

PAPER

# Academic Faculty Perceptions of Incorporating Industry 4.0 Technologies in Engineering Higher Education

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## ABSTRACT

As engineering higher education adapts to the demands of Industry 4.0 (I4.0), Faculty readiness to incorporate disruptive technologies in their classes becomes critical. This study investigates engineering Faculty's familiarity with I4.0 technologies (I4.0T), perceived importance of their incorporation in engineering education, and intentions to implement them in teaching. A sample of 107 Faculty members from local colleges and universities completed self-report questionnaires, with results analyzed quantitatively. Findings reveal moderate familiarity with I4.0T, low usage levels, and limited self-perceived competence. While half of the Faculty acknowledge the importance of I4.0T incorporation, fewer than one-third feel capable of implementing this incorporation. Approximately three-quarters express little interest or insufficient knowledge to form a relevant opinion. Faculty intentions to incorporate I4.0T are strongly associated with their frequency of use and perceived value. The paper recommends strategies to increase technology use, boost Faculty competence, and support the incorporation of I4.0T into higher education teaching practices.

## KEYWORDS

engineering Faculty perspectives, engineering higher education, Industry 4.0 (I4.0), Industry 4.0 technologies (I4.0T)

## 1 INTRODUCTION

The fourth industrial revolution, aka Industry 4.0 (I4.0), and its set of disruptive digital technologies, was originally designed for industry applications. It has rapidly penetrated many areas of our day-to-day life and is changing the way we live, work, and learn [1], [2], [3]. One of the manifestations of this change is the growing demand for industry workers that own a new set of competencies, focusing on digital literacy and I4.0 knowledge and skills. Among the required competencies are creativity, problem-solving, critical thinking, and teamwork skills [2], [4].

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Cuperman, D., Raveh, I. (2026). Academic Faculty Perceptions of Incorporating Industry 4.0 Technologies in Engineering Higher Education. *International Journal of Engineering Pedagogy (iJEP)*, 16(1), pp. 4–23. <https://doi.org/10.3991/ijep.v16i1.59353>

Article submitted 2025-08-08. Revision uploaded 2025-11-23. Final acceptance 2025-11-23.

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Thus, education systems worldwide are facing the challenge of being quickly adapted to the education of graduates that possess the needed competencies and are ready for the I4.0 era [5], [6], [7].

For engineering higher education institutions (HEIs), the aforesaid challenge is even greater, as they are responsible for preparing a new generation of engineers that will not only be users of current digital technologies but also developers of new ones. In addressing this challenge and performing a successful transformation of HE, the Faculty's preparedness plays a key role and is a challenge in itself [8]. Hence, Faculty need to possess appropriate tools, competencies, and mindset [1], [8], [9], [10]. To facilitate the adaptation, development, and assimilation of new educational pedagogies, educational researchers are required to "hear" the academic Faculty's voice and understand their attitudes and level of preparedness for the incorporation of I4.0 technologies (I4.0T) in their teaching.

While many studies have explored the readiness of industry enterprises and their workers for the era of I4.0, as well as their attitudes towards its core technologies, there are far fewer data on the readiness for and attitudes towards I4.0 in HE. Furthermore, most studies of those issues in HE involve students, whereas those that investigate specifically Faculty are few and focus only on part of the technologies [9], [11], [12]. This study aims to narrow this gap by investigating academic Faculty's perspective on a comprehensive range of I4.0 technologies and their readiness to incorporate them in their teaching. This study focuses on Faculty's familiarity with and perceptions of I4.0 technologies, the importance they attribute to teaching those technologies in their classes, and their intention of doing that in the future.

The research questions are:

1. To what extent are academic Faculty familiar with I4.0 concepts and technologies, and how frequently do they use those technologies?
2. What are Faculty's perceptions of the importance of incorporating I4.0T in HE?
3. What are Faculty's future intentions to incorporate I4.0T in their teaching practice and their sense of professional competence for doing that?
4. Is there a relationship between Faculty's I4.0-related attributes (familiarity, frequency of use, perceived importance, intention to incorporate, and sense of competence) and their personal demographic characteristics?
5. Can the Faculty's intention to incorporate I4.0T in their teaching be predicted by their demographic and professional characteristics?

## 2 THEORETICAL BACKGROUND

This section presents a list of what we refer to as I4.0 technologies, elaborating on opportunities for their implementation in HE. Then, it reviews studies that examine Faculty's preparedness for and intention to incorporate I4.0T in HE.

### 2.1 The I4.0 technologies

In his iconic book, popularizing the term Fourth Industrial Revolution, Schwab [3] pointed out a cluster of innovative and disruptive technologies that "build on and amplify each other in a fusion of technology across the physical, digital, and biological worlds" [3], p. 1. Schwab addressed the technologies of autonomous vehicles, 3D printing, advanced robotics, the Internet of Things (IoT), blockchain

(distributed ledger), augmented reality (AR), artificial intelligence (AI), quantum computing, neurotechnology, and more.

While the list of what are considered I4.0T is evolving, there is a wide consensus that it includes key enabling technologies for smart manufacturing and smart products [13], [14], [15]. The most prevalent technologies in this list are cyber physical systems, the Internet of Things, AR, additive manufacturing, artificial intelligence, cloud computing, big data analytics, simulation and digital twin, and autonomous robots [13], [14], [15], [16], [17], [18], [19], [20]. This is the list used and addressed in this study. To learn more about the essence of each technology, readers can use the above-mentioned references.

## 2.2 Implementation of I4.0T in HE

The I4.0 technologies are already being implemented in HE around the globe [16], [21], offering essential advantages for both students and academic institutions [16], [20], [22]. Hernandez-de-Menendez et al. [16] pointed out that a considerable number of institutions worldwide are already offering their students programs, courses, and workshops addressing I4.0 technologies. The authors elaborated on examples of such programs that are taught in three leading institutions: MIT, ETH Zurich-Swiss Federal Institute of Technology, and RWTH Aachen University. In the latter, students can attend courses about subjects such as data mining, communication and security, machine learning, computer vision, advanced robotics, simulation, and automation technology for production systems. In addition to the development of technical competencies, one of the declared goals of the courses is to promote competencies needed in the era of I4.0, among them: leadership, teamwork, problem-solving, decision-making, coping with complex tasks, and effective presentation of results. Coskun et al. [21] indicated five programs developed in the Turkish German University, including courses that were updated following the vision of I4.0. The programs comprise, for example, courses about machine learning, artificial intelligence, robotics, industrial IT, and virtual product development. Furthermore, the university plans to operate a Visual Production Lab that includes 3D design and manufacturing facilities, as well as a students' club with activities that disseminate I4.0 concepts and technologies. Moraes et al. [20] performed a systematic literature review and acknowledged benefits of incorporating I4.0T into HE for enhancing learning experiences (including better immersion in content, greater student engagement, and improved understanding), development of technical skills and soft skills, and increasing the teaching process efficiency.

## 2.3 Academic Faculty preparedness for I4.0T incorporation

Despite its centrality in preparing students for future implementation of I4.0, studies of the preparedness of academic Faculty to the incorporation of I4.0 concepts and technologies in their teaching are rare (e.g., [9], [1], [12]). Each of the research publications found by authors of this study illustrated only a segment of the whole picture, referring to academic Faculty's preparedness from a different perspective, using different concepts, or focusing on one technology only. Furthermore, some of the studies did not focus only on Faculty and presented results and conclusions based on the examination of heterogeneous groups of participants, including HE stakeholders, students, Faculty and more. Below is a short review of the relevant studies.

Zabidin et al. [23] studied familiarity with I4.0 concepts and technologies among a group of 74 industry and academy people in Malaysia. They found that almost half of their respondents from the academy were not properly acquainted with many I4.0T concepts, e.g., augmented reality, IoT, autonomous robots, cybersecurity, cloud computing, additive manufacturing, AI, and big data. The research findings showed that the respondents from academy found simulations to be the most familiar, while the least familiar was cyber-physical systems (CPS), which is one of the fundamental concepts of I4.0 technologies.

In their study, Gázquez et al. [24] investigated knowledge of I4.0 among 82 students and teachers from HEIs in 11 EU countries, aiming to identify the most relevant technologies that could be implemented in HE curricula. The researchers found that 57% of respondents were unaware of the technologies currently used in the industry. The other 43% of the respondents were asked to indicate what technologies they were familiar with. The results illustrated that 23%–37% of the respondents were familiar with technologies, such as additive manufacturing, AI, big data, robotics, and IoT; 20% were familiar with cloud computing; and only 9% said they were familiar with AR/VR. Gázquez et al. [24] concluded that the results demonstrated a low level of competence, as well as poor training offered in I4.0 and its technologies.

Lima et al. [12] assessed the self-perceived competences in I4.0T among 202 HE industrial engineering teachers in Thailand, as well as the relationship between demographic characteristics and the level of these self-perceived competences. They focused on competences in six knowledge areas: I4.0 Generic Items, industrial management in the I4.0 era, applications technology in the value chain, digital manufacturing, innovative product design, and data analytics. The researchers found that in most of the items addressed in their study, on average, the respondents self-perceived their competences as not high. The lowest levels of competence were registered in digital manufacturing and data analytics. Lima et al. [12] did not find significant differences between teachers' self-perceived competences and different characteristics of teaching experience or professional development. They concluded that "All teaching staff require training for this new context".

Kowang et al. [9] conducted a study of 132 lecturers from one HEI in Malaysia, assessing their perceptions of the importance and level of implementation of I4.0 competencies in HE. They addressed different I4.0 concepts and technologies, among them IoT, big data, cloud computing, AR, and cyber-physical systems, finding that the respondents perceived competencies in all those technologies as important for HE with a mean of 4.1 on a scale of 1–5. With regard to the level of implementation in HE, the respondents perceived it as moderate, with a mean of 3.4 on a scale of 1–5.

Jamaludin et al. [25] investigated the perceived readiness for implementing I4.0-related changes in HEIs across the ASEAN region. The study involved 263 stakeholders, including policy makers, students, and 153 lecturers. On the level of personal readiness, 88% of the respondents answered they were ready for the change that was introduced by Education 4.0. Nevertheless, only 42% answered they had knowledge about Education 4.0.

Mian et al. [26] explored and analyzed factors that affected the enactment of I4.0 in HE. Among other factors, they addressed familiarity with different I4.0 concepts and technologies. The participants of their study were 106 HE students, teaching Faculty, and researchers in Saudi Arabia. The researchers found that 27%–68% of the respondents were familiar with items in a given list of I4.0 concepts and technologies, e.g. cyber-physical systems (27%), AR (44%), additive manufacturing (57%), and IoT (68%). However, only 2%–22% answered they were well informed about the listed items.

Oke and Fernandes [27] explored South African academic Faculty's readiness for I4.0T in their practice. Their findings indicated that the education sector was unprepared for the I4.0 technology transformation.

Based on the aforementioned studies, it is evident that the familiarity, level of competence, and in general, preparedness level of academic Faculty to integrate I4.0T into their teaching was not high. This could be reflected in lecturers' intention to incorporate these technologies in the future—a topic that is elaborated on in the next section.

## 2.4 Academic Faculty perceptions of I4.0T future incorporation

Al-Riyami et al. [11] studied the readiness and acceptance of 275 Faculty in Oman for adopting I4.0T in HE. The authors used the “unified theory of acceptance and use of technology” (UTAUT) framework [28] and investigated whether it can be applied for predicting future intention of Faculty to use I4.0 technologies. The UTAUT model, used also in other studies [27], [29], consists of six constructs:

- Performance expectancy (PE): the expectation of technology capability to provide benefits and enhance the users' performance.
- Effort expectancy (EE): users anticipating level of ease when using technology.
- Social influence (SI): users perceiving the extent to which important people believe they should use the new technologies.
- Facilitating conditions (FCs): the extent to which people perceive the availability of an organizational and technical infrastructure that facilitates the adoption of new technologies.
- Attitude toward using technology (ATUT): teachers' tendency to integrate I4.0-related technologies into their instructional practices.
- Behavioral intention to use technology (BI).

The first five constructs were used as independent variables, while BI was used as the dependent variable. Age, gender, and background/specialization were used as moderating variables. The findings of the study conducted by [11] indicated that PE, FC, EE, SI, and ATUT have considerable impacts on the BI, while PE had the greatest and ATUT had the smallest effect. Romero-Rodríguez et al. [29] investigated the acceptance of IoT by university professors in Spain. The researchers found that the participants presented a high degree of acceptance to IoT, as well as an acceptable predisposition to its future use. In this context, FC appeared to be the powerful factor affecting the behavioral intention to use IoT, and gender has a strong effect on FC.

Regarding the effect of age on various model constructs, the findings are inconclusive. In the study conducted by [11], participants under 46 years old demonstrated higher mean scores in PE, EE, SI, ATUT, and BI than did participants older than 45 years. Moreover, it was noteworthy that adoption of I4.0T by lecturers aged 46 and above depended on their confidence and ability to use them. In the study of Romero-Rodríguez et al. [29], participants older than 36 years demonstrated the highest mean in EE, PE, SI, and ATUT. Teachers at the age of 21–35 attained high scores in FC and BI. This is contrary to the belief that younger lecturers have the attitude and predisposition to use technology. As to gender, Romero-Rodríguez et al. [29] indicated that men and women demonstrated a similar intention for using IoT. However, the highest average scores were obtained by men in all model constructs,

dramatically higher scores being demonstrated for EE, FC, and ATUT. [11] showed that gender had only considerable effects on Social Influence and Facilitation components, and no considerable difference was demonstrated in the behavioral intention between male and female lecturers.

Nikolic et al. [30] performed a systematic literature review of Faculty's attitudes, intentions, and behaviors towards AI and generative AI (GenAI) in higher education. They concluded that Faculty's attitudes towards these technologies were generally positive, acknowledging their potential for the enhancement of teaching and learning. Nevertheless, the Faculty's intentions for adopting AI and GenAI were limited due to obstacles such as lack of formal training and unclear policies regarding the use of these technologies.

### 3 RESEARCH DESIGN AND METHODOLOGY

#### 3.1 Participants

The sample comprised 107 academic Faculty, 84 of them (78%) taught at Braude College of Engineering, and the other 23 taught at eight other colleges and universities in Israel. Most of the Faculty (68%) were males. The average age was 52.70 (SD of 11.04 years). The average experience in teaching was 15.96 years (SD of 9.64 years). The distribution according to the subject of teaching is presented in Table 1. To examine whether the two participant sub-samples (Braude's sample and other academic institutions' sample) can be combined, Multiple Analysis of Variance (MANOVA) was performed, comparing the two groups in all dependent variables. No significant effect was found ( $F(4,92) = 1.71, p > .05$ ). In light of this result, the two samples were united for statistical analyses.

**Table 1.** Distribution of sample according to domain of teaching

Domain of Teaching	Percentage of Sample [%]
Mechanical Engineering	29
Applied Mathematics	8
Industrial Engineering and Management	16
Biotechnology Engineering	10
Electrical and Electronic Engineering	8
Software Engineering	14
Optical Engineering	7
Education in Technology	8

#### 3.2 Research instrument

The researchers developed and validated a self-report questionnaire, which was administered to the participating academic Faculty for the purpose of collecting data related to the research questions. The questionnaire was constructed by the researchers according to their experience in engineering education, their professional work

with I4.0 technologies, and their theoretical background about the issues addressed by the research [9], [11], [12], [23], [24], [25], [26], [29]. The list of I4.0T presented in the questionnaire was assembled based on common lists found in the empirical literature [13], [14], [15], [16], [17], [18], [19], [20]. The items were written in Hebrew, the mother tongue of the research participants. The questionnaire consisted of three sections:

1. Demographic background: including teaching experience, age, gender, and subject of teaching.
2. Familiarity with a list of I4.0T and concepts.
  - Familiarity with I4.0 concepts, such as I4.0 and cyber-physical systems, as well as Familiarity with technologies, such as IoT and machine learning (a matrix of questions with a Likert-type scale).
  - Frequency of using a list of I4.0-related technologies and applications, such as 3D design software, 3D printing, simulations, and robot programming (a matrix of questions with a Likert-type scale). The list of technologies in this section included some of the technologies on which this study focused and also some widespread technological tools associated with I4.0.
3. Perception of the incorporation of I4.0T in HE and readiness and intent to do so in the future.
  - Perceived importance of incorporating a list of I4.0T in HE (a matrix of questions with a Likert-type scale).
  - Intention to use a list of I4.0T as teaching tools (educational technology) or as a teaching subject (a matrix of questions with a Likert-type scale).
  - A sense of professional competence for incorporating I4.0T in courses (a matrix of questions with a Likert-type scale).

### 3.3 Content validity by inter-rater agreement through expert validation

The content validity was determined by full agreement between nine experts, Faculty from four academic institutions (one university and three engineering colleges), holding a PhD degree: the Head of the Teaching Department at the Braude College of Engineering, the Director of the Center for Robotics and Digital Technology Education, three experts in technology and engineering education with over 15 years of teaching state-of-the-art technologies, two experts in teaching pedagogies and teacher education with over 15 years of experience, and two experts in psychology and education with over 20 years of experience. A questionnaire was initially constructed by the authors of this study, carefully reviewed by each of the other seven experts and then revised until full agreement was achieved. All experts' notes were taken into consideration in the final version of the questionnaire. One example of the revisions made following the reviewers' remarks is adding the answer option 'Don't have enough knowledge to answer' in a few of the questions. This addition was made to avoid answers that were not based on real knowledge.

### 3.4 Reliability testing by using Cronbach's alpha coefficients

The reliability of each scale was measured by Cronbach's alpha (refer to Table 2).

**Table 2.** Scale reliability of the questionnaire

Scale	Cronbach's Alpha
Familiarity with I4.0 concepts	0.7
Familiarity with I4.0 technologies	0.85
Frequency of using I4.0-related technologies and applications	0.86
Perceived importance of incorporation I4.0 technologies	0.87
Intention to use I4.0T as teaching tools	0.91
Intention to use I4.0T as teaching subjects	0.90
Feeling of competence to incorporate I4.0 technologies	0.81

As illustrated by Table 2, all the coefficients indicated a satisfactory level of reliability. Hence, general measures were computed by averaging the responses of the items included in each scale.

### 3.5 Procedure

The data were collected from a questionnaire administered online using Google Forms. A request to fill in the questionnaire was sent by email to all 300 academic Faculty of Braude College of Engineering. The request included an invitation to further distribute the questionnaire to colleagues who taught in other HEIs. Participation in the research was voluntary, while anonymity and confidentiality were ensured. All the participants signed the informed consent form. Ethics approval for conducting the study was received from the Research Ethics Committee of the Braude College of Engineering (Approval number: 2022-010).

### 3.6 Data analysis

For the purpose of analyzing the data collected by the research instrument, statistical analyses were performed using the SPSS software, Version 29.0. To examine the reliability of the questionnaire, Cronbach's Alpha coefficients were computed. The research questions were examined through computation of the descriptive statistics of the global measures. Moreover, multiple regression was applied to examine the prediction of academic Faculty intention to incorporate the technologies. The relationship between the research variables and the personal characteristics of the participants was examined by t-test for independent samples (for gender) and Pearson correlation for age and years of experience.

## 4 FINDINGS

The findings are presented in accordance with the research questions.

### 4.1 Familiarity with I4.0 concepts and technologies and frequency of use of technologies

This subsection presents the findings relating to research question No. 1: To what extent are academic Faculty familiar with I4.0 concepts and technologies, and how frequently do they use those technologies?

Respondents' answers were on a Likert-type scale, ranging from 1 to 5 (1 implying 'Never heard about the concept/technology' and 5 implying 'Able to teach the concept/technology in academic courses'). The summary of the findings is presented in Table 3.

**Table 3.** Means of familiarity and use of I4.0T (N = 107)

Topic	Mean (out of 5)	Std. Deviation
Familiarity with I4.0 concepts	2.72	1.37
Familiarity with I4.0 technologies	3.23	1.11
Frequency of using I4.0-related technologies	2.16	1.39

As illustrated in Table 3, the mean for familiarity with the listed concepts (2.72) and with the listed technologies (3.23) was generally not very high. Below is a separate elaboration of concepts and technologies.

**Familiarity with I4.0 concepts.** Based on descriptive statistics, the distributions of respondents' answers regarding their familiarity with a given listed concept or I4.0T are presented in Tables 4 and 5, respectively. In each table, the lines present the percentage of respondents who estimated their familiarity with the concept/technology at the designated level, in terms of their ability to explain it to others. Answers of 4 and 5 were considered good ability to explain, answers of 3 were considered intermediate ability to explain, and answers of 1 and 2 were considered no ability to explain. The columns contain the values for each given concept/technology, while the rightmost column contains the mean values for all the concepts/technologies.

**Table 4.** Respondents' familiarity with I4.0 concepts (N = 107)

Concept % of Replies	Industry 4.0	Education 4.0	Cyber-Physical System	Mean
% reported a good ability to explain the concept	39	27	20	29
% reported an intermediate ability to explain the concept	34	20	20	25
% reported on no ability to explain the concept	27	53	60	46

As Table 4 illustrates, on average, 29% of the respondents answered they have a good ability to explain the concepts, while 46% have no ability at all. The concept with which the respondents were the most familiar was Industry 4.0, with 39% of them feeling they had a good ability to explain it. For the other two concepts, more than half of the respondents stated they had no explaining ability at all.

**Familiarity with I4.0 technologies.** As Table 5 illustrates, on average, 41% of the respondents replied they had a good ability to explain the technologies, while 59% had an intermediate or no ability at all to do so. The technology that was the most familiar to the respondents was Additive manufacturing (AM), which more than half of them felt they had a good ability to explain. The technology that was the most unfamiliar to the respondents was digital twin, which more than half of them had no ability to explain. For the other technologies, about 40% of the respondents stated

they had good ability to explain them, while the other remaining about 60% stated they had an intermediate or no ability to explain them.

**Table 5.** Respondents' familiarity with I4.0T (N = 107)

Technology % of Replies	<i>IoT</i>	<i>AR</i>	<i>AM</i>	<i>Machine Learning</i>	<i>Cloud Computing</i>	<i>Autonomic Robots</i>	<i>Big Data</i>	<i>Simulation (Digital Twin)</i>	Mean
% reported a good ability to explain the technology	45	37	54	40	40	42	40	28	<b>41</b>
% reported an intermediate ability to explain the technology	30	40	35	41	46	32	35	17	<b>34</b>
% reported no ability to explain the technology	25	22	11	19	14	26	26	55	<b>25</b>

**Frequency of using I4.0-related technologies and applications.** For the frequency of using technologies and applications related to I4.0 technologies, the answers were on a Likert-type scale of 1 to 5 (1 implies 'Never used,' and 5 implies 'Using regularly in the courses I teach'). As previously presented in Table 3, the mean value of respondents' answers was low (2.16), reflecting that Faculty seldom used the technologies. Based on descriptive statistics, the distribution of respondents' answers regarding the frequency of using one of the listed technologies and applications is presented in Table 6.

**Table 6.** Frequency of respondents' use of I4.0-related technological tools (N = 107)

Tool % of Replies	<i>3D Design</i>	<i>3D Printing</i>	<i>AR</i>	<i>Simulations</i>	<i>Robot Programming</i>	<i>Microcontroller Programming</i>	Mean
% reported much experience in using the tool	19	18	6	37	14	18	<b>19</b>
% reported an intermediate experience in using the tool	19	12	6	25	10	11	<b>14</b>
% reported little or no experience in using the tool	62	70	88	38	76	71	<b>67</b>

In Table 6, the lines present for each listed I4.0 technological tool the percentage of respondents who estimated their use of it at the designated level. The columns indicate the numbers for each listed tool, while the rightmost column shows the mean values for all the tools.

As illustrated in Table 6, on average, only 19% of the respondents stated they were using the listed technological tool on a regular basis, while 67% had seldom or never used those tools. The technological tool that, on average, was most used by the respondents was simulations. However, even for this tool, only 37% of the respondents stated they were using it regularly, whereas 38% seldom or never

used it. The least used tool was AR, which only 6% of the respondents used, whereas 88% seldom or never used it.

## 4.2 Perception of the importance of incorporating I4.0 technologies

This subsection presents the findings relating to research question No. 2: What are Faculty's perceptions of the importance of incorporating I4.0T in HE?

The respondents were asked to rate the importance they attribute to the incorporation of the listed I4.0T in HE on a 1 to 5 Likert-type scale (1 implies 'No importance at all,' and 5 implies 'Extreme importance'). In case the respondents felt that they could not give a founded answer, they could state, 'Don't have enough knowledge to answer.' Based on descriptive statistics, the distribution of respondents' answers regarding their perceived importance of incorporating I4.0T in HE is presented in Table 7.

**Table 7.** Perceived importance of incorporating I4.0T (N = 107)

Technology \ % of Replies	IoT	AR	AM	Machine Learning	Cloud Computing	Autonomic Robots	Big Data	Simulation (Digital twin)	Mean
% attributed great importance	38	27	47	56	57	41	56	38	45
% attributed intermediate importance	11	20	17	12	14	14	10	12	14
% attributed little or no importance	17	24	24	12	17	18	19	18	19
% stated 'Don't have enough knowledge to answer'	34	29	12	20	12	27	15	32	22

Answers of 4 and 5 were considered of great importance, answers of 3 were considered of intermediate importance, and answers of 1 and 2 were considered of little or no importance at all. The last line indicates the percentage of respondents who stated, 'Don't have enough knowledge to answer.' The columns contain the values for each listed technology, while the rightmost column contains the mean values for all the technologies.

The findings presented in Table 7 indicate that, on average, 45% of the respondents attributed great importance to the incorporation of I4.0T in HE. Thirty-three percent attributed intermediate, low, or no importance, and 22% stated they did not have enough knowledge to answer. The technologies that were perceived as the most important for incorporation and were rated with great importance by more than half of the respondents were machine learning, cloud computing, and big data. On the other hand, AR was rated with great importance by only a little more than a quarter of the respondents, while almost the same number of them attributed to it little or no importance. For the other technologies, between 38%–47% of the respondents attributed great importance to their incorporation.

The findings in the last line (% stated 'Don't have enough knowledge to answer') corresponded in most cases to those in the previous section that dealt

with Faculty's familiarity and frequency of using the technologies. In both cases, the respondents reflected a relatively high common lack of familiarity with IoT, AR, Autonomous robots, and Digital twin, whereas high familiarity was attributed to Additive manufacturing and Cloud computing. Nevertheless, for Big data, in this section the respondents reflected a smaller lack of familiarity than in the previous section.

### 4.3 Academic Faculty perception of their future incorporation of I4.0 technologies

This subsection presents the findings relating to research question No. 3: What are the Faculty's future intentions to incorporate I4.0T in their teaching practice and their sense of professional competence for doing that?

**Intention of incorporating I4.0T.** Regarding respondents' interest in future incorporation of the technologies in their teaching as teaching tools/course subjects, the answers were on a Likert-type scale of 1 to 6 (1 implies 'Totally not interested, 5 implies 'Extremely interested,' and 6 implies 'I already use the technology in academic courses I teach'). In case respondents felt that they were unable to give a founded answer, they could state, 'Don't have enough knowledge to answer.' Based on descriptive statistics, the distributions of respondents' answers regarding their interest in future incorporation of the technologies in their courses as teaching tools or as course subjects were presented in Tables 8 and 9, respectively. In each table, the first line presented the percentage of respondents who were already using the technology in academic courses. Lines 2–4 presented the percentage of respondents who estimated their interest at the designated level. Answers of 4 and 5 were considered high interest, answers of 3 were considered intermediate interest, and answers of 1 and 2 were considered little or no interest at all. The last line showed the percentage of respondents who stated, 'Don't have enough knowledge to answer.' The columns indicated the values for each listed technology, while the rightmost column illustrated the mean values for all the technologies.

**Table 8.** Intent to incorporate I4.0T as teaching tools (N = 107)

Technology \ % of Replies	IoT	AR	AM	Machine Learning	Cloud Computing	Autonomous Robots	Big Data	Simulation (Digital Twin)	Mean
% using the technology in academic courses	8	2	12	9	9	9	8	9	8
% expressed high interest	16	12	17	20	23	16	24	18	18
% expressed intermediate interest	2	8	6	12	7	8	12	9	8
% expressed little or no interest	37	41	46	36	38	37	35	24	37
% stated 'Don't have enough knowledge to answer'	37	37	19	23	23	30	21	40	29

**Table 9.** Intent to incorporate I4.0T as course subjects (N = 107)

Technology % of Replies	IoT	AR	AM	Machine Learning	Cloud Computing	Autonomic Robots	Big Data	Simulation (Digital Twin)	Mean
% using the technology in academic courses	8	2	11	10	7	9	9	12	9
% expressed high interest	14	10	16	17	19	14	13	14	15
% expressed intermediate interest	4	7	4	5	6	5	8	4	5
% expressed little or no interest	45	59	51	47	45	48	46	34	45
% stated 'Don't have enough knowledge to answer'	29	32	18	21	23	24	24	36	26

As illustrated in Tables 8 and 9, on average, only 8%–9% of the respondents already used the technologies in courses they taught. The three technologies most used by the respondents in their courses were Additive manufacturing, Simulation (Digital twin), and Machine learning. The least used technology was Augmented reality, being incorporated in courses by only 2% of the respondents.

Other respondents (on average 15%–18%) expressed high interest in incorporating I4.0T in their courses. Together with those already using the technologies, they constituted a group of about a quarter of the respondents. A small number of respondents (on average 5%–8%) expressed intermediate interest in the incorporation, while the greatest number of respondents (37%–45%) expressed little or no interest in incorporating I4.0T in courses they taught. More than a quarter of the respondents stated that they did not have enough knowledge for answering the question.

The three technologies in which most respondents expressed high interest for using as educational technology were Big data, Cloud computing, and Machine learning. The three technologies that the greatest number of respondents were highly interested in teaching in their courses were Cloud computing, Machine learning, and Additive manufacturing.

The findings of this study did not indicate a statistically significant difference between the data in Tables 8 and 9.

**Academic Faculty feeling of professional competence for incorporating I4.0 technologies.** The answers were on a Likert-type scale of 1 to 5 (1 implies 'Not ready at all,' and 5 implies 'Extremely ready'). Based on descriptive statistics, the distributions of respondents' answers regarding their sense of competence for incorporating the technologies in their courses are presented in Table 10.

**Table 10.** Sense of competence to incorporate at least one of the I4.0T (N = 107)

	Not Ready at All	Ready to a Small Extent	Ready to an Intermediate Extent	Ready to a Great Extent	Ready to a Very Great Extent
% of respondents	23	25	20	14	18

The columns present the percentage of respondents who estimated at the designated level their readiness to incorporate I4.0T in the courses they taught.

As Table 10 illustrates, less than a third sensed they were ready to a great or very great extent to incorporate I4.0T in their courses.

#### 4.4 Relationship between Faculty attributes and demographic characteristics

This subsection presents the findings relating to research question No. 4: Is there a relationship between Faculty's I4.0-related attributes (familiarity, frequency of use, perceived importance, intention to incorporate, and sense of competence) and their personal demographic characteristics?

The relationship between Faculty's attributes related to I4.0T (familiarity, frequency of use, perceived importance, intention to use, and sense of competence) and personal demographic characteristics of Faculty was examined with regard to gender, age, and experience in teaching. Gender differences were examined by t-test for independent samples, and the results are presented in Table 11.

**Table 11.** Relationship between respondents' attributes and personal characteristics (N = 107)

Attribute	Gender	N	Mean	Std. Deviation	t
Familiarity with concepts	Male	71	2.83	1.15	1.98*
	Female	33	2.39	0.71	
Familiarity with technologies	Male	70	3.26	0.90	1.76*
	Female	33	2.95	0.62	
Frequency of use	Male	71	2.58	1.22	4.63***
	Female	33	1.55	0.59	
Perceived importance of incorporation	Male	66	3.4905	1.01835	0.25
	Female	32	3.4371	.86417	
Intention to use as teaching tool	Male	58	2.7156	1.47797	0.92
	Female	30	2.4089	1.50597	
Intention to use as teaching subject	Male	60	2.6229	1.51674	1.65
	Female	28	2.0546	1.47638	
Sense of competence	Male	68	3.0294	1.46573	2.43**
	Female	32	2.3125	1.14828	

Notes: \*p < .05 \*\*p < .01 \*\*\*p < .001.

The analysis indicated that the means for males were significantly higher than for females in four measures: familiarity with concepts, familiarity of technologies, frequency of use, and sense of competence for using the technologies. Pearson correlations between two personal characteristics—age and years of experience—and the research variables yielded no significant results. Thus, no significant relationships were found for I4.0-related attributes with regard to age and years of experience.

#### 4.5 Predicting academic Faculty intention of incorporating I4.0 technologies

This subsection discusses the findings related to research question 5: Can the Faculty's intention to incorporate I4.0T in their teaching be predicted by their demographic and professional characteristics?

Regression analyses were performed in order to find out whether the academic Faculty intention to incorporate I4.0T in their teaching can be predicted by their demographic characteristics, familiarity with I4.0 technologies, frequency of using I4.0 related technologies, sense of competence, or perception of the importance of-incorporation. The dependent variable was an index computed by the sum of two measures: their intention to incorporate I4.0T as a course subjects and as a teaching tool. The results are presented in Table 12.

**Table 12.** Regression analysis of intention to incorporate I4.0 technologies

Predictor	Beta	t
Gender (0 = female, 1 = male)	.08	.60
Years of experience	1.00	.77
Age	-.07	.48
Familiarity with concepts	.04	.34
Familiarity with technologies	.310	.82
Sense of competence	.17	1.55
Perceived importance of incorporation	.45	4.64**
Frequency of using I4.0-related technologies and applications	.29	2.52**
R Square	0.35**	

Note: \*\*p < .01.

The results showed that all the predictors contributed 35% to account for the variance of the intention to use I4.0 technologies. Two variables were found to be significantly related to the intention to use the technologies: Frequency of using I4.0T and Perceived importance of I4.0 technology incorporation.

## 5 DISCUSSION

The discussion is presented according to the research questions. The first research question refers to Faculty's familiarity and past experience with I4.0 concepts and technologies. In this respect, the findings indicated that respondents were familiar with I4.0 concepts and technologies to a moderate extent, while they practically used related technologies and applications to a small extent. Those findings supported other studies [12], [23], [24], [25], [26], arguing that academic Faculty were not properly acquainted with many I4.0T concepts. This study found that the most familiar concept was Industry 4.0, while less familiar were Education 4.0 (in line with [25]) and CPS (in line with [23], [26]). Regarding familiarity with I4.0 technologies, the two most familiar were found to be Additive manufacturing (AM) and IoT (in line with [24, 26]), while the most unfamiliar was Digital twin. Findings of this study indicated that the majority of Faculty had seldom or never used I4.0-related technologies and related applications. This usage level was lower than the moderate extent reported by [9] and lower than the self-perceived level of competences ("not high") reported by Lima et al. [12]. According to the findings of this study, the most used technology was simulations (in line with [23]), while the least used was AR (in line with [24]).

The second research question referred to Faculty's perceptions of the importance of incorporating I4.0T in HE. Findings of this study showed that about a quarter of the respondents stated they did not have sufficient knowledge for forming an opinion on the issue of importance. This fact further supported the lack of familiarity with I4.0 technologies, discussed in the previous paragraph. Most of the respondents that did express an opinion, attributed intermediate or great importance to the incorporation of I4.0T in HE (in line with [9]). The technologies that were perceived as the most important for incorporation were machine learning, cloud computing, and big data. AR was perceived by the respondents as the least important for incorporation.

The third research question referred to Faculty's perceptions of future incorporation of I4.0T in their teaching practice. Regarding Faculty's competence, less than a third felt highly ready to incorporate I4.0T in the courses they taught (in line with [12]). These findings corresponded to Faculty's intention to incorporate I4.0T in their teaching practice, and the respondents could be divided into two distinct groups. The first group (about three-quarters) had little or no interest in incorporating I4.0T in their courses or did not have sufficient knowledge for forming an opinion on this issue. The second group (about a quarter) were either highly interested in incorporating or had already incorporated the technologies in their classes. Those findings did not support the findings of Jamaludin et al. [25], who illustrated that most of their respondents were ready for the change introduced by Education 4.0. This gap could be accounted for by the fact that in their study the population included not only lecturers but also policymakers and students.

The technologies most Faculty intended to incorporate or had already incorporated in courses were Additive manufacturing, Simulation (Digital twin), Machine learning, and Cloud computing, while AR was found to be the least incorporated by far. This last fact could be related to findings of this study regarding a little degree of Faculty's familiarity with AR. Given the low level of familiarity with Digital twin reflected in Table 5 and the high level of experience specifically with simulations shown in Table 6, here we interpret the respondent's answer regarding Simulation (Digital twin) as referring to Simulation rather than to Digital twin.

The fourth research question referred to the relationship between Faculty I4.0-related attributes (familiarity, frequency of use, perceived importance, intention to use, and sense of competence) and their personal demographic characteristics (age, gender, and teaching experience). The findings indicated that the highest means for all the attributes were demonstrated by men (in line with [29]). Nevertheless, considerably higher means were demonstrated by men, only with respect to familiarity with concepts and technologies, frequency of use, and sense of competence for using technologies (in line with [29], with reference to the ATUT construct). As for intention to use I4.0 technologies, the findings did not indicate significant differences between genders (in line with [11], [29]). Moreover, no significant relationships were found for all the attributes associated with age (contrary to [11], who found significant differences in participants under 46 and older than 45 in some of the constructs, as well as to [29], who found significant differences between younger and older participants in different constructs) and years of experience.

The fifth research question referred to the possibility of predicting Faculty's intention to incorporate I4.0T in their teaching on the basis of their demographic and professional characteristics. Frequency of using technology and the perceived importance of technology incorporation were found to be significantly related to the intention to use technologies (in line with [11], who found that the constructs of ATUT and PE had considerable impacts on the behavioral intent of Faculty to use I4.0 technology in HE).

## 6 CONCLUSIONS

This study examined academic Faculty's perceptions of I4.0T incorporation in higher education. It explored the Faculty's past experience with the technologies and their future intention to incorporate them in teaching. With regard to past experience, the findings indicated intermediate familiarity with I4.0 concepts and technologies and a low level of use. Such a level of familiarity and level of use of related technologies reflected a situation whereby, currently, many Faculty did not have sufficient background needed for teaching the concepts and technologies in HE. However, even given such a limited past experience, most Faculty that regarded themselves as having enough knowledge for forming an opinion on I4.0 technologies attributed medium or great importance to the incorporation of I4.0T in HE. It is noteworthy that a considerable number of respondents considered they did not have enough knowledge for formulating an opinion on I4.0 technologies.

Looking into the future, one could conclude that this incorporation would not be easy. The findings showed that only less than a third of Faculty sensed they were competent for incorporating the technologies, and only a quarter intended to do so in the future or had already incorporated the technologies in their teaching.

The findings of this study illustrate that Faculty intention to incorporate I4.0T in their teaching could be predicted by Faculty's frequency of using technology and the perceived importance they attributed to incorporation of I4.0T in HE. Consequently, in order to increase Faculty's frequency of using technology, HE needs to develop and formulate a policy that encourages and drives Faculty, particularly female Faculty, to practice by themselves and frequently use I4.0 technologies. This could be achieved by investing in research laboratories and digital fabrication laboratories (Fab Labs) and stimulating Faculty to use them, learn and practice the technologies, collaborate, share experience, and develop interdisciplinary ideas for using the technologies in teaching.

In this context, this study recommends two technologies, namely 3D printing, which is the most familiar to Faculty, and AR, which is the least used by Faculty. Enabling easy access to 3D printing facilities in parallel with the Faculty's familiarity with the technology can attract and motivate them to be involved and to learn technologies that are less familiar. As for AR, this study identified a dissonance between the big opportunities inherent in this technology for science and engineering education across fields [31], [32], [33] and the little knowledge and experience associated with it by participants in this study. Hence, it is recommended to expose Faculty to this technology and enable active experimentation to convince them of its importance for teaching across disciplines. Authors of this paper believe that hands-on experimentation with those two useful technologies can help Faculty acknowledge the importance of use them and other technologies for teaching, resulting in increased intention to use it in the future.

The research instrument of this study was a self-report questionnaire filled in by Faculty from eight different disciplines, while the statistical analysis did not yield findings that allowed determination of differences between the disciplines. Therefore, another recommendation of this study is expanding the research population, enabling a comparison between different disciplines, and seeking to identify unique characteristics and needs of each of them. In addition to widescale research, the authors suggest studies that focus on a single discipline (as recently done for AD), while integrating more qualitative research instruments, such as interviews, focus groups, and observations. This can lead to a more comprehensive picture, enabling unique and adapted ways for coping with the needs of each discipline.

## 7 ACKNOWLEDGEMENT

This study was supported by the Braude College of Engineering.

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