to identify the main requirements for PBL organization (e.g. resources, teams, assessment), is the one with the lowest (relative) score. On the other hand, item I1 – I am able to understand Project-Based Learning (PBL) principles, attained the highest score.

Table 17. Results for module I.

	Module 2.3: Problem and Project-Based Learning (PBL)	N	Mean	Std. Deviation
I1	I am able to understand Project-Based Learning (PBL) principles.	202	3.53	1.107
I2	I am able to recognize different Project-Based Learning (PBL) typologies, i.e. different ways to put PBL in practice.	202	3.43	1.036
I3	I am able to identify problems or themes to be implemented in PBL context.	202	3.46	1.018
I4	I am able to identify the main requirements for PBL organization (e.g. resources, teams, assessment).	202	3.37	1.010
I5	I am able to create a PBL proposal for your teaching context.	202	3.42	1.020

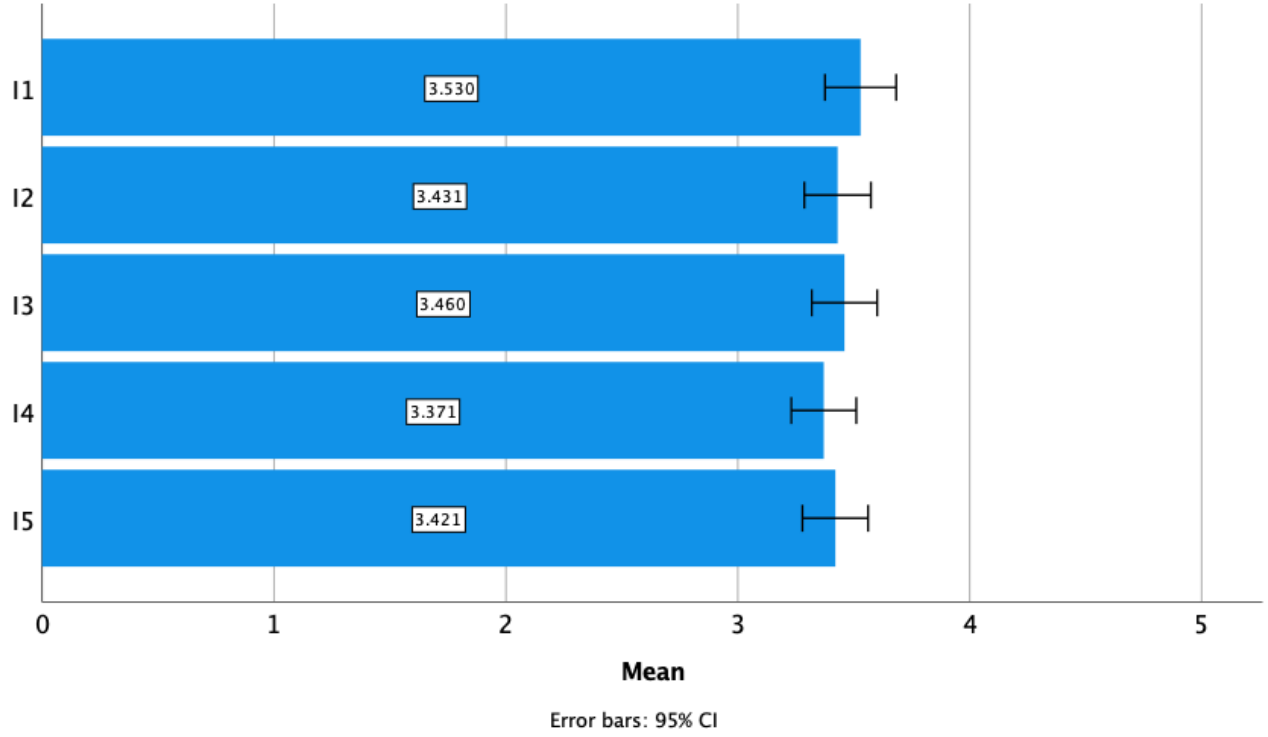

Figure 22. Results for module I

5.2.10 Module 2.4: Coaching and Mentoring Skills development

The mean scores of the items of module J (2.4) - Coaching and Mentoring Skills development, range from 3.47 to 3.62. The mean value for the entire module is 3.547 thus corresponding to a self-perceived competence level of 70.9%. Item J5 - I am able to plan appropriate interventions or additional support for students based on their identified needs, is the one with the lowest (relative) score. On the other hand, item J2 – I am able to provide additional explanations and communicate expectations for student achievement, attained the highest score.

Table 18. Results for module J.

	Module 2.4: Coaching and Mentoring Skills development	N	Mean	Std. Deviation
J1	I am able to understand the differences between coaching and mentoring.	202	3.55	1.037
J2	I am able to provide additional explanations and communicate expectations for student achievement.	202	3.62	1.031
J3	I am able to motivate students so that they can produce high-quality work.	202	3.53	1.023
J4	I am able to provide formative feedback to students on their work indicating how they can improve.	202	3.56	1.016
J5	I am able to plan appropriate interventions or additional support for students based on their identified needs.	202	3.47	1.008
J6	I am able to support students in ensuring their work meets the appropriate standard including academic integrity (ethics).	202	3.55	1.012

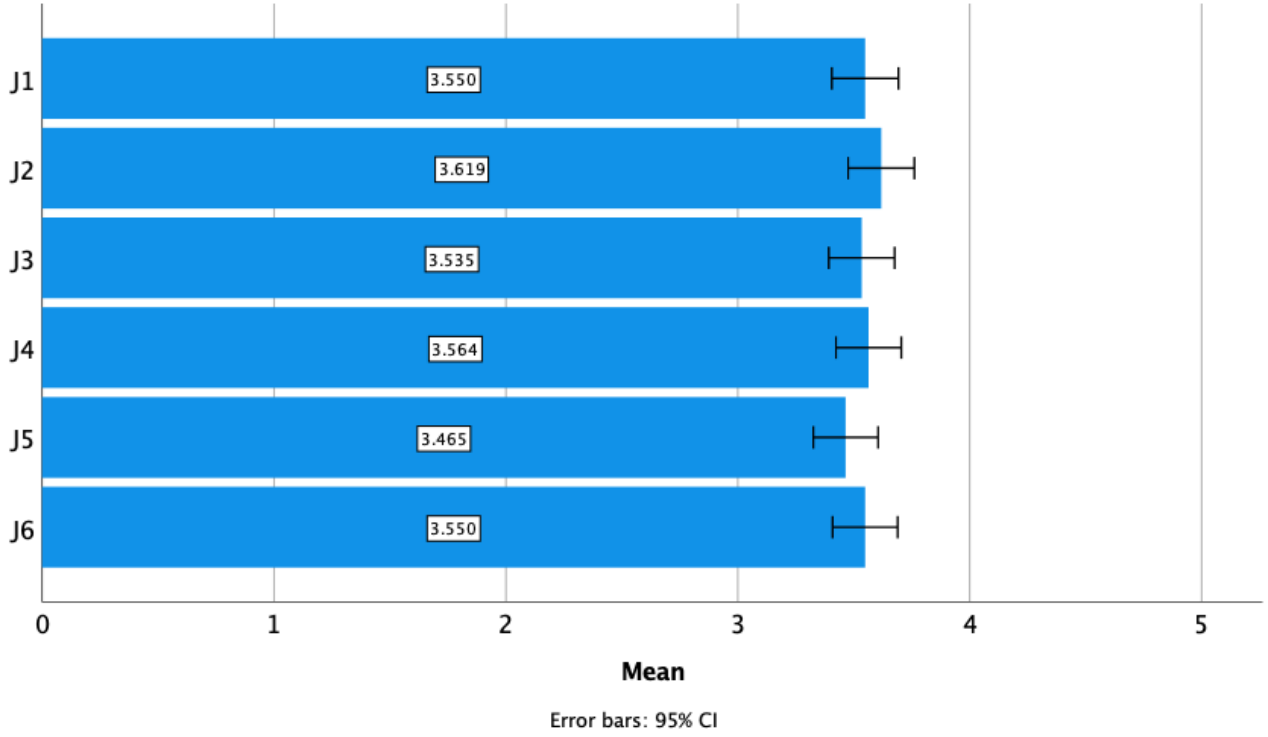

Figure 23. Results for module J

5.2.11 Module 2.5: Learning experience-focused course design and development

The mean scores of the items of module K (2.5) - Learning experience-focused course design and development, range from 2.98 to 3.39. The mean value for the entire module is 3.231 thus corresponding to a self-perceived competence level of 64.6%. Item K5 - I consider myself an expert on Kolb's Learning Cycle, is the one with the lowest (relative) score. On the other hand, item K1 – I consider myself highly experienced in curriculum (programme) development and/or revision, attained the highest score.

Table 19. Results for module K.

	Module 2.5: Learning experience-focused course design and development	N	Mean	Std. Deviation
K1	I consider myself highly experienced in curriculum (programme) development and/or revision.	202	3.39	1.055
K2	I consider myself highly experienced in developing courses.	202	3.37	.995
K3	I consider myself highly experienced in revising course structure, including the syllabus, study and teaching materials, learning outcomes, class plan and assessment plan.	202	3.38	1.035
K4	I consider myself an expert on Bloom's Taxonomy.	202	3.06	1.127
K5	I consider myself an expert on Kolb's Learning Cycle.	202	2.98	1.137
K6	I am able to discuss the differences between forward and backward curriculum design.	202	3.20	1.065
K7	I am able to develop a curriculum coherently integrating the following elements for both the courses and the whole program: objectives, learning outcomes, outline, resources, teaching and learning methods, time distribution and study load, evaluation and grading criteria.	202	3.25	1.037

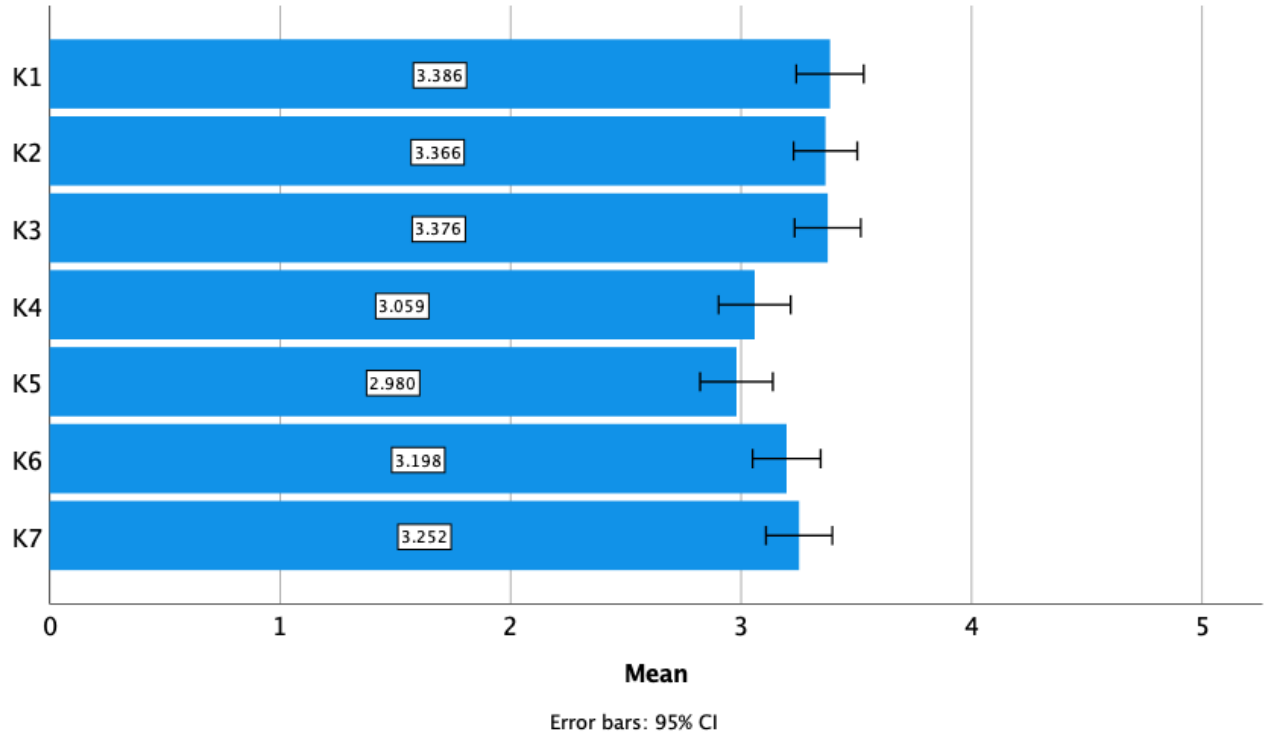

Figure 24. Results for module K

5.2.12 Interest in Training Modules

Globally (i.e., aggregating data from Rajabhat and Rajamangala Universities), the gathered preferences regarding training modules for the industry 4.0 part indicate that module 1.3 - Digital Manufacturing (D), was the one that aroused the least interest (participants were asked to indicate the two most preferred modules). On the other hand, module 1.4 - Innovative Product Design and Development (E), was the most preferred in terms of training, closely followed by module 1.1 - Industrial Management in Industry 4.0 Era (B), and module 1.2 - Applications of Optimization, and Technology in Value Chain (C).

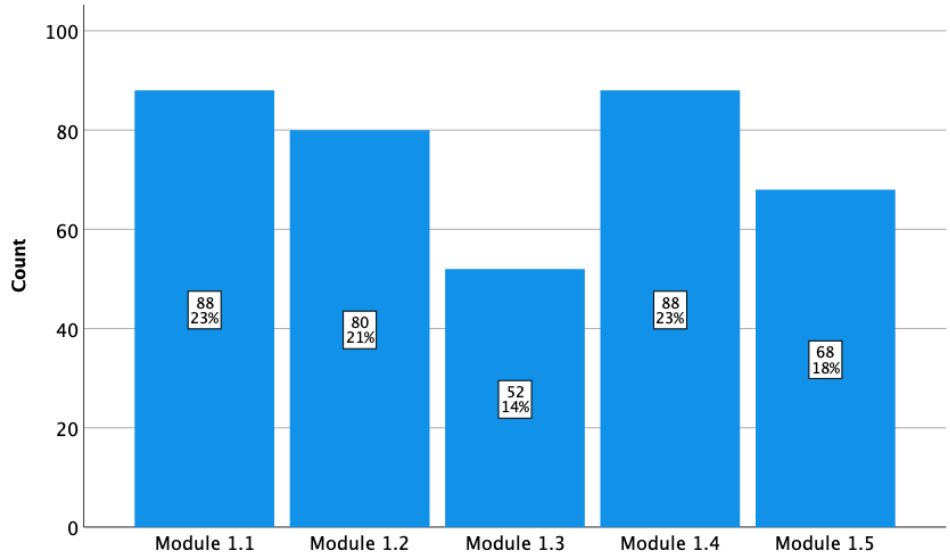

Figure 25. Aggregated preferences of Industry 4.0 Training Modules

However, the analysis by type of institution reveals some significant differences between Rajabhat and Rajamangala Universities. In fact, the ranking of training preferences of Rajabhat institutions points to modules 1.1 > 1.5 > 1.4 > 1.2 > 1.3, while the Rajamangala institutions indicate modules 1.4 > 1.2 > 1.1 > 1.3 > 1.5. As can be observed, both the most preferred and least preferred modules are different depending on the type of institution. Additionally, it is worth mentioning that the module that aroused the least interest in the Rajamangala institutions is the one that appears in second place in the Rajabhat institutions' preferences (module 1.5 - Data Analytic).

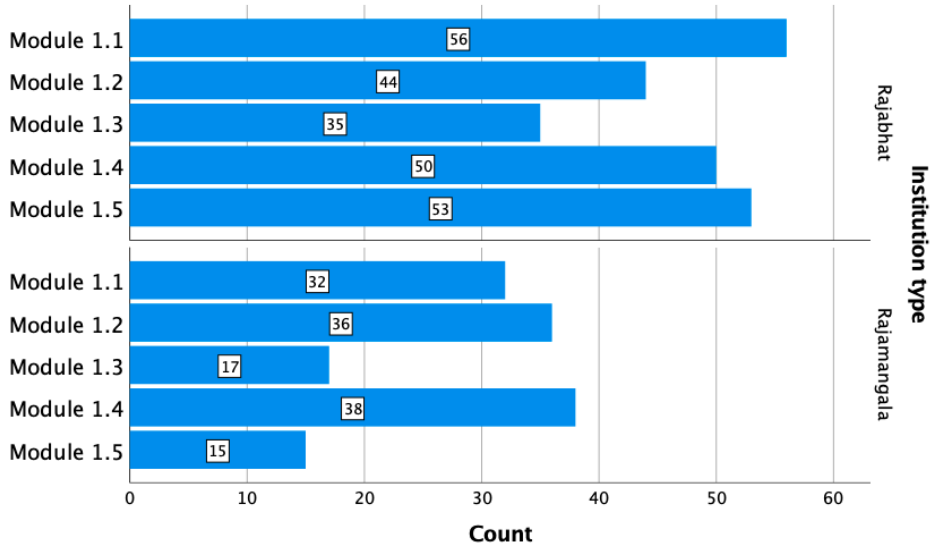

Figure 26. Preferences of Industry 4.0 Training Modules by type of institution

Globally (i.e., aggregating data from Rajabhat and Rajamangala Universities), the gathered preferences regarding training modules for the educational part clearly indicate that module 2.2 - Innovative teaching and learning methods (H), was the most preferred. On the other hand, module 2.4 - Coaching and Mentoring Skills development (J), was the least preferred in terms of training, closely followed by module 2.1 - Communication and people skills development (G).

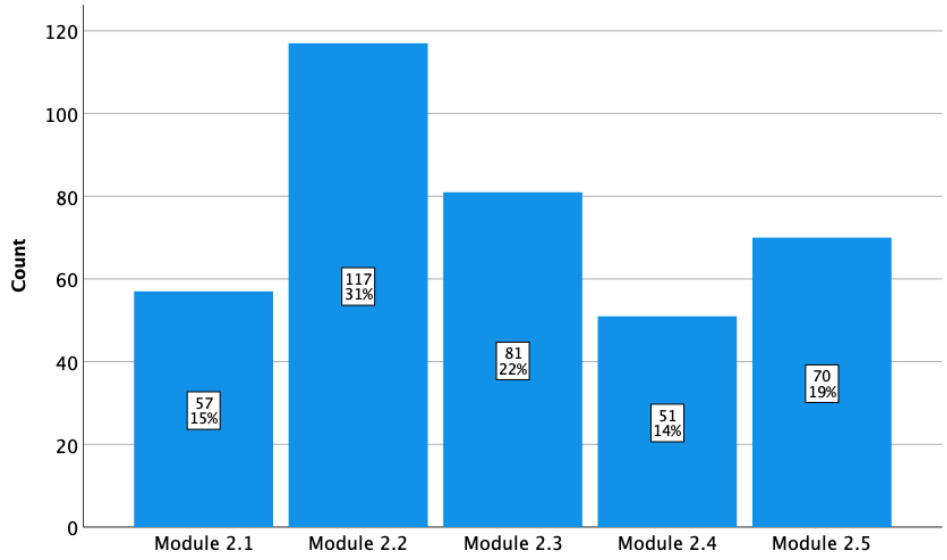

Figure 27. Aggregated preferences of Educational Training Modules

However, the analysis by type of institution do not reveal significant differences between Rajabhat and Rajamangala Universities. In fact, the ranking of training preferences of Rajabhat institutions points to modules 2.2 > 2.3 > 2.5 > 2.1 > 2.4, while the Rajamangala institutions indicate modules 2.2 > 2.3 > 2.5 > 2.4 > 2.1. As can be observed, the first three preferred modules are the same, and only the least preferred have inverted positions.

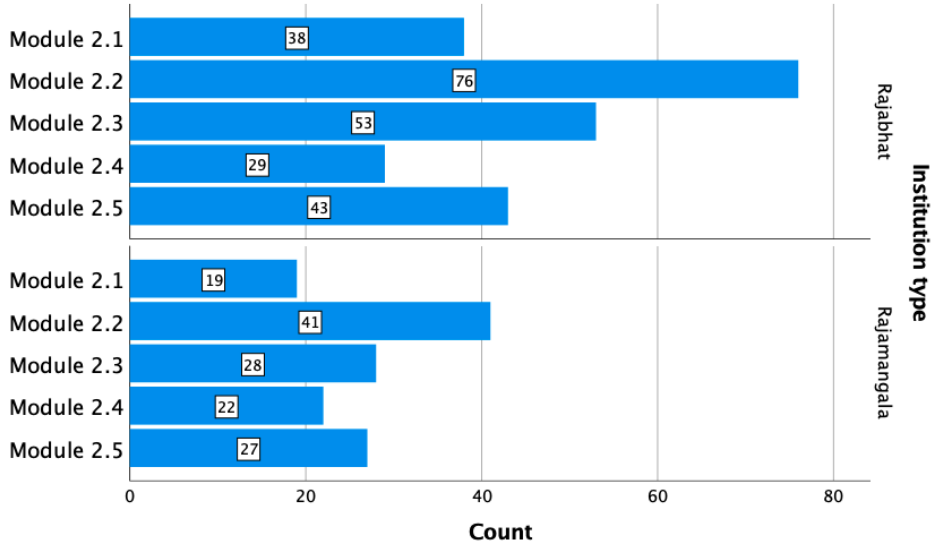

Figure 28. Preferences of Educational Training Modules

5.3 Summary of all averages for all items of the questionnaire

Table 20 presents a summary of all averages calculated for all items in the questionnaire. This table is presented as an overview of the results.

Table 20. Highlighted summary of the means of all items of the questionnaire

Average	3.27	3.17	3.01	2.96	3.09	2.94	3.59	3.51	3.44	3.55	3.23
Module	A	B	C	D	E	F	G	H	I	J	K
Item 1	3.56	3.19	2.97	3.14	3.29	2.98	3.71	3.44	3.53	3.55	3.39
Item 2	3.18	3.13	3.09	3.13	3.08	2.94	3.62	3.67	3.43	3.62	3.37
Item 3	3.31	3.13	2.95	3.07	3.07	2.91	3.51	3.54	3.46	3.53	3.38
Item 4	3.34	3.19	2.94	3.02	3.15	2.89	3.41	3.63	3.37	3.56	3.06
Item 5	3.19	3.31	2.99	2.83	3.01	3.07	3.71	3.42	3.42	3.47	2.98
Item 6	3.18	3.18	3.10	2.80	2.94	2.95	3.56	3.40		3.55	3.20
Item 7	3.18	2.99	2.99	3.03		2.99		3.48			3.25
Item 8	3.27	3.09	3.03	2.80		2.86					
Item 9	3.25	3.23		2.94		2.91					
Item 10	3.28	3.16		2.95							
Item 11	3.23	3.15		2.89							
Item 12	3.28	3.27		2.97							
Item 13	3.22	3.16		2.88							
Item 14	3.23	3.20									
Item 15		3.17									
Item 16		3.13									

5.4 Correlation between respondent characteristics and items

Associations between the number of years of experience, the highest academic degree, the English level proficiency and the mean scores for modules A, B, C, D, E, F, G, H, I, J and K were tested using ANOVA tests. The assumptions (normality and homogeneity of variances) for the application of ANOVA were also tested.

No significant differences were found between the number of years of experience or the highest academic degree and the mean scores of all modules.

Significant differences between the English level proficiency and the mean scores for modules A (p-value=0.07), B (p-value=0.019), E (p-value=0.021), G (p-value=0.001), H (p-value=0.003), I (p-value<0.001) and J (p-value<0.001) were found. In all these modules, significant differences in the mean scores between Elementary level and High intermediate level and, also, between Low intermediate level and High intermediate level were found.

Figure 26 shows the 95% interval confidences for the mean scores by English proficiency level. In general, mean scores for Elementary level and Low intermediate level are inferior to the High intermediate level. The advanced level has very low answers and for that reason the results in this level are not relevant for the analysis.

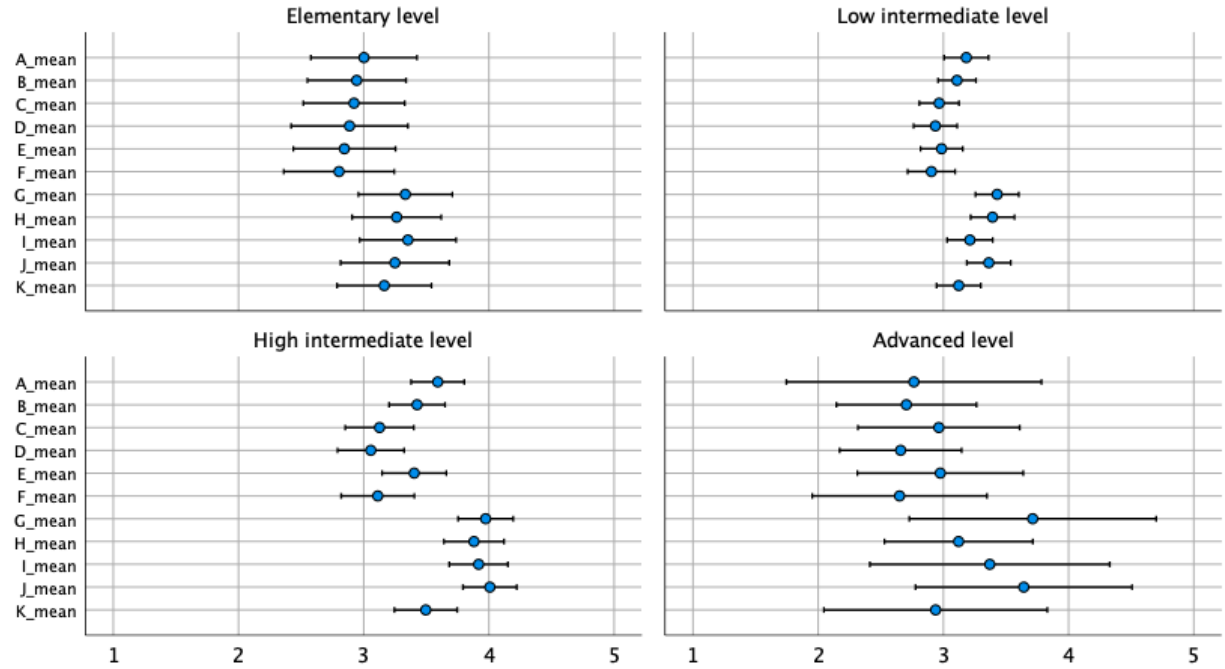

Figure 29. 95% IC for the mean scores by the English proficiency level.

6 Assessment results

Considering the entire questionnaire (industry 4.0 and educational parts), the lowest self-perceived competence level (59%) occurred for module F (1.5) - Data Analytic, while the highest score (72%) was attained by module G (2.1) - Innovative teaching and learning methods. In general, for the second part of the questionnaire (educational part), the self-perceived competence level was higher than for the first part (industry 4.0). Except for module K (2.5) - Learning experience-focused course design and development, with a self-perceived competence level of 64.6%, all other modules of the educational part attained higher scores than the industry 4.0 modules. For the sake of simplicity, this numbers may be checked in Table 20.

There is no clear and direct relation between the self-perceived competence level and the training preferences indicated by the participants, which are to some extent opposite when considering the industry 4.0 and educational parts of the questionnaire.

Considering the respondents from Rajabhat institutions and their answers related to the Industry part (Figure 26), two of the three least preferred training module (D (1.3) - Digital Manufacturing; C (1.2) - Applications of Optimization, and Technology in Value Chain), are also two of three areas with the lowest self-perceived competence level (Table 8).

Considering the respondents from Rajabhat institutions and their answers related to the Educational part (Figure 28), the least preferred training modules (G (2.1) - Communication and people skills development; J (2.4) - Coaching and Mentoring Skills development), are two of three areas with the highest self-perceived competence level (Figure 13).

Although one could consider that a lower level of a self-perceived competence could indicate that a person would be interested in developing that competence, for several reasons, this may not be the case. As an example, one could prefer to reinforce its own strengths by personal motivations, and/or because it has a stronger link with its own professional activities.

A more detailed analysis of each dimension follows, which is based on the details of each item in every dimension, presented in “Annex 4 - Responses from the final version of the questionnaire”. The analysis will highlight mainly the items where more than 55% of the participants chose disagreement or “not sure” options. The rationale behind this analysis is that in this case most of the participants show a lower self-perceived competence level and by that reason they may benefit from training opportunities in those competences.

Regarding the general notions about Industry 4.0 according to the Acatech elements, the results show the following trends in relation to the respondents' competencies: there is a prevalence of familiarity about basic concepts about the resources needed for Industry 4.0 (technology) and about maturity models as a tool for reconfiguring processes and business models. The validity of this hypothesis can be seen in item A1, where 36% are unsure about the question or disagree that they are able to assess it, and 64% consider themselves comfortable with it. The answers are somehow similar for items A3, which deals with the physical resources employed in Industry 4.0, A4, which is related with the technological aspect of the Information Systems, and A8, related with efficient communication between people and between people and machines. However, most of the respondents do not consider themselves secure about the development and execution of Industry 4.0 implementation projects, as can be seen in item A2, about the application of technology for coordinated data collection (A7), internal organization required (A5), managerial aspects of information systems (A10), and general aspects of organizational culture and other specific ones that involve concepts such as collective intelligence, collaborative management and appreciation of innovation and change (A6, A9, A11, A13, A14). The answers are close in both Rajabhat and Rajamangala, although in question A10, the values are similar, between *Somewhat agree* and *Strongly agree*, in the other scales there is a significant variation. On *Strongly disagree* respondents from Rajabhat are 7% versus 3% from Rajamangala, and on *Somewhat disagree* the values are 10% versus 4%.

The answers indicate that more than half of the respondents do *not agree* or are *not sure* with topics of Industry 4.0. The only questions where this did not happen markedly (less than 60% of the answers) were those about general topics such as being able to discuss agile project management concepts in the context of I4.0 (B1), the ability to work in distributed teams (B5), knowledge about production planning and control (B10), plan and control the company's operations considering smart production concepts (B11), quality management (B12-15), general concepts about Digital Factory and digital technologies (D1, D2), and general concepts about innovation (E1, E3, and E4). However, a large number of cases seem to be enough for the expression "in the context of Industry 4.0" to appear for the answers to indicate an apparent tendency on

disagreement. In any case, in all the questions, there is a high rate of answers that indicate the need for development of the themes, some to a lesser degree, others to a greater degree.

In the analysis of the answers referring to Module B (1.1), the lower self-perceived competence levels are those about the application of maturity model assessment (B2), application of agile project management techniques (B3), team development (B4), develop projects of business process reconfiguration (B6), business process modelling (B7), use of performance indicators (B8), and about the role of customer-oriented services (B9).

In Module C (1.2) - Applications of Optimization, and Technology in Value Chain, which is basically a module of application of concepts and techniques, all items have 60% or more of responses that indicate demands for the development of teaching competences, especially in the ability to conduct sensitive analysis (C4) in which 71% of the participants responded that they have no knowledge on the subject or were not sure. The other items also presented high indexes in this same path, that may indicate the need for training in development and application of optimization models (C1-3, C5), and application of optimization models in Supply Chain Management (SSCM) (C6-8).

In Module D (1.3) - Digital Manufacturing, in several items, more than 70% of the participants answered that they were not skilled in concepts such as Cyber Physical System (CPS) and its applications (D5, D6 and D8), and similarly in Additive Manufacturing (D11, D13). When asked about general notions about these technologies, this rate improves somewhat, but still remains above 60% for those who consider they do not have enough knowledge about these subjects (D9, D10 and D12). With similar indexes, the answers indicate that the respondents present demands in the use of simulation models for performance analysis (D3), and in related techniques and applications such as digital technologies and its limitations for the development of Digital Factories, specification of digital transformation models (D4) and use of Internet of Things (D7). The answers are very similar in both Rajabhat and Rajamangala, however in question D11, which refers to Additive Manufacturing, there is an remarkable difference. Although in the scales related to knowledge on the subject the values are practically equal, in the scales that point to ignorance of the subject or refer to those who do not know how to answer, the discrepancies are large. Among the teachers from Rajabhat, the number of those who do not know how to answer is much higher than those who marked the same option as Rajamangala, 25% against 13%. The same is true among those who answer that they have no doubt that they do not know the subject, 10% in Rajabhat and 4% in Rajamangala.

Regarding Module E (1.4) - Innovative Product design and development, 70% of the answers indicate needs in the subject of valorisation (E6), capitalization and protection of products and intellectual property in innovation policies. Regarding the techniques applied in the innovation process the respondents also indicate accentuated demands as in analysis of strategic elements of innovation (E2), techniques of development of ideas for innovation (E3), application of innovation methods (E4) and development of marketing strategies in the innovation process (E5).

In Module F (1.5) - Data Analytic, 72% or more of the participants responded that they were not skilled in the development of data analytics algorithms (F8) and in the design and development of projects in this area (F4 and F9). There is also still a strong perception (more than 60%) of the need to develop skills in general knowledge of Intelligent Decision Support System (IDSS) (F1 and F3) and in the application of its techniques (F2). The same occurs regarding the principles of data analytics (F5) and the application of techniques related to this area (F6 and F7).

In Educational Part, with the exception of Module K (2.5) - Learning experience-focused course design and development, which concerns curriculum development, where in all items (K1-K7) most of the respondents declared to have no mastery, in the other modules, the opposite occurs. The respondents are confident in declaring aptitude. The indices become a little more balanced only in specific and more technical topics, as in the concept of emotional intelligence (G4), use of the flipped classroom approach (H6) and in the creation of strategies and problems for the application of Project-Based Learning (PBL) (I3-5), despite feeling comfortable with the technique and with the application of PBL (I1 and I2).

7 Recommendations

The competency assessment of teachers in the non-university sector in Thailand was conducted through a self-perception questionnaire that covered knowledge on Industry 4.0, teaching skills enhancement and competence-based curriculum development. Based on the evaluation of the questionnaire responses, it is possible to present the following recommendations. This is part of the input that the project team may consider, adding to the literature review, and the knowledge of the involved teachers.

Knowledge related to product, process, and production in Industry 4.0 Era

The responses are very close in both Rajabhat and Rajamangala institutions except for items A10 and D11. However, the variations do not interfere with the interpretation of the competences since they occur on scales that belong to the same interpretation group, that is, group (1), those who attest to having considerable ignorance about the subject and those who do not know how to answer, and group (2), those who are confident and comfortable with the subject in question.

The answers indicate that the participants have general knowledge about Industry 4.0 - definition, needs and impacts, and can point to the technology that makes Industry 4.0 possible, such as artificial intelligence, machine learning and the Internet of Things. However, the answers related to the self-perceived competence level show that the target audience have a higher opportunity for development of competences mainly in the following domains: organizational, people management, methodologies, and techniques:

a. Organizational: development of business strategy for adequacy to the Industry 4.0 environment (external factors) that favours the provision of services for adding value to products and correlated digital reconfiguration of business processes (internal factors). This requires the development of competences on the design and application of maturity models, agile project management applied to business process reconfiguration, use of business process modelling tools, development and application of performance indicators, design of data collection strategies and use of data analysis for decision making, and operations management in the context of Industry 4.0.

b. People management: strategy design and application of techniques and resources for project management in the context of Industry 4.0 with emphasis on agile philosophy and team development.

c. Methodologies and techniques: technologies associated with digital factory or Cyber Physical System (CPS), use of Internet of Things (IoT), development of strategies and implementation of Additive Manufacturing, product development and innovation in the context of Industry 4.0, implementation of Intelligent Decision Support System (IDSS) with data analysis, development and application of data analysis algorithms and development and application of simulation models and simulation techniques.

Teaching skills enhancement and Competence-based curriculum development

The responses indicate that the participants are confident about teaching and learning skills, student motivation, and the actions necessary for students to learn. However, they indicate that they need training in specific topics, methods, and techniques such as emotional intelligence and Problem and Project-Based Learning (PBL). The same is true in virtually all aspects of curriculum development, with less emphasis on structure and more emphasis on knowledge and application of methodologies and techniques such as Bloom's Taxonomy, Kolb's Learning Cycle, forward and backward curriculum design, and the integration of all the elements that make up the curriculum.

8 Concluding Remarks

The assessment of the capacity of the non-university sector at tertiary level in Thailand in the aspects of Industrial 4.0, teaching skills, and competency-based curriculum development, was carried out by means of a questionnaire whose answers provide the main output of WP1, namely, an assessment of competence level and a set of recommendations on the specific training needs.

The capacity assessment design was performed through the following steps: development of critical knowledge about Industry 4.0, teaching skills and curriculum development, development of items, improvement of the questionnaire through the think-aloud procedure, and test and retest procedure, application of the questionnaire, analysis of the data and reporting.

The data analysis was summarized showed some lack on the self-perceived competence level that, in conjunction with the interest demonstrated in training modules, allowed to develop some main recommendations (sections 6 and 7). These recommendations are part of the input for work package 2.

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Annex 1 - Survey Items - Version 1, applied in Think-aloud

Part 0 – Introduction and participant characterization

The ERASMUS+ project ReCap4.0 aims to enhance the capacity and ability of Rajabhat Universities and Rajamangala Universities of Technology in Thailand, for the effective delivery of engineering and technology knowledge and skills related to Industry 4.0, to support Thailand sustainable smart industry and to strengthen a partnership among participating European and Thai universities. The main target group are teachers from Rajabhat Universities, followed by teachers of Rajamangala Universities of Technology. This project proposes the following modules for the enhancement of teachers' capacities and abilities:
Module 1.1: Industrial Management in Industry 4.0 Era
Module 1.2: Applications of Optimization, and Technology in Value Chain
Module 1.3: Digital Manufacturing
Module 1.4: Innovative Product Design and Development
Module 1.5: Data Analytic
Module 2.1: Communication and people skills development
Module 2.2: Innovative teaching and learning methods
Module 2.3: Problem and Project-Based Learning (PBL)
Module 2.4: Coaching and Mentoring Skills development
Module 2.5: Learning experience-focused course design and development

In order to be able to develop a training programme aligned with the needs of the teachers from the referred institutions, the first work package (WP1) of the ReCap4.0 project aims to apply a questionnaire to those teachers. This questionnaire should allow to develop a perspective of the required capacities and in this way give support for training development decisions. Thus, as an example of interpretation of the results, if the questionnaire shows a high level of capacity in some specific area, then in that area the training should be more complex. Additionally, the questionnaire should also support understanding what are the main interests of the participants regarding the training options.
The training and the questionnaire will be focused in three main parts: Educational part, Industry 4.0 part, and training interest part. Due to the challenging objectives of the ReCap 4.0 ERASMUS+ project, this questionnaire is somewhat long. We would much appreciate it if you patiently go through all questions.
Due to answer control reasons, we will ask for an email login, but only a small part of the team will access that information, and we will guarantee the privacy of the participants.

PARTICIPANT CHARACTERIZATION

Institution*: {Names;Other}
If not listed, please add your institution: {Text}
School and/or department: {Text}

Main area of actuation as teacher*: {Text}
Years of experience as teacher*: {1-5;6-10;11-20;21-30;>30}

Highest academic degree*: {Bachelor's / Master's / Doctorate}
Area of highest academic degree*: {Text}
English proficiency level*: {Elementary level; Low intermediate level; High intermediate level; Advanced level}

Age*: {Integer}
Gender: {Male;Female;Other}

Part 1 – Industry 4.0

Industry 4.0 Generic Items based on Acatech Elements

This part of the questionnaire is inspired by some of the main elements of the Acatech maturity index, which is "a methodology for establishing manufacturing companies' current Industry 4.0 maturity stage and

identifying areas where further action is required" (https://en.acatech.de/publication/industrie-4-0-maturity-index-update-2020/).

In all following items, consider that you are self-assessing your own capacity in each of the assertions, and each one starts with "I am able to".

Code	Item
A1	I am able to understand that it is possible to apply the concept of maturity levels to classify companies in different Industry 4.0 stages.
A2	I am able to apply a maturity level model to a company in order to develop a project to evolve its Industry 4.0 stage.
A3	I am able to recognize the required tangible resources (physical) for Industry 4.0, including a company's workforce (human resources), machinery and equipment, tools, materials and the final product.
A4	I am able to recognize the required information systems for Industry 4.0, in which information is provided by both people and "information and communication technology".
A5	I am able to recognize the required organisational structure for Industry 4.0, referring to both a company's internal organisation (structure and operational processes) and its position within the value network.
A6	I am able to recognize the required learning and agile corporate culture for Industry 4.0, including willing to change, innovate, and develop employees' skills.
A7	I am able to h the importance of digital capability for Industry 4.0, both in terms of human resources competencies, as well as decentralized pre-processing of automated data acquisition through sensors and actuators.
A8	I am able to understand that Industry 4.0 encompasses efficient communication between people and between people and machines, through task-based interfaces that enable relevant, traceable, and redundancy-free messages.
A9	I am able to understand the importance of data and self-learning information processing for Industry 4.0, supported by a resilient IT infrastructure, allowing data delivery in a context-sensitive way.
A10	I am able to understand that Industry 4.0 information systems must be horizontally and vertically integrated, using heterogeneous computing resources with standardized interaction interfaces, managed by governance policies and protected by information technology security.
A11	I am able to understand that in the context of Industry 4.0 the organization is an organism endowed with a nervous system enabled by a collective intelligence and agile management, i.e. the actions of people are free of hierarchical barriers, motivated for change, able to dynamically articulate skills for problem solving, improvement and evolution.
A12	I am able to understand that Industry 4.0 focuses on customer benefits enabled by transparent collaboration networking intra and inter-companies.
A13	I am able to understand that collaborative management is important in the context of Industry 4.0, including democratic leadership, and work is driven by transparent communication between people and protected by responsible confidentiality.
A14	I am able to understand that in the context of Industry 4.0, people recognize the value of mistakes, are open to innovation, seek continuous professional development, driven by knowledge databases and decision-making in a continuous process of change.

Industry 4.0 Specific Items based on training modules

This part of the questionnaire is based on the predefined training modules.

In all following items, consider that you are self-assessing your own capacity in each of the assertions, and each one starts with "I am able to".

Module 1.1: Industrial management in Industry 4.0 Era

Code	Item
B1	I am able to discuss the relevance of agile project management in the context of Industry 4.0.
B2	I am able to identify the requirements for Industry 4.0 transformation projects.
B3	I am able to apply frameworks of project management (e.g. Scrum) in the context of Industry 4.0.
B4	I am able to discuss team development phases.
B5	I am able to work effectively in a distributed team.
B6	I am able to develop Industry 4.0 projects in real industrial contexts.
B7	I am able to model industrial processes considering smart production concepts.
B8	I am able to recognize the meaning of company operating efficiency in the context of Industry 4.0.
B9	I am able to recognize the role of customer service in the context of Industry 4.0.
B10	I am able to plan and control the company's operations considering smart production concepts.
B11	I am able to design real time data analytics to support operations planning and control.
B12	I am able to discuss the impact of digitalization on quality management.
B13	I am able to identify quality management indicators in the context of Industry 4.0.
B14	I am able to select operational quality-related data for a quality management system.
B15	I am able to design a data visualization solution for operational quality and productivity indicators.
B16	I am able to design a quality management system for smart factories.

Module 1.2: Applications of Optimization, and Technology in Value Chain

Code	Item
C1	I am able to formulate mathematical optimization programs for practical problems in industrial applications.
C2	I am able to apply appropriate optimization techniques in industrial applications.
C3	I am able to use optimization software (i.e., MATLAB, LINGO, or MPL software) in industrial applications.
C4	I am able to conduct sensitivity analysis to examine solutions robustness.
C5	I am able to develop real time optimization solutions for Industry 4.0.
C6	I am able to discuss Sustainable Supply Chain management (SSCM) principles
C7	I am able to discuss models of sustainable supply chains
C8	I am able to manage a SSCM network in the context of Industry 4.0
C9	I am able to redesign a supply chain considering sustainability and Industry 4.0 requirements

Module 1.3: Digital Manufacturing

Code	Item
D1	I am able to understand the concept of Digital Factory.
D2	I am able to understand the capacities and limitations of current digital technologies.
D3	I am able to use simulation for the analysis of production systems' performance.
D4	I am able to specify a digital transformation model for a given case study.
D5	I am able to understand the concept of Cyber Physical System (CPS).
D6	I am able to apply concepts of smart production and product co-design in CPS.
D7	I am able to use the Internet of Things (IoT) to collect real time data from sensors.
D8	I am able to develop CPS projects to improve business performance.
D9	I am able to identify principles of additive manufacturing.
D10	I am able to apply reverse engineering in the context of additive manufacturing.
D11	I am able to elaborate on process parameters for effective additive manufacturing.
D12	I am able to select additive manufacturing technologies.
D13	I am able to develop products using the design for Additive Manufacturing (DfAM) concept.

Module 1.4: Innovative Product design and development

Code	Item
E1	I am able to recognize the benefits of implementing innovations.
E2	I am able to analyze strategic elements of new product innovation.
E3	I am able to identify ideas for innovative products in the context of Industry 4.0.
E4	I am able to apply methods for innovation (e.g. design thinking).
E5	I am able to Propose marketing strategies for launching new products.
E6	I am able to valorize, capitalize and protect the original solutions obtained from the creative activity.

Module 1.5: Data Analytic

Code	Item
F1	I am able to discuss the concept of Intelligent Decision support System (IDSS).
F2	I am able to apply techniques of IDSS (e.g. artificial neural networks, machine learning or rule-based systems) to solve industrial problems.
F3	I am able to appraise the frameworks of IDSS.
F4	I am able to design an IDSS to support a smart production system.
F5	I am able to identify data analytics principles.
F6	I am able to apply data visualization techniques in dealing with big data sets.
F7	I am able to apply key data mining techniques (e.g., classification analysis, associate rule learning, anomaly/outlier detection, clustering analysis, regression analysis) in dealing with big data sets.
F8	I am able to develop data analytics algorithms for big data sets.
F9	I am able to develop data analytics projects in the context of Industry 4.0.

Part 2 – Educational Part

This part of the questionnaire is based on the predefined training modules for teacher educational development.

In all following items, consider that you are self-assessing your own capacity in each of the assertions, and each one starts with "I am able to".

Module 2.1: Communication and people skills development

Code	Item
G1	I am able to explain ideas effectively in a way that others understand
G2	I am able to make effective presentations professionally
G3	I am able to understand emotional intelligence concepts in different professional situations
G4	I am able to apply emotional intelligence concepts in different professional situations
G5	I am able to work in a team environment in interaction with other colleagues
G6	I am able to lead, persuade, motivate and inspire others to achieve goals

Module 2.2: Innovative teaching and learning methods

Code	Item
H1	I am able to enhance teaching using a range of technology
H2	I am able to provide opportunities for students to collaborate
H3	I am able to use online learning management systems
H4	I am able to record videos and other resources for use by students subsequently
H5	I am able to teach on a synchronous and asynchronous basis
H6	I am able to optimise student engagement using a flipped classroom approach
H7	I am able to Incorporate the use of self-directed learning approaches

Module 2.3: Problem and Project-Based Learning (PBL)

Code	Item
I1	I am able to understand PBL principles.
I2	I am able to recognize different PBL typologies.
I3	I am able to identify problems or themes to be implemented in PBL context.
I4	I am able to identify the main requirements for PBL organization (e.g. resources, teams, assessment).
I5	I am able to create a PBL proposal for your teaching context.

Module 2.4: Coaching and Mentoring Skills development

Code	Item
J1	I am able to understand the differences between coaching and mentoring.
J2	I am able to provide additional explanations and communicate expectations for student achievement.
J3	I am able to motivate students so that they can produce high-quality work.
J4	I am able to provide formative feedback to students on their work indicating how they can improve subsequent efforts.
J5	I am able to plan appropriate interventions or additional support for students based on their identified needs.
J6	I am able to support students in ensuring their work meets the appropriate standard including academic integrity.

Module 2.5: Learning experience-focused course design and development

Code	Item
K1	I consider myself as being highly experienced in curriculum development and/or curriculum revision.
K2	I consider myself as being highly experienced in developing courses.
K3	I consider myself as being highly experienced in revising courses.
K4	I consider myself as being an expert on Bloom's Taxonomy.
K5	I consider myself as being an expert on Kolb's Learning Cycle.
K6	I am able to discuss the differences between forward and backward curriculum design.
K7	I am amble to develop a curriculum coherently integrating the following elements: Course objective, Course learning outcomes, Course outline, Learning resources (e.g., textbook, reference books, teaching and learning methods, Time distribution and study load, Evaluation and grading criteria.

Part 3 – Interest in Training Modules

This part of the questionnaire aims at collecting the participants' interest in different training modules for the development of professional competences. In all following items, consider that you are reflecting upon the importance of different training modules for the development of your professional competences.

Training modules importance for the process of your professional competences' development

Considering the following training module how would you classify its importance. Scale: Not at all important; Of Little Importance; Of Average Importance; Very Important; Absolutely Essential.

Module 1.1: Industrial Management in Industry 4.0 Era

Module 1.2: Applications of Optimization, and Technology in Value Chain

Module 1.3: Digital Manufacturing

Module 1.4: Innovative Product Design and Development

Module 1.5: Data Analytic

Module 2.1: Communication and people skills development

Module 2.2: Innovative teaching and learning methods

Module 2.3: Problem and Project-Based Learning (PBL)

Module 2.4: Coaching and Mentoring Skills development

Module 2.5: Learning experience-focused course design and development

Annex 2 - Survey Items - Version 2, applied in Test-Retest

Part 0 – Introduction and participant characterization

The ERASMUS+ project ReCap4.0 aims to enhance the capacity and ability of Rajabhat Universities and Rajamangala Universities of Technology in Thailand, for the effective delivery of engineering and technology knowledge and skills related to Industry 4.0, to support Thailand sustainable smart industry and to strengthen a partnership among participating European and Thai universities. The main target group are teachers from Rajabhat Universities, followed by teachers of Rajamangala Universities of Technology. This project proposes the following modules for the enhancement of teachers' capacities and abilities:
Module 1.1: Industrial Management in Industry 4.0 Era
Module 1.2: Applications of Optimization, and Technology in Value Chain
Module 1.3: Digital Manufacturing
Module 1.4: Innovative Product Design and Development
Module 1.5: Data Analytic
Module 2.1: Communication and people skills development
Module 2.2: Innovative teaching and learning methods
Module 2.3: Problem and Project-Based Learning (PBL)
Module 2.4: Coaching and Mentoring Skills development
Module 2.5: Learning experience-focused course design and development

In order to be able to develop a training programme aligned with the needs of the teachers from the referred institutions, the first work package (WP1) of the ReCap4.0 project aims to apply a questionnaire to those teachers. This questionnaire should allow to develop a perspective of the required capacities and in this way give support for training development decisions. Thus, as an example of interpretation of the results, if the questionnaire shows a high level of capacity in some specific area, then in that area the training should be more complex. Additionally, the questionnaire should also support understanding what are the main interests of the participants regarding the training options. So, the training and the questionnaire will be focused in three main parts: Industry 4.0 parts (1.1 and 1.2), Educational part, and relative interest in different training modules.
Due to the challenging objectives of the ReCap 4.0 ERASMUS+ project, this questionnaire is somewhat long. We would much appreciate it if you patiently go through all questions.
Due to answer control reasons, we will ask for an email login, but only a small part of the team will access that information, and we will guarantee the privacy of the participants.

PARTICIPANT CHARACTERIZATION

Institution*: {Names;Other}
If not listed, please add your institution: {Text}
School and/or department: {Text}
Main area of actuation as teacher*: {Text}
Years of experience as teacher*: {1-5;6-10;11-20;21-30;>30}
Highest academic degree*: {Bachelor's / Master's / Doctorate}
Area of highest academic degree*: {Text}
English proficiency level*: {Elementary level; Low intermediate level; High intermediate level; Advanced level}
Age*: {Integer}
Gender: {Male;Female;Other}

Part 1 – Industry 4.0

Industry 4.0 Generic Items based on Acatech Elements

This part of the questionnaire is inspired by some of the main elements of the Acatech maturity index, which is "a methodology for establishing manufacturing companies' current Industry 4.0 maturity stage and identifying areas where further action is required" (https://en.acatech.de/publication/industrie-4-0-maturity-index-update-2020/).

In all following items, consider that you are self assessing your own capacity in each of the assertions; if you do not understand some concept in the question, please select one of the disagreements part of the scale. Please take note that this is an agreement scale.

Code	Item
A1	I am able to understand that companies have different Industry 4.0 maturity levels.
A2	I am able to apply a maturity level model to a company in order to develop a project to evolve its Industry 4.0 stage.
A3	I am able to recognize the required tangible, physical resources, including a company's workforce (human resources), facilities, machinery and equipment, tools, materials and the final product for Industry 4.0.
A4	I am able to recognize the required information systems in which information is provided by both people and "information and communication technology" for Industry 4.0.
A5	I am able to recognize the required organisational structure referring to both a company's internal organisation (structure and operational processes) and its position within the value network (value stream), in the context of Industry 4.0.
A6	I am able to recognize the required learning and agile corporate culture, including willing to change, innovate, and develop employees' skills, in the context of Industry 4.0.
A7	I am able to understand the importance of digital capability both in terms of human resources competencies, as well as decentralized pre-processing of automated data acquisition through sensors and actuators.
A8	I am able to understand that Industry 4.0 encompasses efficient communication between people and between people and machines through task-based interfaces that enable relevant, traceable, and unnecessary (redundant) messages.
A9	I am able to understand the importance of data and self-learning information processing, supported by a resilient Information Technology (IT) infrastructure, allowing data delivery in a context-sensitive way.
A10	I am able to understand that Industry 4.0 information systems must be horizontally and vertically integrated using different computing resources (heterogeneous) with standardized interaction interfaces, managed by governance policies and protected by information technology security.
A11	I am able to understand that in the context of Industry 4.0 the organization is an organism with a nervous system enabled by a collective intelligence and agile management, i.e. the actions of people are free of hierarchical barriers, motivated for change, able to dynamically articulate skills for problem solving, improvement and evolution.
A12	I am able to understand that Industry 4.0 focuses on customer benefits enabled by transparent collaboration networking inside (intra) the company and between (inter) companies.
A13	I am able to understand that collaborative management is important in the context of Industry 4.0, including democratic leadership, and work is driven by transparent communication between people and protected by responsible confidentiality.
A14	I am able to understand that in the context of Industry 4.0, people recognize the value of mistakes, are open to innovation, seek continuous professional development, driven by knowledge databases and decision-making in a continuous process of change.

Industry 4.0 Specific Items based on training modules

This part of the questionnaire is based on the predefined training modules.

In all following items, consider that you are self assessing your own capacity in each of the assertions; if you do not understand some concept in the question, please select one of the disagreements part of the scale.

Please take note that this is an agreement scale.

Module 1.1: Industrial management in Industry 4.0 Era

Code	Item
B1	I am able to discuss the relevance of agile project management in the context of Industry 4.0.
B2	I am able to identify the need to develop Industry 4.0 transformation projects.
B3	I am able to apply agile project management approaches in the context of Industry 4.0.
B4	I am able to discuss team development phases (Forming, Storming, Norming, Performing, Adjourning).
B5	I am able to work effectively in a distributed team.
B6	I am able to develop Industry 4.0 projects in real industrial contexts.
B7	I am able to model industrial processes considering smart production concepts.
B8	I am able to recognize the meaning of company operating efficiency in the context of Industry 4.0.
B9	I am able to recognize the role of customer service in the context of Industry 4.0.
B10	I am able to plan and control the company's operations considering smart production concepts.
B11	I am able to design real time data analytics to support operations planning and control.
B12	I am able to discuss the impact of digitalization on quality management.
B13	I am able to identify quality management indicators in the context of Industry 4.0.
B14	I am able to select operational quality-related data for a quality management system.
B15	I am able to design a data visualization solution for operational quality and productivity indicators.
B16	I am able to design a quality management system for smart factories.

Module 1.2: Applications of Optimization, and Technology in Value Chain

Code	Items
C1	I am able to formulate mathematical optimization programs for practical problems in industrial application.
C2	I am able to apply appropriate optimization techniques in industrial applications.
C3	I am able to use optimization software (e.g. MATLAB, LINGO, or MPL software) in industrial applications.
C4	I am able to conduct sensitivity analysis to examine solutions robustness.
C5	I am able to develop real time optimization solutions for Industry 4.0.
C6	I am able to discuss Sustainable Supply Chain management (SSCM) models.
C7	I am able to manage a Sustainable Supply Chain management (SSCM) network in the context of Industry 4.0.
C8	I am able to redesign a supply chain considering sustainability and Industry 4.0 requirements.

Module 1.3: Digital Manufacturing

Code	Items
D1	I am able to understand the concept of Digital Factory.
D2	I am able to understand the capacities and limitations of current digital technologies.
D3	I am able to use simulation for the analysis of production systems' performance.
D4	I am able to specify a digital transformation model for a given case study.
D5	I am able to understand the concept of Cyber Physical System (CPS).
D6	I am able to apply concepts of smart production and product co-design in Cyber Physical System (CPS).
D7	I am able to use the Internet of Things (IoT) to collect real time data from sensors.
D8	I am able to develop Cyber Physical System (CPS) projects to improve business performance.

D9	I am able to identify principles of additive manufacturing.
D10	I am able to apply reverse engineering in the context of additive manufacturing.
D11	I am able to elaborate on process parameters for effective additive manufacturing.
D12	I am able to select additive manufacturing technologies.
D13	I am able to develop products using the design for Additive Manufacturing (DfAM) concept.

Module 1.4: Innovative Product design and development

Code	Items
E1	I am able to recognize the benefits of implementing innovations.
E2	I am able to analyze strategic elements of new product innovation.
E3	I am able to identify ideas for innovative products in the context of Industry 4.0.
E4	I am able to apply methods for innovation (e.g. design thinking).
E5	I am able to propose marketing strategies for launching new products.
E6	I am able to valorize, capitalize and protect the original solutions obtained from the creative activity.

Module 1.5: Data Analytic

Code	Items
F1	I am able to discuss the concept of Intelligent Decision support System (IDSS).
F2	I am able to apply techniques of Intelligent Decision support System (e.g. artificial neural networks, machine learning or rule-based systems) to solve industrial problems.
F3	I am able to evaluate the frameworks of Intelligent Decision support System (IDSS).
F4	I am able to design an Intelligent Decision support System (IDSS) to support a smart production system.
F5	I am able to identify data analytics principles.
F6	I am able to apply data visualization techniques in dealing with big data sets.
F7	I am able to apply key data mining techniques (e.g. classification analysis, clustering analysis, regression analysis) in dealing with big data sets.
F8	I am able to develop data analytics algorithms for big data sets.
F9	I am able to develop data analytics projects in the context of Industry 4.0.

Part 2 – Educational Part

This part of the questionnaire is based on the predefined training modules for teacher educational development.

In all following items, consider that you are self assessing your own capacity in each of the assertions; if you do not understand some concept in the question, please select one of the disagreements part of the scale.

Please take note that this is an agreement scale.

Module 2.1: Communication and people skills development

Code	Items
G1	I am able to make effective presentations to the students.

G2	I am able to explain ideas effectively in a way that students understand.
G3	I am able to understand the concept of emotional intelligence in different contexts of the teaching practice.
G4	I am able to apply emotional intelligence concepts in different contexts of the teaching practice.
G5	I am able to work in a team environment in interaction with other teachers from your department or university.
G6	I am able to lead, persuade, motivate and inspire students to achieve goals

Module 2.2: Innovative teaching and learning methods

Code	Items
H1	I am able to enhance teaching using different technology solutions (e.g. mentimeter, kahoot, miro, amongst others).
H2	I am able to provide opportunities for students to collaborate.
H3	I am able to use online learning management systems.
H4	I am able to record videos for use by students later.
H5	I am able to teach on a synchronous and asynchronous basis.
H6	I am able to optimise student engagement using a flipped classroom approach.
H7	I am able to incorporate the use of self-directed learning approaches.

Module 2.3: Problem and Project-Based Learning (PBL)

Code	Items
I1	I am able to understand PBL principles.
I2	I am able to recognize different PBL typologies, i.e. different ways to put PBL in practice
I3	I am able to identify problems or themes to be implemented in PBL context.
I4	I am able to identify the main requirements for PBL organization (e.g. resources, teams, assessment).
I5	I am able to create a PBL proposal for your teaching context.

Module 2.4: Coaching and Mentoring Skills development

Code	Items
J1	I am able to understand the differences between coaching and mentoring.
J2	I am able to provide additional explanations and communicate expectations for student achievement.
J3	I am able to motivate students so that they can produce high-quality work.
J4	I am able to provide formative feedback to students on their work indicating how they can improve.
J5	I am able to plan appropriate interventions or additional support for students based on their identified needs.
J6	I am able to support students in ensuring their work meets the appropriate standard including academic integrity (ethics)

Module 2.5: Learning experience-focused course design and development

Code	Items
K1	I consider myself highly experienced in curriculum (programme) development and/or revision.
K2	I consider myself highly experienced in developing courses.
K3	I consider myself highly experienced in revising courses.
K4	I consider myself an expert on Bloom's Taxonomy.

K5	I consider myself an expert on Kolb's Learning Cycle.
K6	I am able to discuss the differences between forward and backward curriculum design.
K7	I am able to develop a curriculum coherently integrating the following elements: Course objective, Course learning outcomes, Course outline, Learning resources, teaching and learning methods, Time distribution and study load, Evaluation and grading criteria.

Part 3 – Interest in Training Modules

This part of the questionnaire aims at collecting the participants' interest in different training modules for the development of professional competences. In all following items, consider that you are reflecting upon the importance of different training modules for the development of your professional competences.

Considering the following training modules related to Industry 4.0 part, how would you classify its importance? Choice 1 is the most important.

Module 1.1: Industrial Management in Industry 4.0 Era
Module 1.2: Applications of Optimization, and Technology in Value Chain
Module 1.3: Digital Manufacturing
Module 1.4: Innovative Product Design and Development
Module 1.5: Data Analytic
Module 2.1: Communication and people skills development
Module 2.2: Innovative teaching and learning methods
Module 2.3: Problem and Project-Based Learning (PBL)
Module 2.4: Coaching and Mentoring Skills development
Module 2.5: Learning experience-focused course design and development

Annex 3 - Survey Items - Version 3, final version of the questionnaire

Part 0 – Introduction and participant characterization

The ERASMUS+ project ReCap4.0 aims to enhance the capacity and ability of Rajabhat Universities and Rajamangala Universities of Technology in Thailand, for the effective delivery of engineering and technology knowledge and skills related to Industry 4.0, to support Thailand sustainable smart industry and to strengthen a partnership among participating European and Thai universities. The main target group are teachers from Rajabhat Universities, followed by teachers of Rajamangala Universities of Technology. This project proposes the following modules for the enhancement of teachers' capacities and abilities:
Module 1.1: Industrial Management in Industry 4.0 Era
Module 1.2: Applications of Optimization, and Technology in Value Chain
Module 1.3: Digital Manufacturing
Module 1.4: Innovative Product Design and Development
Module 1.5: Data Analytic
Module 2.1: Communication and people skills development
Module 2.2: Innovative teaching and learning methods
Module 2.3: Problem and Project-Based Learning (PBL)
Module 2.4: Coaching and Mentoring Skills development
Module 2.5: Learning experience-focused course design and development

In order to be able to develop a training programme aligned with the needs of the teachers from the referred institutions, the first work package (WP1) of the ReCap4.0 project aims to apply a questionnaire to those teachers. This questionnaire should allow to develop a perspective of the required capacities and in this way give support for training development decisions. Thus, as an example of interpretation of the results, if the questionnaire shows a high level of capacity in some specific area, then in that area the training should be more complex. Additionally, the questionnaire should also support understanding what are the main interests of the participants regarding the training options. So, the training and the questionnaire will be focused in three main parts: Industry 4.0 parts (1.1 and 1.2), Educational part, and relative interest in different training modules.
Due to the challenging objectives of the ReCap 4.0 ERASMUS+ project, this questionnaire is somewhat long. We would much appreciate it if you patiently go through all questions.
Due to answer control reasons, we will ask for an email login, but only a small part of the team will access that information, and we will guarantee the privacy of the participants.

PARTICIPANT CHARACTERIZATION

Institution*: {Names;Other}
If not listed, please add your institution: {Text}
School and/or department: {Text}
Main area of actuation as teacher*: {Text}
Years of experience as teacher*: {1-5;6-10;11-20;21-30;>30}
Highest academic degree*: {Bachelor's / Master's / Doctorate}
Area of highest academic degree*: {Text}
English proficiency level*: {Elementary level; Low intermediate level; High intermediate level; Advanced level}
Age*: {Integer}
Gender: {Male;Female;Other}

Part 1 – Industry 4.0

Industry 4.0 Generic Items based on Acatech Elements

Code	Items
A1	I am able to understand that companies have different Industry 4.0 maturity levels.
A2	I am able to evaluate the maturity level of a company in order to develop a project to evolve its Industry 4.0 stage.

A3 I am able to recognize a company required tangible, physical resources, including a company's workforce (human resources), facilities, machinery and equipment, tools, materials and the final product for Industry 4.0.

A4 I am able to discuss the required information systems for Industry 4.0, in which the information is provided by both people and "information and communication technology".

A5 I am able to recognize the required Industry 4.0 organisational structure, referring to both a company's internal organisation (structure and operational processes) and its position within the value network (value stream).

A6 I am able to discuss the required learning and agile corporate culture, including willing to change, innovate, and develop employees' skills, in the context of Industry 4.0.

A7 I am able to understand the importance of digital capability for decentralized pre processing of automated data acquisition through sensors and actuators.

A8 I am able to understand that Industry 4.0 includes efficient communication between people and between people and machines through task based interfaces.

A9 I am able to understand the importance of data and self learning systems for delivering context dependent data.

A10 I am able to understand that Industry 4.0 information systems must provide full integration between processes under governance policies and protected by data security systems.

A11 I am able to understand that in the context of Industry 4.0 the organization is a system enabled by a collective intelligence and agile management, i.e. involving motivation to change (problem solving, improvement), proper use of people skills and decentralized decision making.

A12 I am able to understand that Industry 4.0 is focused on the customer benefits enabled by networked collaboration inside the company (i.e. intra company) and between different companies (i.e. inter companies).

A13 I am able to recognize that collaborative management is important in the context of Industry 4.0, i.e. including democratic leadership and transparent communication between people.

A14 I am able to discuss that in the context of Industry 4.0, people recognize the value of mistakes, are open to innovation, search for continuous professional development and are driven by knowledge databases and decision making in a continuous process of change.

Industry 4.0 Specific Items based on training modules

This part of the questionnaire is based on the predefined training modules. Please take note that this is an agreement scale.

In all following items, consider that you are self assessing your own capacity in each of the assertions. If you do not understand some concept in the question, please select one of the disagreements part of the scale ("Strongly disagree" or "Somewhat disagree").

Module 1.1: Industrial management in Industry 4.0 Era

B1 I am able to discuss the relevance of agile project management in the context of Industry 4.0.

B2 I am able to define the Industry 4.0 level of maturity of a company.

B3 I am able to apply agile project management approaches in the context of Industry 4.0.

B4 I am able to apply the team development phases (Forming, Storming, Norming, Performing, Adjourning) to support teamwork.

B5 I am able to work effectively in a distributed team.

B6 I am able to develop projects for the transformation of a company in the context of Industry 4.0.

B7 I am able to use a modelling tool (e.g. BPMN, VSM) to represent industrial processes considering smart production concepts.

B8 I am able to use performance indicators of a company's operating efficiency in the context of Industry 4.0.

B9 I am able to recognize the role of customer service in the context of Industry 4.0.

B10 I am able to plan and control the company's operations considering smart production concepts.

B11 I am able to design real time data analytics systems to support operations planning and control.

B12 I am able to discuss the impact of Industry 4.0 on quality management.

B13 I am able to identify performance indicators of quality management area in the context of Industry 4.0.

B14 I am able to collect quality management data for Industry 4.0.

B15 I am able to design a data visualization solution for quality management and productivity indicators.

B16 I am able to design a quality management system for Industry 4.0.

Module 1.2: Applications of Optimization, and Technology in Value Chain

C1 I am able to formulate mathematical optimization models for practical problems in industrial application.

C2 I am able to select appropriate optimization techniques to solve practical problems in industrial applications.

C3 I am able to use optimization software (e.g. MATLAB, LINGO, or MPL software) to solve practical problems in industrial applications.

C4 I am able to conduct sensitivity analysis to examine solutions robustness.

C5 I am able to develop real time optimization approaches for Industry 4.0.

C6 I am able to describe Sustainable Supply Chain Management (SSCM) models.

C7 I am able to manage a Sustainable Supply Chain Management (SSCM) network in the context of Industry 4.0.

C8 I am able to redesign a supply chain considering sustainability and Industry 4.0 requirements.

Module 1.3: Digital Manufacturing

D1 I am able to describe the concept of Digital Factory.

D2 I am able to understand the functionalities and limitations of current digital technologies.

D3 I am able to use simulation to analyse the performance of a production system.

D4 I am able to specify a digital transformation model for an industrial case study.

D5 I am able to describe the concept of Cyber Physical System (CPS).

D6 I am able to implement concepts of Smart Production using Cyber Physical Systems (CPS).

D7 I am able to use the Internet of Things (IoT) to collect real time data from sensors.

D8 I am able to develop Cyber Physical System (CPS) projects to improve business performance.

D9 I am able to describe principles of Additive Manufacturing.

D10 I am able to apply Reverse Engineering concepts in the context of Additive Manufacturing.

D11 I am able to choose process parameters for effective Additive Manufacturing.

D12 I am able to choose Additive Manufacturing technologies.

D13 I am able to develop products using the Design for Additive Manufacturing (DfAM) concept.

Module 1.4: Innovative Product design and development

E1 I am able to recognize the benefits of implementing innovations.

E2 I am able to analyze strategic elements of new product innovation.

E3 I am able to identify ideas for innovative products in the context of Industry 4.0.

E4 I am able to apply methods for innovation (e.g. design thinking).

E5 I am able to propose marketing strategies for launching new products.

E6 I am able to valorize, capitalize and protect (e.g. using patents) the original solutions obtained from the creative activity.

Module 1.5: Data Analytic

F1 I am able to describe the concept of Intelligent Decision Support System (IDSS).

F2 I am able to apply techniques of Intelligent Decision Support Systems (e.g. artificial neural networks, machine learning or rule- based systems) to solve industrial problems.

F3 I am able to describe a framework of Intelligent Decision Support System (IDSS).

F4 I am able to design an Intelligent Decision Support System (IDSS) to support a smart production system.

F5 I am able to identify data analytics principles.

F6 I am able to apply data visualization techniques in dealing with big data sets.

F7 I am able to apply key data mining techniques (e.g. classification analysis, clustering analysis, regression analysis) in dealing with big data sets.

F8 I am able to develop data analytics algorithms for big data sets.

F9 I am able to develop data analytics projects in the context of Industry 4.0.

Part 2 – Educational Part

This part of the questionnaire is based on the predefined training modules for teacher educational development. Please take note that this is an agreement scale.

In all following items, consider that you are self assessing your own capacity in each of the assertions. If you do not understand some concept in the question, please select one of the disagreements part of the scale ("Strongly disagree" or "Somewhat disagree").

Module 2.1: Communication and people skills development

G1 I am able to make effective presentations to the students.

G2 I am able to explain ideas effectively in a way that students understand.

G3 I am able to understand the concept of emotional intelligence in different contexts of the teaching practice.

G4 I am able to apply emotional intelligence concepts in different contexts of the teaching practice.

G5 I am able to work in teams, collaborating with other teachers from the department or university.

G6 I am able to lead, persuade, motivate and inspire students to achieve goals

Module 2.2: Innovative teaching and learning methods

H1 I am able to enhance teaching using different technology solutions (e.g. mentimeter, kahoot, miro, amongst others).

H2 I am able to provide opportunities for students to collaborate.

H3 I am able to use online learning management systems (e.g. Moodle, Blackboard).

H4 I am able to record videos for use by students later.

H5 I am able to plan and teach a class either on a synchronous or asynchronous mode.

H6 I am able to increase student engagement using a flipped classroom approach.

H7 I am able to incorporate the use of self- directed learning approaches.

Module 2.3: Problem and Project-Based Learning (PBL)

I1 I am able to understand Project- Based Learning (PBL) principles.

I2 I am able to recognize different Project- Based Learning (PBL) typologies, i.e. different ways to put PBL in practice

I3 I am able to identify problems or themes to be implemented in PBL context.

I4 I am able to identify the main requirements for PBL organization (e.g. resources, teams, assessment).

I5 I am able to create a PBL proposal for your teaching context.

Module 2.4: Coaching and Mentoring Skills development

J1 I am able to understand the differences between coaching and mentoring.

J2 I am able to provide additional explanations and communicate expectations for student achievement.

J3 I am able to motivate students so that they can produce high- quality work.

J4 I am able to provide formative feedback to students on their work indicating how they can improve.

J5 I am able to plan appropriate interventions or additional support for students based on their identified needs.

J6 I am able to support students in ensuring their work meets the appropriate standard including academic integrity (ethics)

Module 2.5: Learning experience-focused course design and development

K1 I consider myself highly experienced in curriculum (programme) development and/or revision.

K2 I consider myself highly experienced in developing courses.

K3 I consider myself highly experienced in revising course structure, including the syllabus, study and teaching materials, learning outcomes, class plan and assessment plan.

K4 I consider myself an expert on Bloom's Taxonomy.

K5 I consider myself an expert on Kolb's Learning Cycle.

K6 I am able to discuss the differences between forward and backward curriculum design.

K7 I am able to develop a curriculum coherently integrating the following elements for both the courses and the whole program: objectives, learning outcomes, outline, resources, teaching and learning methods, time distribution and study load, evaluation and grading criteria.

Part 3 – Interest in Training Modules

This part of the questionnaire aims at collecting the participants' main preferences in different training modules for the development of professional competences. In all following items, consider that you are reflecting upon your preference related to the different training modules for the development of your professional competences.

Select two of the following Industry 4.0 training modules according to your preference:

Module 1.1: Industrial Management in Industry 4.0 Era

Module 1.2: Applications of Optimization, and Technology in Value Chain

Module 1.3: Digital Manufacturing

Module 1.4: Innovative Product Design and Development

Module 1.5: Data Analytic

Select two of the following educational training modules according to your preference:

Module 2.1: Communication and people skills development

Module 2.2: Innovative teaching and learning methods

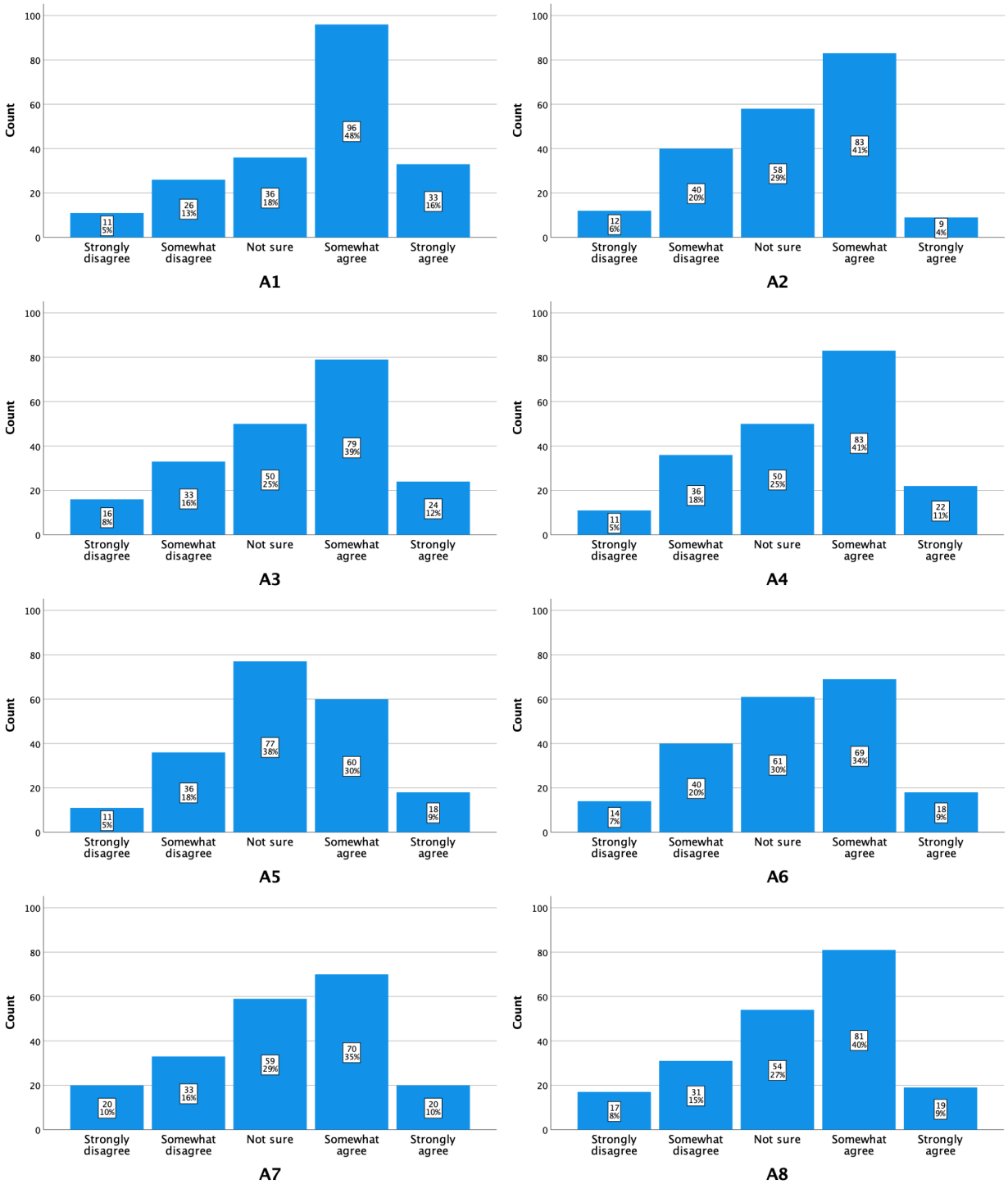
Module 2.3: Problem and Project-Based Learning (PBL)

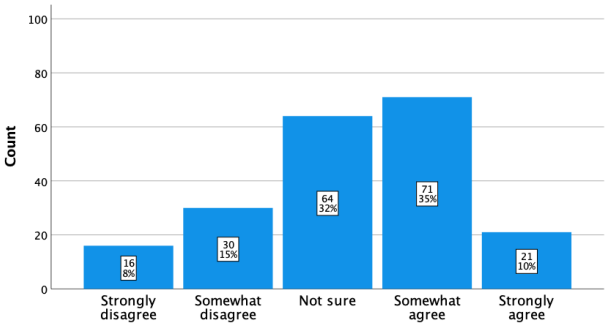
Module 2.4: Coaching and Mentoring Skills development

Module 2.5: Learning experience-focused course design and development

Annex 4 - Responses from the final version of the questionnaire

Industry 4.0 Generic Items based on Acatech Elements





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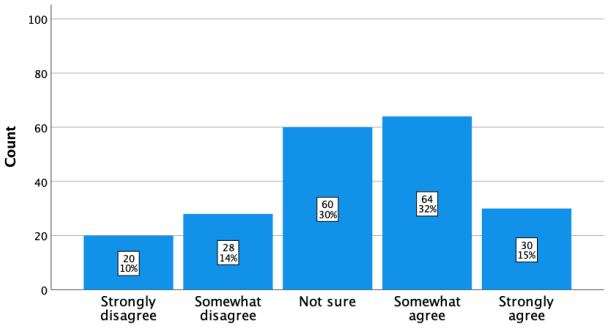

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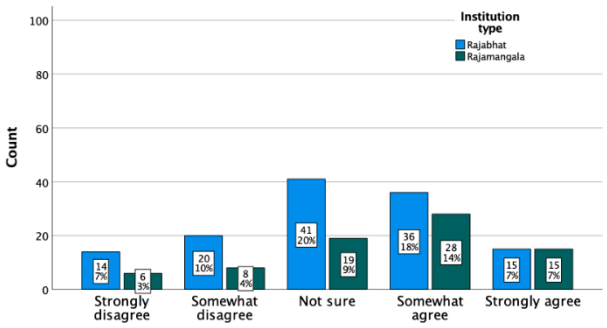

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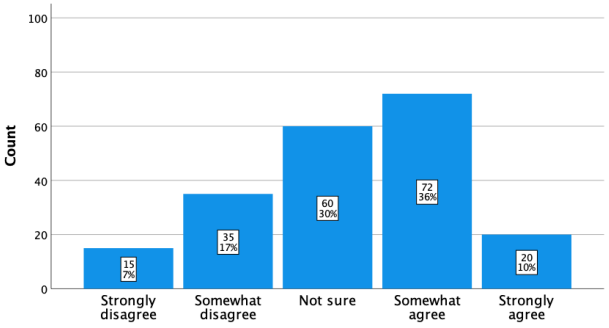

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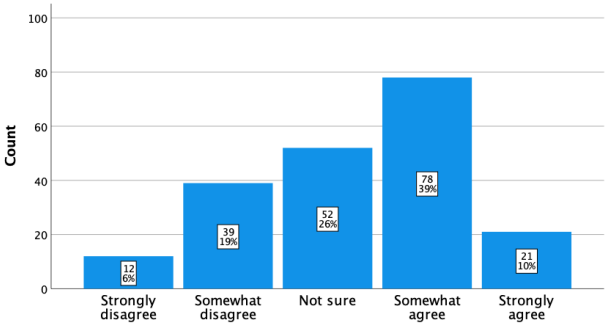

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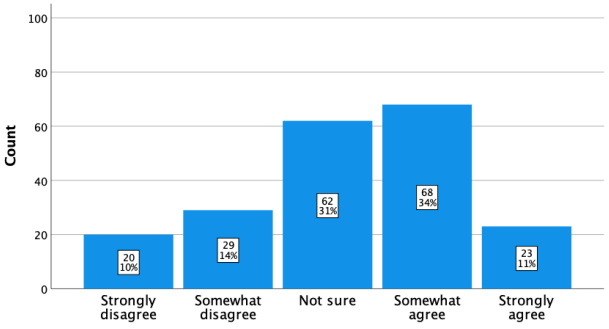

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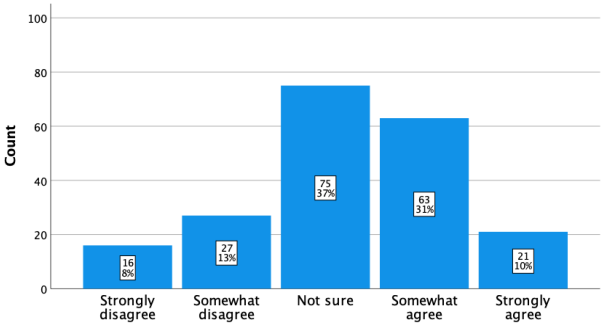

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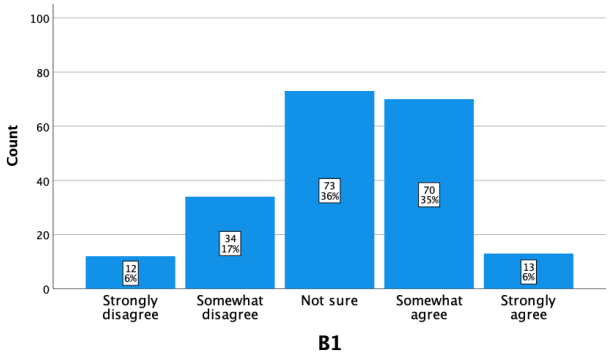
Industry 4.0 Specific Items based on training modules

Module 1.1: Industrial management in Industry 4.0 Era



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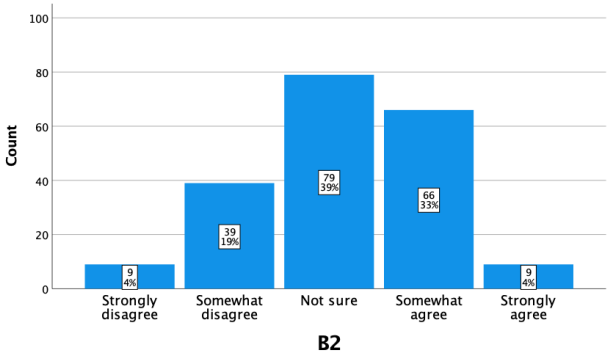

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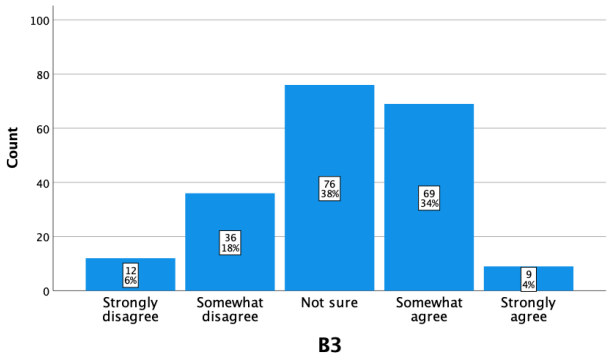

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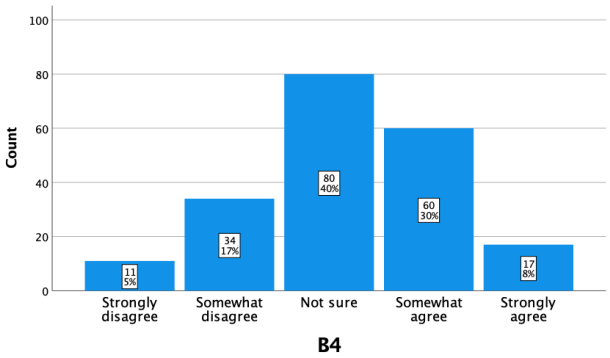

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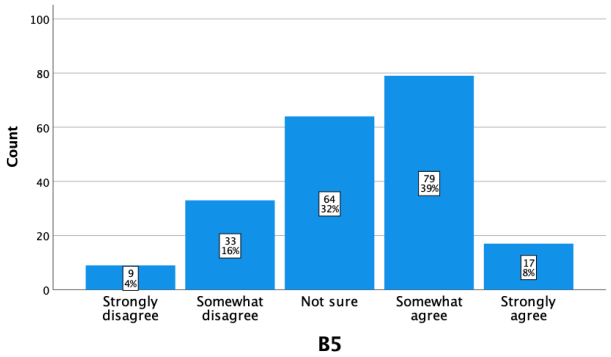

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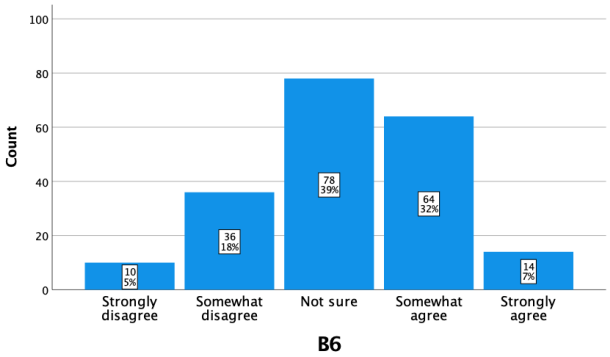

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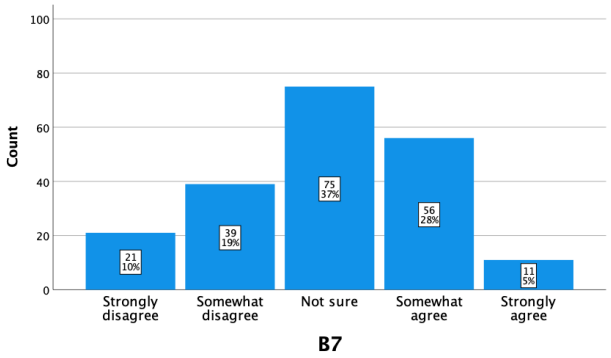

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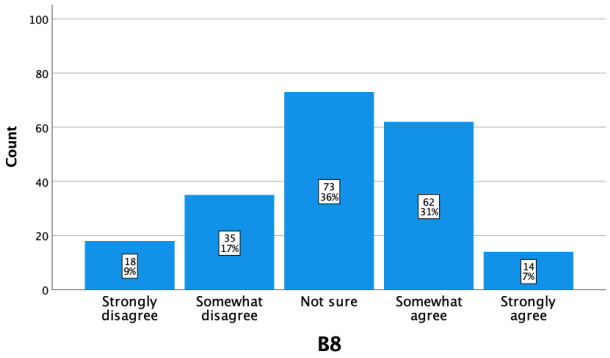

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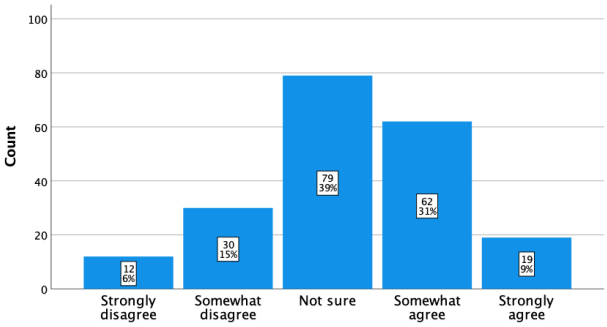

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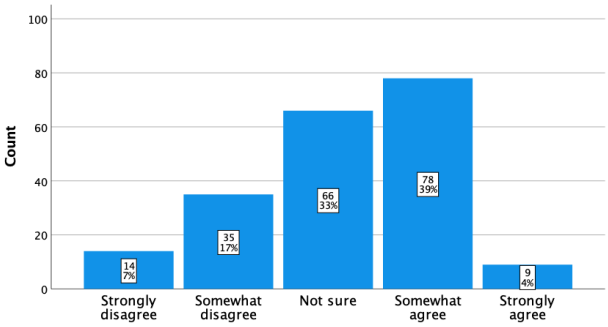

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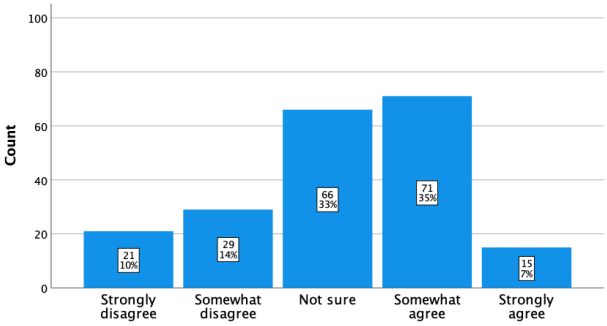

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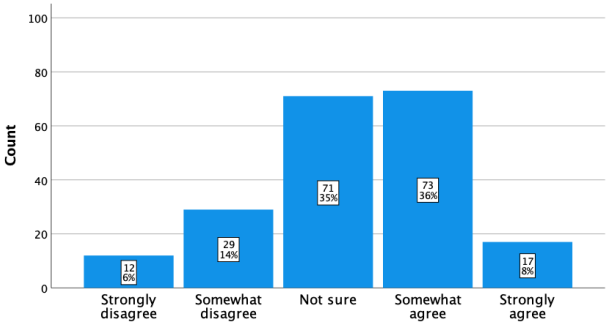

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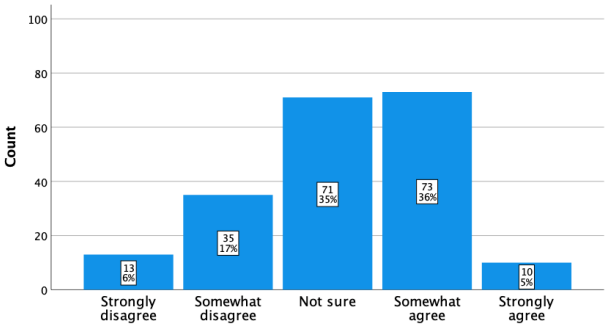

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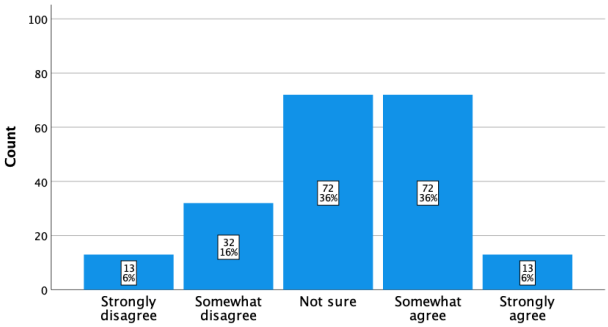

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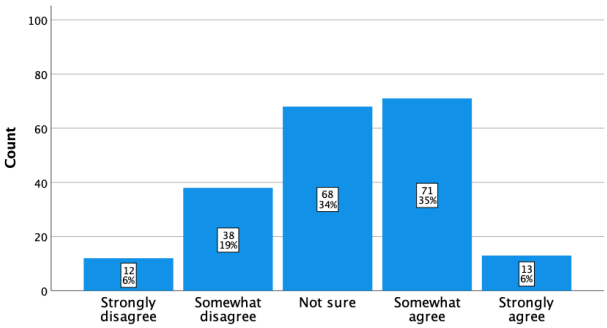

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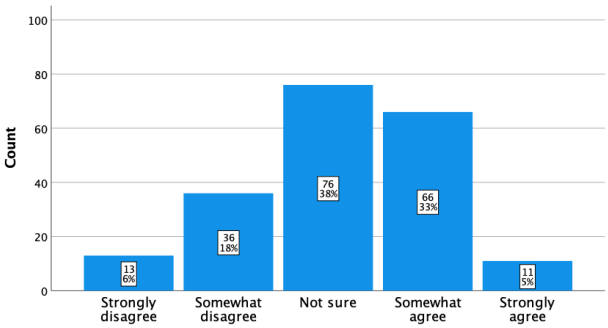

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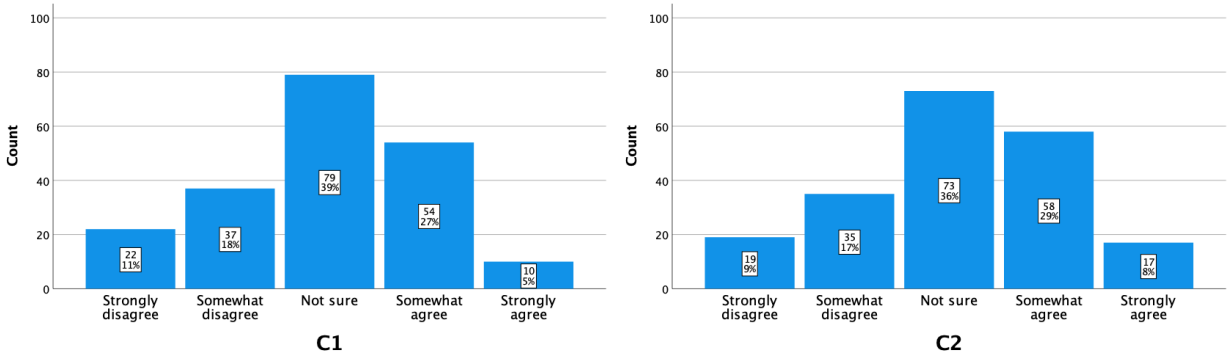
Module 1.2: Applications of Optimization, and Technology in Value Chain



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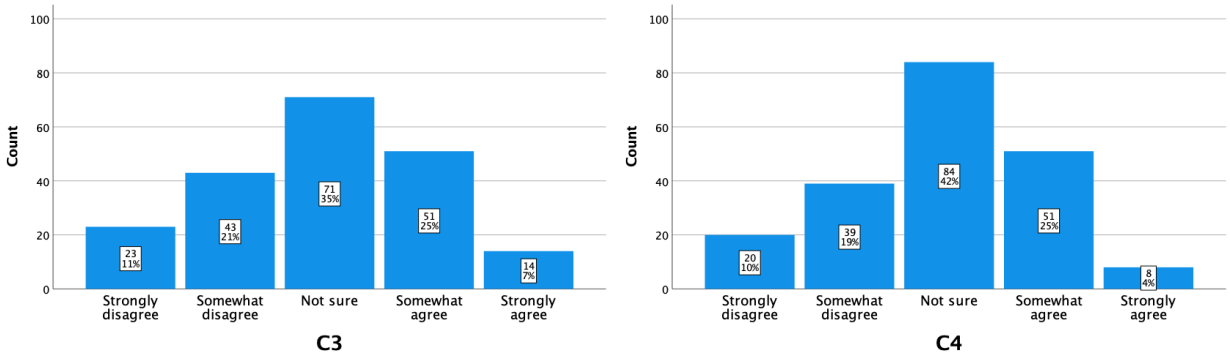

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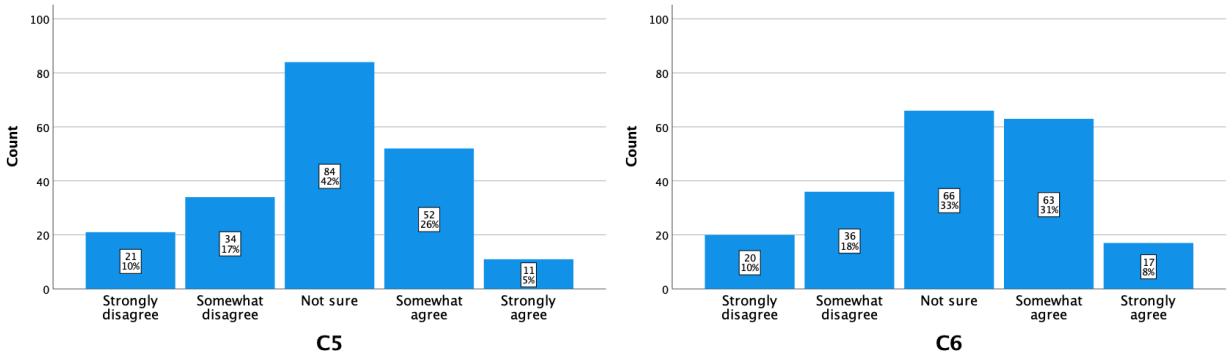

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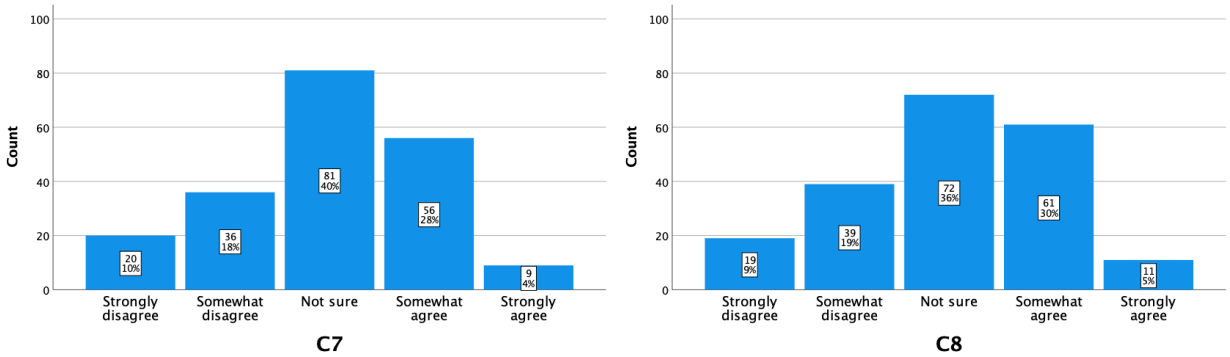

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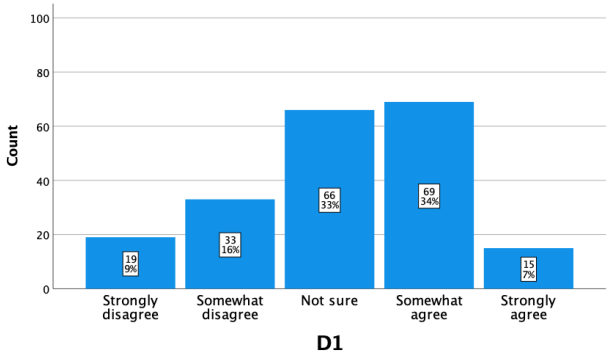
Module 1.3: Digital Manufacturing



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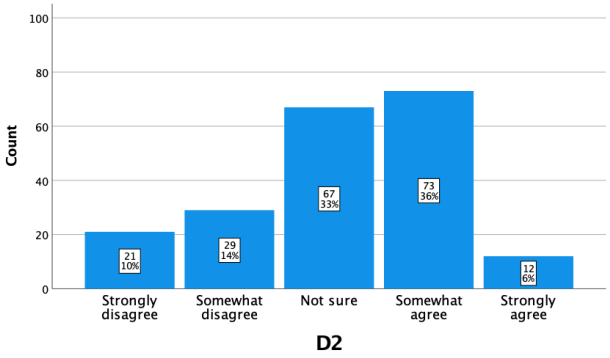

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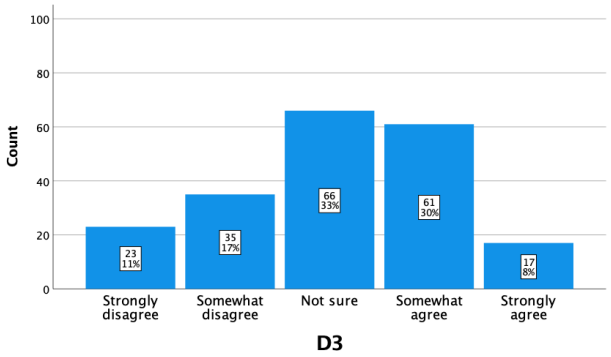

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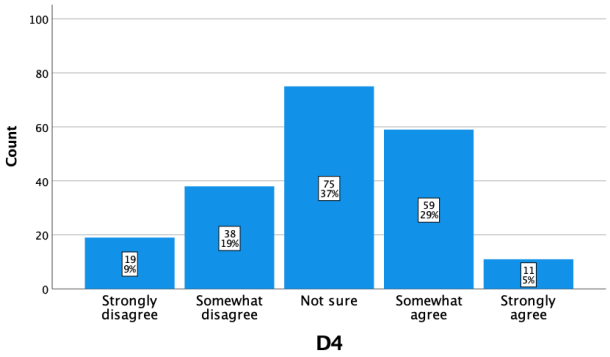

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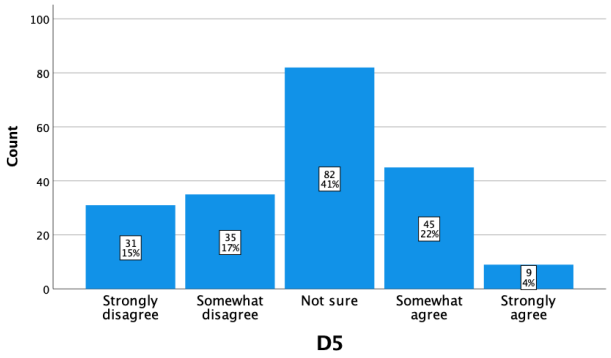

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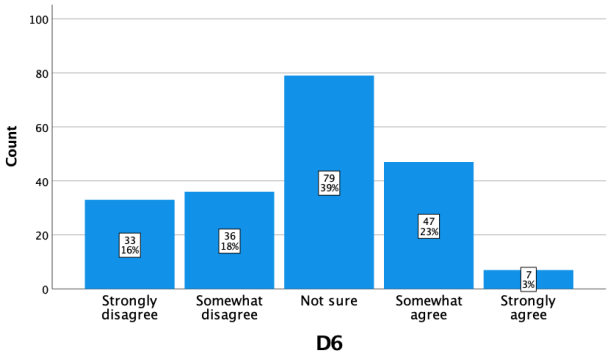

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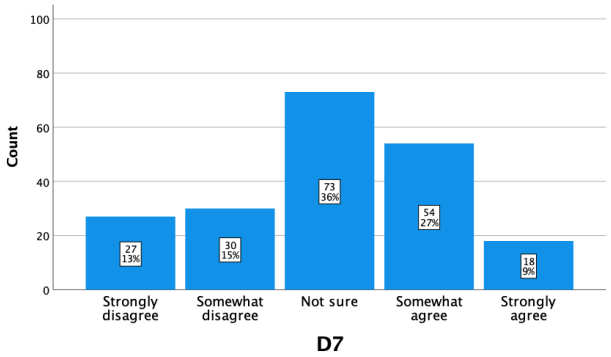

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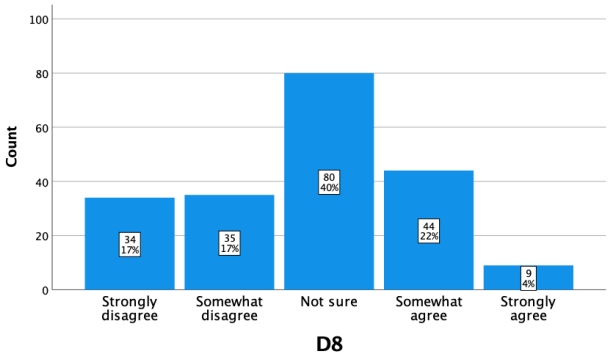

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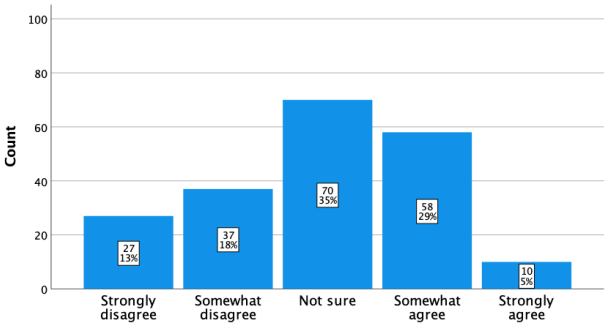

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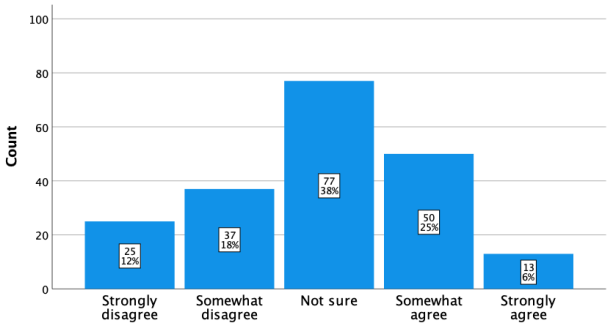

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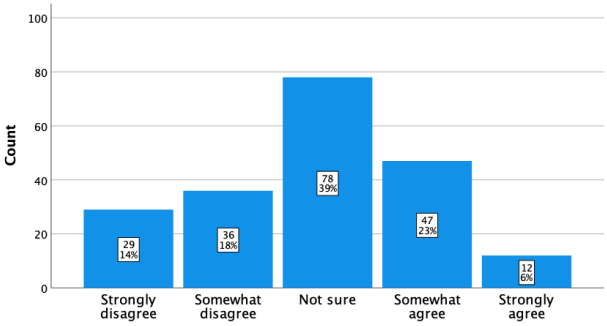

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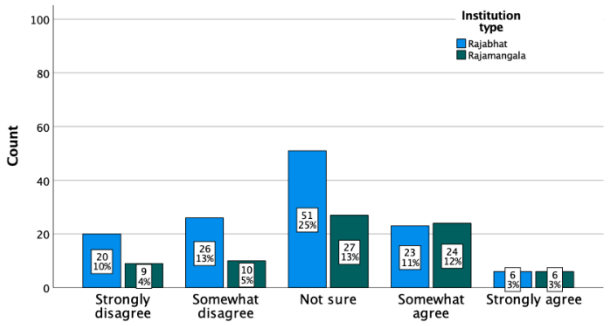

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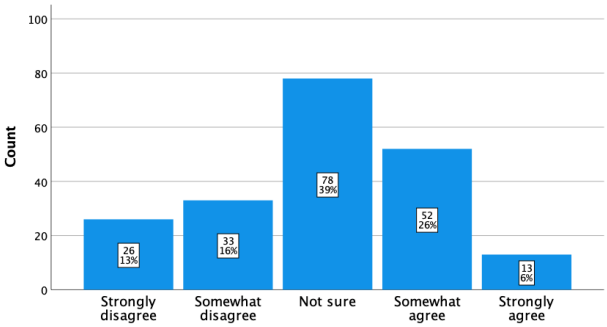

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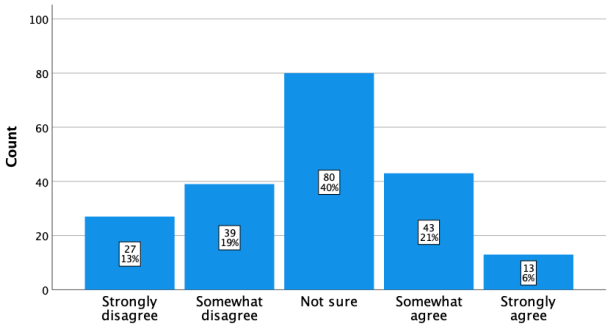

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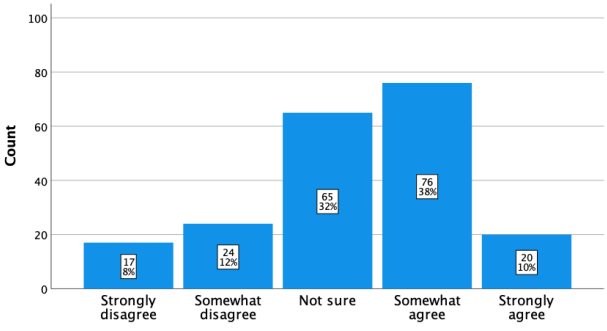
Module 1.4: Innovative Product design and development



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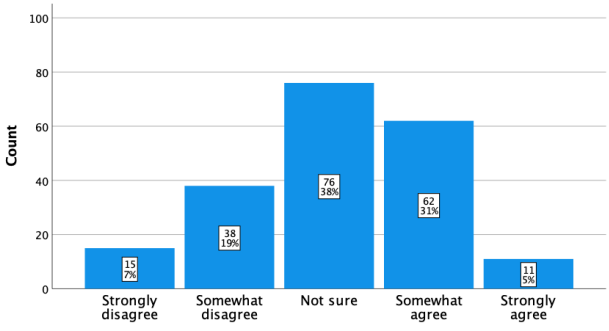

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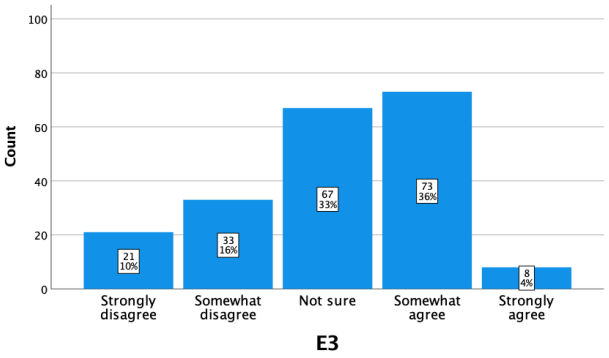
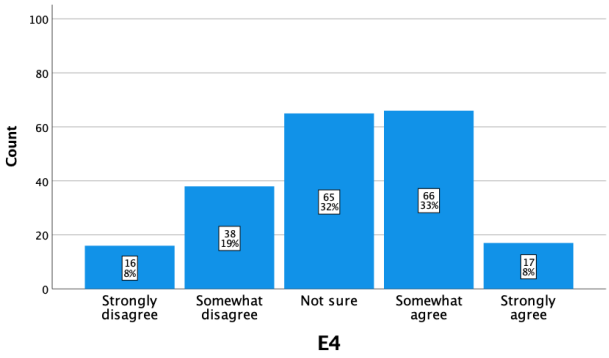
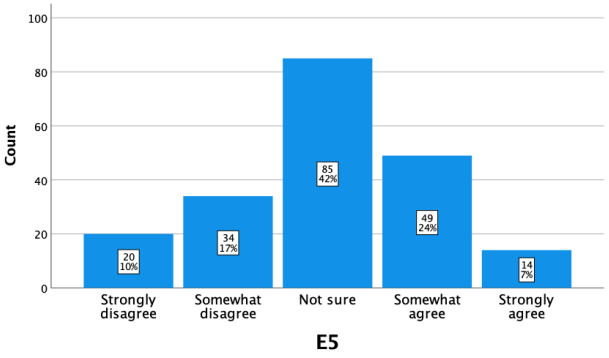
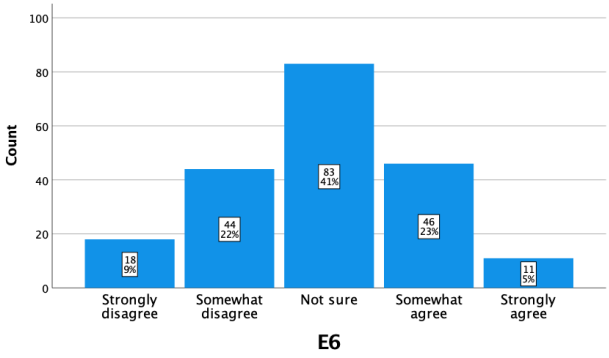
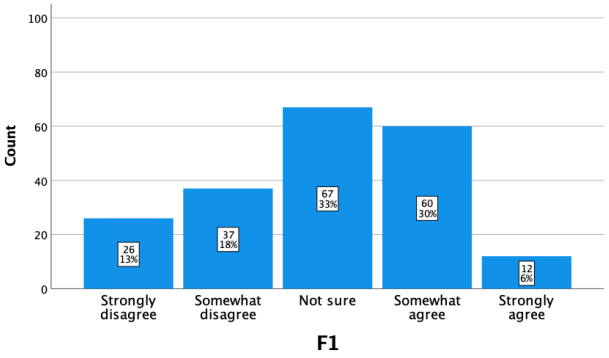


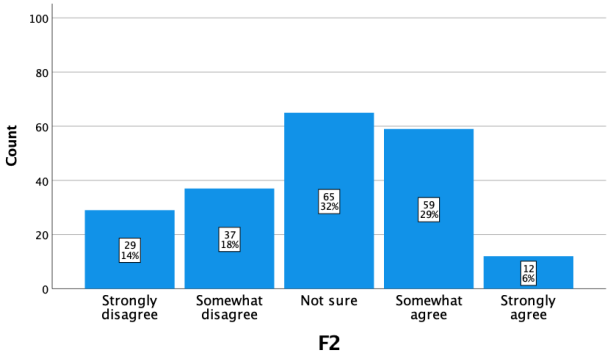


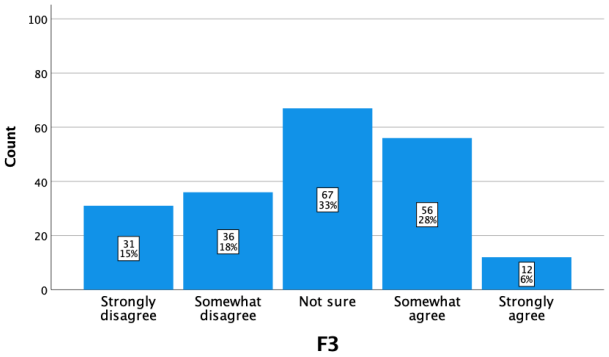


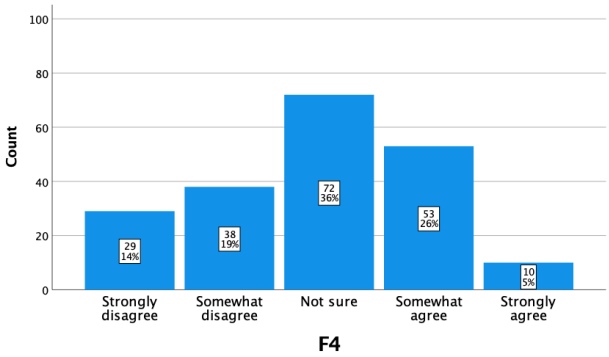


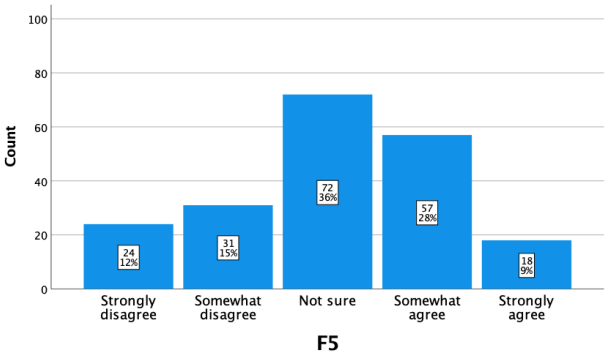
Module 1.5: Data Analytic











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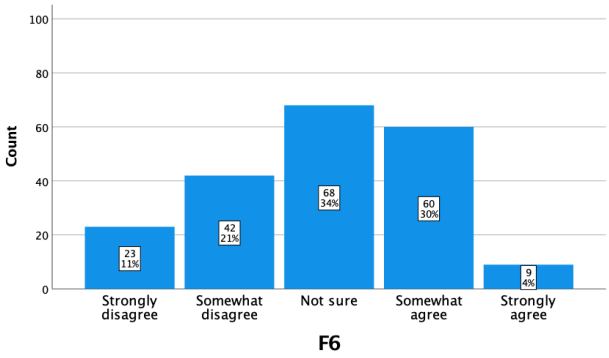

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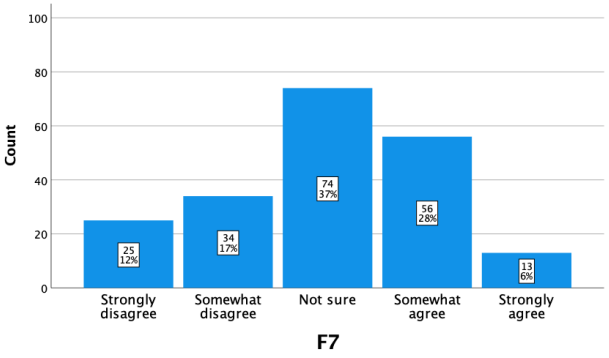

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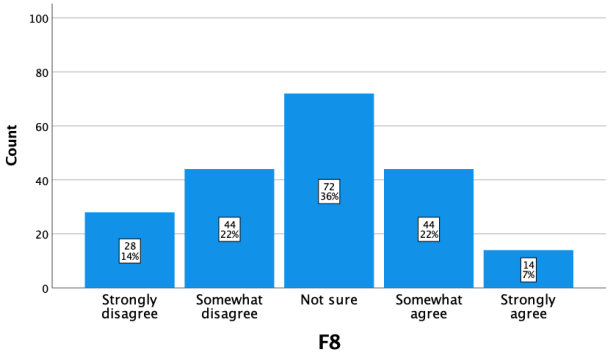

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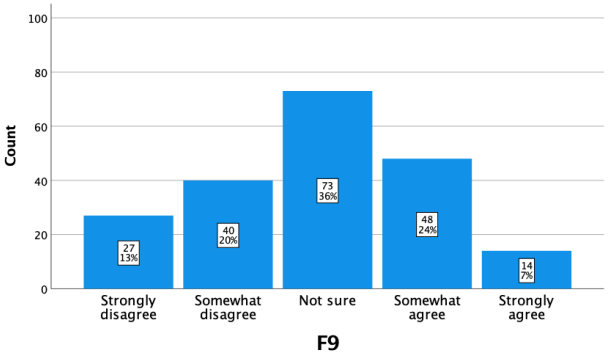

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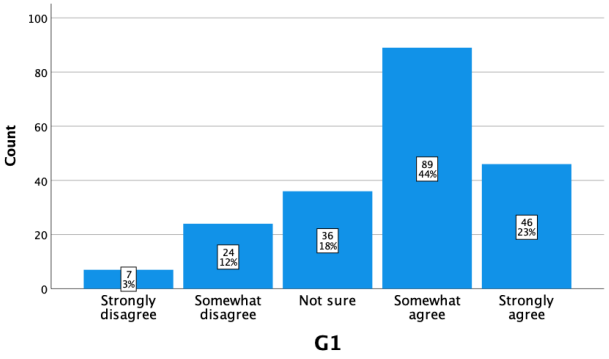
Educational Part

Module 2.1: Communication and people skills development



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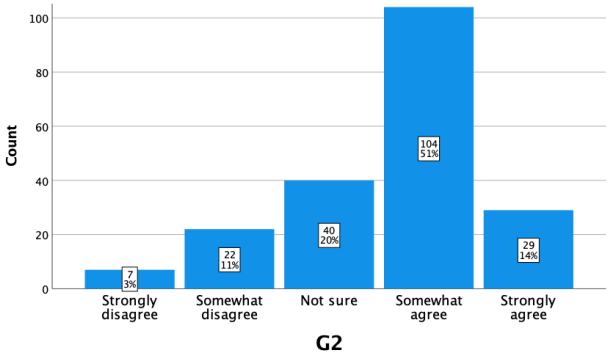
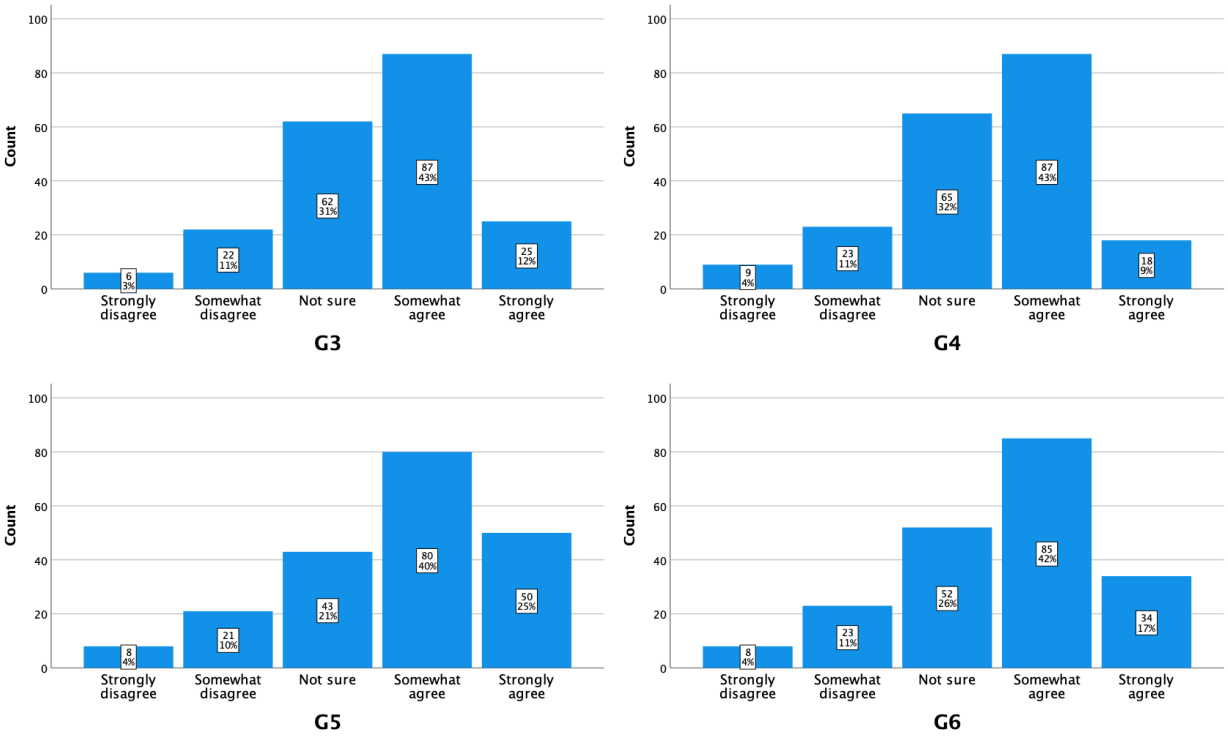
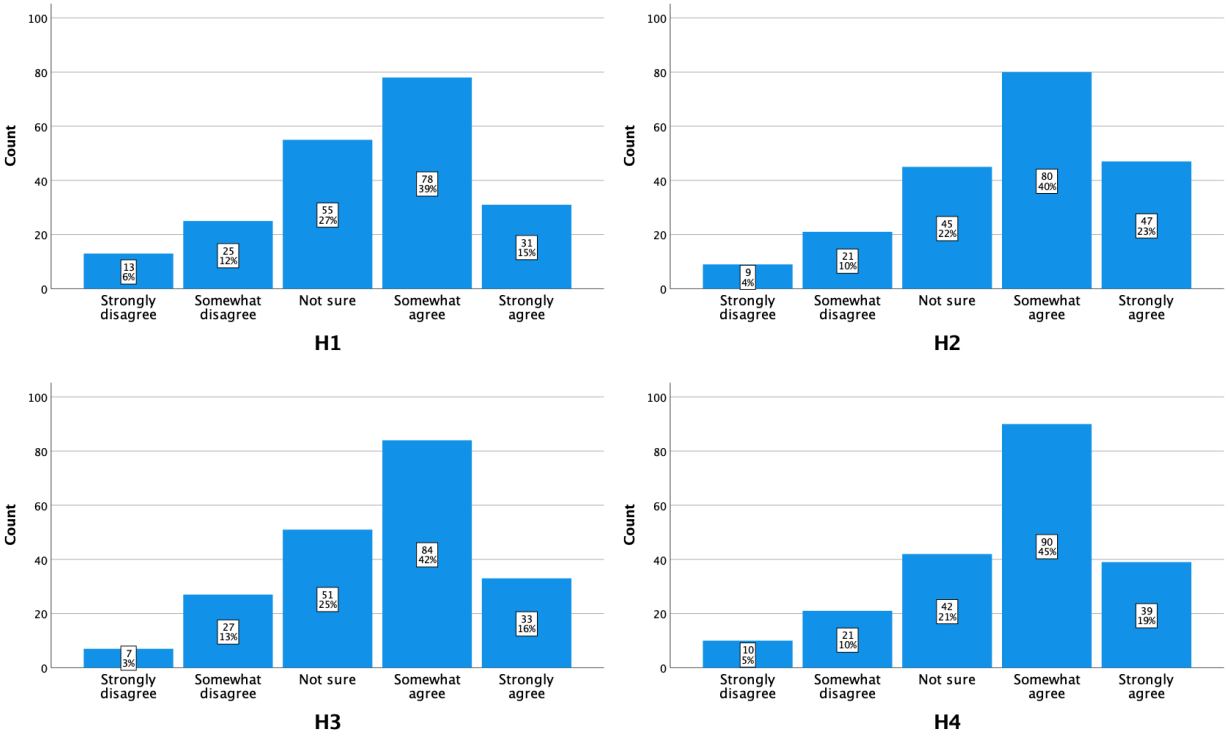
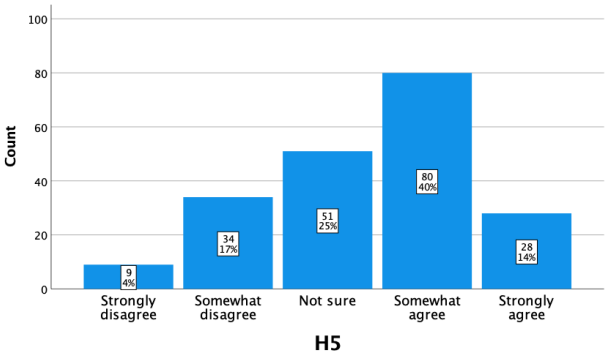


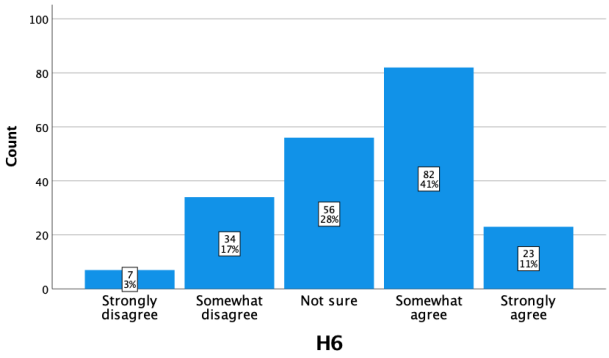
G2

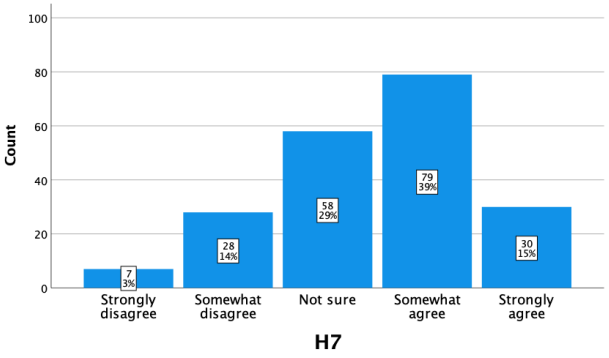


Module 2.2: Innovative teaching and learning methods

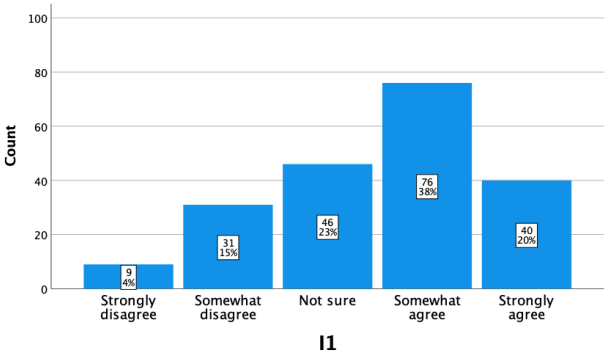


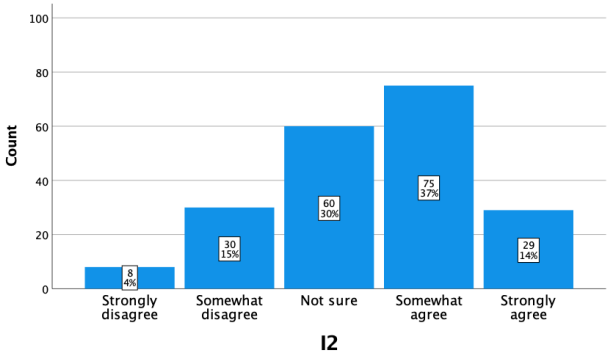


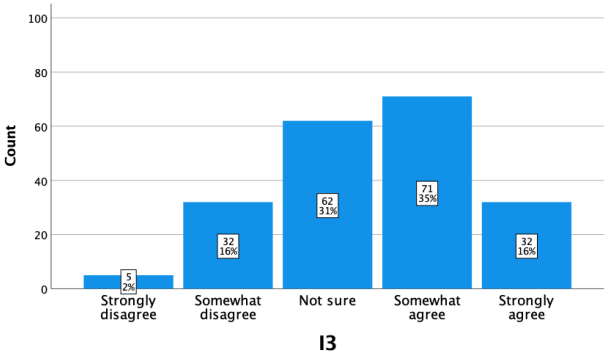


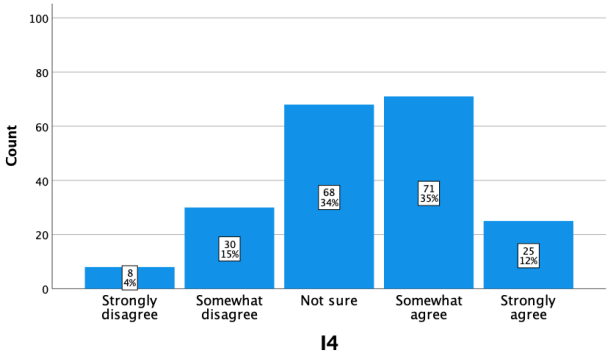


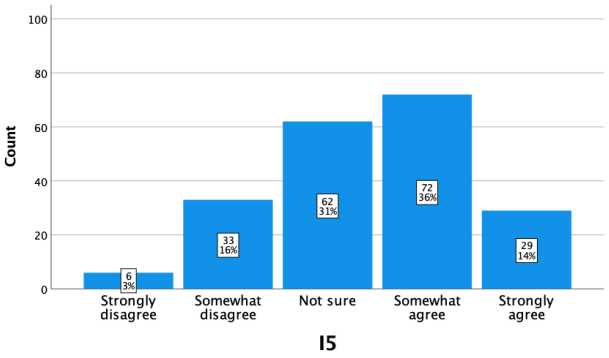
Module 2.3: Problem and Project-Based Learning (PBL)



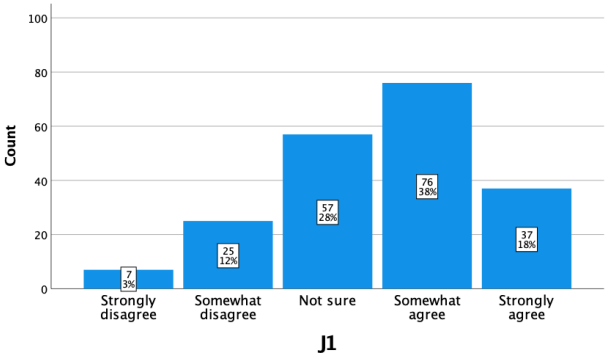


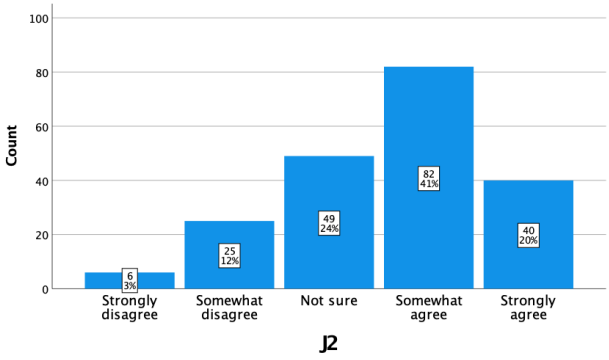


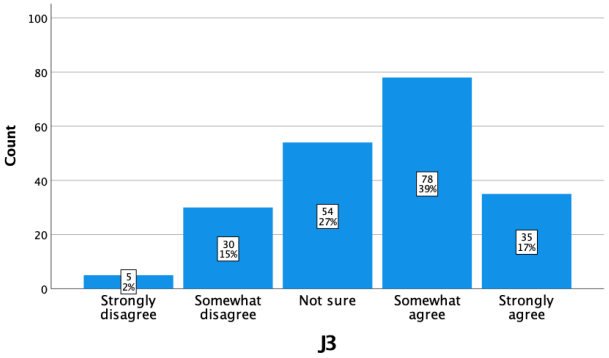


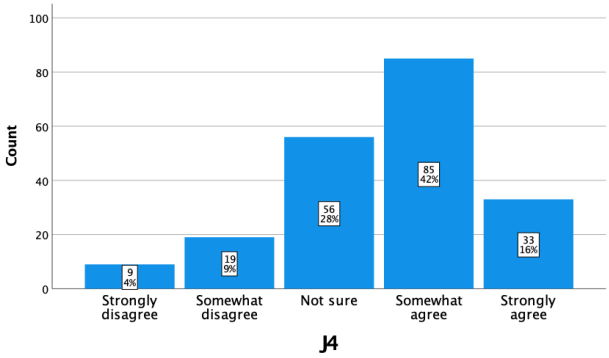


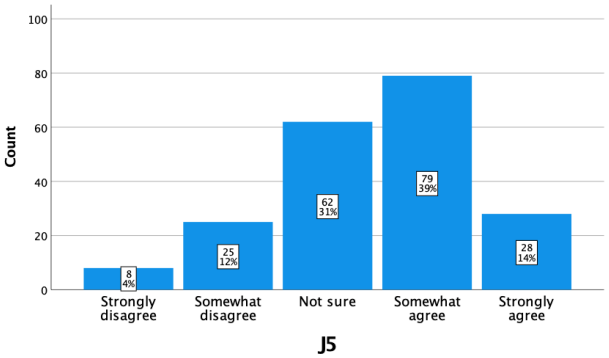
Module 2.4: Coaching and Mentoring Skills development

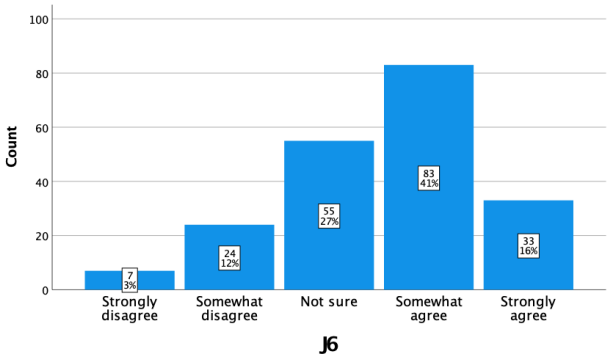




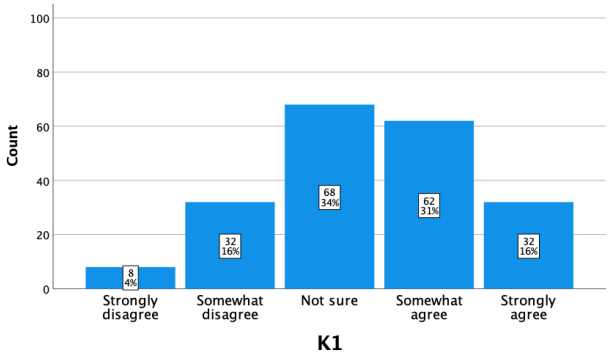




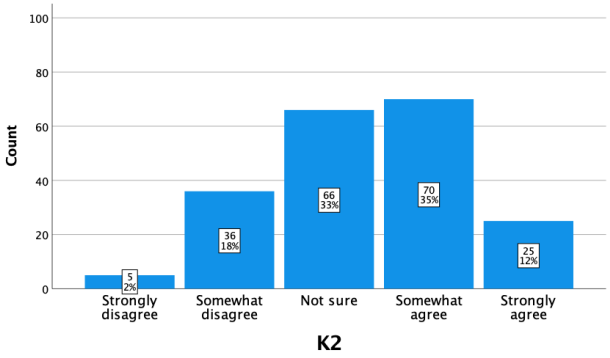




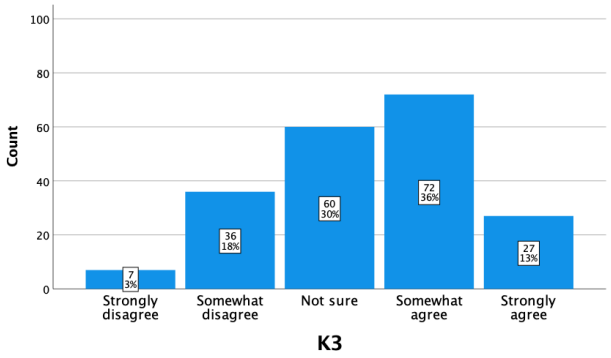
Module 2.5: Learning experience-focused course design and development



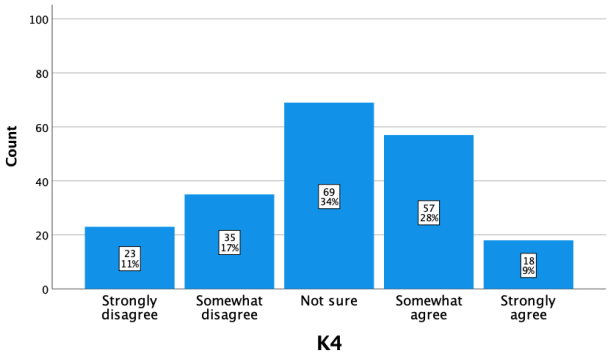
K1



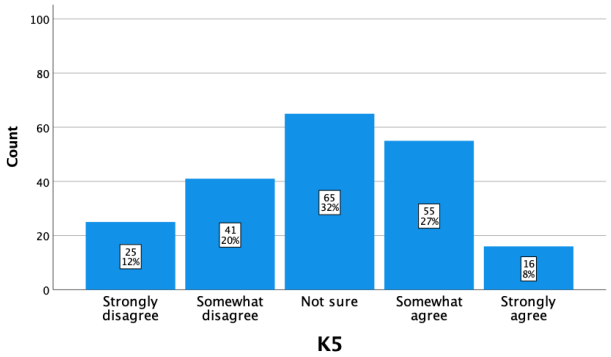
K2



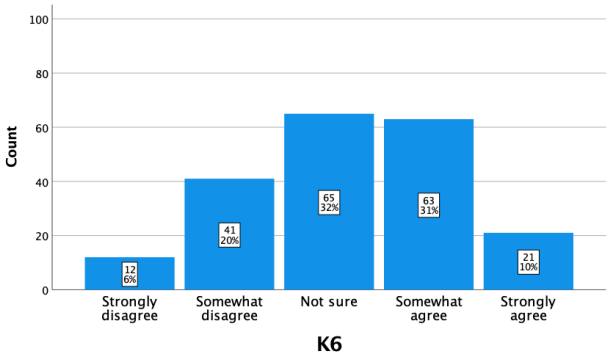
K3



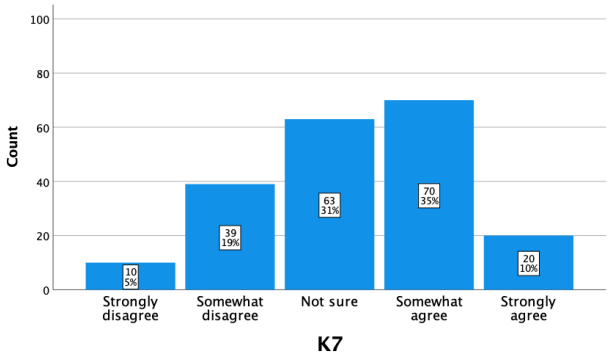
K4



K5



K6



K7

Independent samples t-student test for items between institutions

Independent Samples Test

	t-test for Equality of Means			
	t	df	Sig. (2-tailed)	Mean Difference
A1	-.687	200	.493	-.108
A2	-1.177	200	.241	-.170
A3	-.734	200	.464	-.120
A4	-.961	200	.338	-.148
A5	-.820	200	.413	-.120
A6	-1.234	200	.219	-.192
A7	-1.822	200	.070	-.297
A8	-1.688	200	.093	-.268
A9	-1.862	200	.064	-.291
A10	-2.115	200	.036	-.357
A11	-1.522	200	.130	-.239
A12	-1.428	200	.155	-.223
A13	-1.033	200	.303	-.170
A14	-.640	200	.523	-.099

Independent Samples Test

	t-test for Equality of Means			
	t	df	Sig. (2-tailed)	Mean Difference
B1	-.103	200	.918	-.015
B2	-1.544	200	.124	-.208
B3	-.731	200	.465	-.102
B4	-.248	200	.804	-.036
B5	.048	200	.962	.007
B6	-1.116	200	.266	-.157
B7	-.568	200	.570	-.087
B8	-.392	200	.695	-.060
B9	-.243	200	.809	-.036
B10	-.667	200	.505	-.097
B11	-1.429	200	.155	-.226
B12	-1.109	200	.269	-.162
B13	-.879	200	.381	-.126
B14	-.720	200	.472	-.104
B15	-.553	200	.581	-.081
B16	-1.066	200	.288	-.152

Independent Samples Test

	t-test for Equality of Means			
	t	df	Sig. (2-tailed)	Mean Difference
C1	.746	200	.456	.113
C2	-.382	200	.703	-.060
C3	.164	200	.870	.026
C4	-.509	200	.611	-.074
C5	-.668	200	.505	-.100
C6	-.276	200	.783	-.044
C7	-.107	200	.915	-.016
C8	-.241	200	.809	-.037

Independent Samples Test

	t-test for Equality of Means			
	t	df	Sig. (2-tailed)	Mean Difference
D1	-1.276	200	.204	-.200
D2	-1.389	200	.167	-.216
D3	-1.780	200	.077	-.290
D4	-.715	200	.476	-.108
D5	-.644	200	.520	-.101
D6	-1.405	200	.162	-.220
D7	-1.237	200	.218	-.206
D8	-1.515	200	.131	-.241
D9	-1.849	200	.066	-.293
D10	-1.625	200	.106	-.256
D11	-2.215	200	.028	-.351
D12	-1.820	200	.070	-.288
D13	-1.608	200	.109	-.254

Independent Samples Test

	t-test for Equality of Means			
	t	df	Sig. (2-tailed)	Mean Difference
E1	-.972	200	.332	-.151
E2	-1.594	200	.113	-.232
E3	-.793	200	.429	-.121
E4	-1.591	200	.113	-.247
E5	-1.096	200	.274	-.166
E6	-1.370	200	.172	-.201

Independent Samples Test

	t-test for Equality of Means			
	t	df	Sig. (2-tailed)	Mean Difference
F1	-1.292	200	.198	-.208
F2	-1.089	200	.277	-.180
F3	-1.116	200	.266	-.185
F4	-1.540	200	.125	-.246
F5	-1.912	200	.057	-.311
F6	-.375	200	.708	-.058
F7	-.893	200	.373	-.142
F8	-.069	200	.945	-.011
F9	-.750	200	.454	-.122

Independent Samples Test

	t-test for Equality of Means			
	t	df	Sig. (2-tailed)	Mean Difference
G1	-.853	200	.395	-.131
G2	.804	200	.422	.114
G3	-.344	200	.731	-.047
G4	-.628	200	.531	-.088
G5	-.702	200	.483	-.110
G6	-.439	200	.661	-.066

Independent Samples Test

	t-test for Equality of Means			
	t	df	Sig. (2-tailed)	Mean Difference
H1	.595	200	.552	.095
H2	.643	200	.521	.101
H3	.991	200	.323	.148
H4	.516	200	.607	.080
H5	.492	200	.624	.076
H6	.014	200	.989	.002
H7	.070	200	.944	.010

Independent Samples Test

	t-test for Equality of Means			
	t	df	Sig. (2-tailed)	Mean Difference
I1	-.621	200	.535	-.100
I2	-1.302	200	.194	-.195
I3	-.714	200	.476	-.106
I4	-1.410	200	.160	-.206
I5	-1.143	200	.255	-.169

Independent Samples Test

	t-test for Equality of Means			
	t	df	Sig. (2-tailed)	Mean Difference
J1	-1.723	200	.086	-.258
J2	-.982	200	.327	-.147
J3	-.761	200	.447	-.113
J4	-1.016	200	.311	-.150
J5	-.667	200	.506	-.098
J6	-.464	200	.643	-.068

Independent Samples Test

	t-test for Equality of Means			
	t	df	Sig. (2-tailed)	Mean Difference
K1	-1.750	200	.082	-.267
K2	-1.785	200	.076	-.256
K3	-1.464	200	.145	-.220
K4	-1.878	200	.062	-.306
K5	-1.474	200	.142	-.243
K6	-1.498	200	.136	-.231
K7	-1.377	200	.170	-.207

Anova for mean item scores by English proficiency

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
A_mean	Between Groups	10.571	3	3.524	4.120	.007
	Within Groups	169.344	198	.855		
	Total	179.915	201			
B_mean	Between Groups	7.124	3	2.375	3.389	.019
	Within Groups	138.714	198	.701		
	Total	145.838	201			
C_mean	Between Groups	1.223	3	.408	.477	.699
	Within Groups	169.124	198	.854		
	Total	170.346	201			
D_mean	Between Groups	1.383	3	.461	.486	.693
	Within Groups	188.034	198	.950		
	Total	189.417	201			
E_mean	Between Groups	8.634	3	2.878	3.321	.021
	Within Groups	171.594	198	.867		
	Total	180.227	201			
F_mean	Between Groups	2.967	3	.989	.906	.439
	Within Groups	216.076	198	1.091		
	Total	219.043	201			
G_mean	Between Groups	13.350	3	4.450	5.465	.001
	Within Groups	161.217	198	.814		
	Total	174.567	201			
H_mean	Between Groups	12.257	3	4.086	4.901	.003
	Within Groups	165.080	198	.834		
	Total	177.337	201			
I_mean	Between Groups	19.423	3	6.474	7.224	.000
	Within Groups	177.451	198	.896		
	Total	196.874	201			
J_mean	Between Groups	18.621	3	6.207	7.341	.000
	Within Groups	167.405	198	.845		
	Total	186.025	201			
K_mean	Between Groups	6.140	3	2.047	2.296	.079
	Within Groups	176.505	198	.891		
	Total	182.646	201			