WHAT'S IN A NAME? "HOLISTIC," "INTEGRATIVE," AND "INTEGRATED" ENGINEERING EDUCATION THROUGH THE LENS OF FINK'S TAXONOMY

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Abstract – *Some educators within engineering have used "holistic," "integrative" and "integrated" frameworks to support their initiatives. They intend to improve the connection between engineering courses, non-technical disciplines and aspects of human dimensions. The problem is that the vocabulary for these frameworks is not wholly shared, and their definitions are usually interchangeable. Associating these terms with their level of integration will facilitate communication between educators. Hence, the purpose of this paper is to explore what definitions authors give to the terms "holistic," "integrative" and "integrated" when used as frameworks, and to analyze their level of integration when compared to Fink's taxonomy. The conclusion was that "holistic" tended to incorporate most aspects of Fink's taxonomy, "integrative" was more concerned with the integration of interdisciplinary knowledge, and "integrated" approaches were more focused on connecting the courses within engineering.*

Keywords: Learning Taxonomies, Fink's Taxonomy, Holistic, Integrative, Integrated, Frameworks.

1. INTRODUCTION

We, as a society, will have better chances to solve the challenges of the 21st century if universities change the way they prepare future professionals, especially engineers. This sense of urgency is one of the reasons why the Royal Academy of Engineering, in 2007, asserted in their report, *Educating Engineers for the 21st Century* [1], that engineering programs must equip students with innovative problem-solving abilities to allow them to work efficiently in the industry.

However, based on a study of engineering programs at some institutions in the U.S. [2], the current curricula are heavily weighted toward analysis at the expense of developing the design, experimentation, and professional skills. This goes against the idea of fostering innovative problem-solving skills and holds back engineers from successfully integrating systems, ideas and devices in order to create what has never been [3].

The point is that design and innovative thinking requires experience and knowledge from different disciplines and areas of life [4], and an education that is focused and narrowed to a single subject area is certainly not promoting them. Besides that, the way technology is present in our

lives requires students to be aware of the human-technology interactions, and how these new technologies impact our culture and society [5].

To improve the students' capacity to build connections between seemingly disparate fields, we need to teach them synthesis in balance with analysis, [3]. Some authors argue that the close attention and focus on going deeper and deeper in the same "discipline hole" has made us unable to see the interconnectedness among all the aspects of a problem [6]. It is essential that we equip students with different tools to make sure our future engineers will be able to dig different "disciplinary holes," that is, to deal with complexity and ambiguity [6] in their designs and problem solutions.

In order to overcome these challenges in engineering education, many instructors, departments and universities have used "holistic," "integrative" and "integrated" philosophies as the pillars to support their initiatives. While there are authors who understand these frameworks as promoters of a better connection between the sciences, mathematics and engineering disciplines within a curriculum [7, 8], others also consider crucial to these frameworks the incorporation of non-technical disciplines (e.g., humanities and arts) [6, 9], aspects of human dimensions (e.g., self-awareness and empathy) [10, 11], and lifelong learning skills [3]. Therefore, for this paper only, we will use the term "comprehensive" to refer to this broader and general concept that encompasses all these ideas.

1.1. The Problem

The problem is that the vocabulary for comprehensive initiatives within engineering education is not wholly shared, and their definitions for "holistic," "integrative" and "integrated" frameworks are usually interchangeable regardless of what is being integrated, that can vary from connecting two courses to including meditation in the classroom. The number of diverse definitions and lack of consistency act as a barrier that hinders the assessment and promotion of these frameworks throughout the literature.

Even if there were a common language for comprehensive initiatives, it would not mean that all efforts and practices under the same framework would be equal. There are factors that can influence the development of comprehensive initiatives, such as differences in mission, number of students, culture, autonomy and budget [12].

Here, the intention is to talk about the theory that supports these practices. That is, what authors understand by “holistic,” “integrative” and “integrated” frameworks and how these terms are used to justify and guide their efforts. It is crucial to emphasize that even though these terms might frequently be vague in terms of theorization [11, 13], it does not take any merit from the initiatives based on them.

The development of a common language to categorize and talk about comprehensive frameworks in engineering education is a critical step towards consolidating these initiatives. Having more precise definitions, and what each of these frameworks covers, will benefit the discussion and share of ideas between engineering educators, researchers, practitioners and even students. It will also facilitate advancements of effective efforts, and foster curriculum and pedagogy development [11].

1.2. Learning Taxonomies

Learning taxonomies are great ways to idealize educational outcomes, objectives and develop methods to evaluate students’ achievements [14]. One of the most successful and widely known is Bloom’s taxonomy [15]. However, its language is not in harmony with the comprehensive frameworks in engineering education [11]; there are not enough terms and structures to organize the educational goals and learning outcomes of comprehensive efforts. “Holistic,” “integrative” and “integrated” frameworks need a taxonomy that offers a complete vocabulary to help shape and organize them.

This is where L. Dee Fink [14] can significantly help. He shared similar concerns regarding the future of society and how we should educate our future professionals. Fink believed that higher education must be meaningful and train students beyond the technical and cognitive domains. Hence, he developed the Taxonomy of Significant Learning, which defends that full educational experience happens only when there are changes in six learning dimensions: “Foundation Knowledge,” “Application,” “Integration,” “Human Dimension,” “Caring” and “Learning How to Learn.”

This taxonomy is in resonance with most comprehensive engineering education initiatives. Most of the vocabulary and structure needed can be found in it, whether it is the broadest concept of holistic engineering education, where students should learn how to meditate and develop empathy [16], to more specific integrated engineering curriculum that connects its courses to improve their relevance [7], “Human Dimension” and “Integration” are present to provide the initial tools.

Hence, this paper draws from Fink’s taxonomy as a model of the full learning experience in order to better group comprehensive efforts in engineering education. The purpose of this work is to explore what definitions authors in the engineering education literature give to the terms

“holistic,” “integrative” and “integrated” when used to describe initiatives and to analyze their level of integration when compared to Fink’s taxonomy.

1.3. Methodology

To better study the usage of the terms “holistic,” “integrative” and “integrated” within the engineering education context, a preliminary review of the literature was conducted. The goal was to explore the explicit and implicit definitions of these terms when used as frameworks. This paper considered as explicit definitions those that authors stated clearly, while implicit definitions as those that could be understood by interpreting the motivations, objectives and desired outcomes.

The material was collected by combining the terms “holistic,” “integrative” and “integrated” with “approach,” “education,” “engineering,” “curriculum” and “pedagogy.” The results were narrowed down by searching only in journals and conferences proceeding that focus primarily in engineering education in North America, such as *Engineering Education*, *Engineering Studies*, *Journal of Engineering Education*, *IEEE Transactions on Education*, *Proceeding of the Canadian Engineering Education Association*, and *American Society for Engineering Education Conference Proceedings*.

For this work, it was used the summative content analysis [17], which involves comparisons and counting of keywords or specific terms, and then interpreting them in a given context. It was analyzed how the definitions of “holistic,” “integrative” and “integrated” frameworks related to the six learning dimensions of Fink’s Taxonomy [14]. Also, Fink’s concept of “Integration” was divided in three layers to better categorize each definition. The first layer is the promotion of the connection between courses of a single curriculum; the second layer relates to the integration of ideas, concepts, and courses *within* engineering, and the third layer incorporates ideas, concepts and courses from other disciplines *outside* engineering.

After that, the definitions were grouped according to the number of dimensions of Fink’s taxonomy and their level of integration. The final step was studying the patterns within each of the “holistic,” “integrative” and “integrated” frameworks.

1.4. Relevance to the Literature

Results showed that “holistic” frameworks tend to incorporate most elements of Fink’s taxonomy, especially “Human Dimension” and “Caring,” while “integrative” ones seemed more concerned with expanding the engineering boundaries and reaching out for knowledge in other disciplines, and “integrated” definitions were more focused on connecting the knowledge within engineering programs.

These results can help to promote "holistic," "integrative" and "integrated" efforts by clarifying their definitions, where it will improve communication and facilitate information gathering and dissemination between educators.

2. BACKGROUND

Historian of technology Bruce Seely argues that the necessity for change is "perhaps the most constant feature of American engineering education" [18]. The reports from engineering associations, including the Grinter Report [19], the National Academy of Engineering report *Engineer of 2020* [20] and more recently the NAE's report *Educating the Engineer of 2020* [21], further confirm his argument. These reports reflect the dissatisfaction from industry, government policy-makers, professional societies, and students with the state of engineering education.

Recent calls for the reform emphasize that engineers need to be prepared to address complex multidisciplinary problems in a rapidly-changing world. Some issues are related to the standard curricula and pedagogies, in which students learn in unconnected courses, making it hard for them to see the importance [22] and the relation between concepts and topics taught in classes [23].

The Sigma XI National Advisory Group [24] concluded in their research that this standard way in which educational institutions teach engineering impact the students in several ways. For example, students feel that instead of having classes where they feel motivated and see the importance of what they are learning, the classes are in fact impersonal, too focused on memorization, and without stimuli to engagement. As a consequence of the students' dissatisfaction with this way of education, universities in North America are dealing with low retention of students [23, 25]. Also, the impacts of this standard pedagogy are even more severe for women and other underrepresented minorities [26].

Besides universities having to deal with the loss of interest from students and lack of diversity, educational institutes of engineering must also carry out the visions for the 21st century [21]. This "21st-century engineer" will have to relate with complex and unprecedented challenges. Problems about resource depletion, environmental protection and climate change [27], along with the complexity of new technologies and their permeation in more areas of our lives and society [10, 27, 28], appeal for engineers that are capable of considering several layers of contexts into their designs and solutions.

We cannot ignore complexity anymore. The disciplinary boundaries predominant in much of engineering education programs go against the interdisciplinary and contextual characteristics of real-life problems [27]. Our reductionist way of educating fragments knowledge and teaches it as if it were separate

in nature, what does not correspond with the holistic essence of society, technology and real life [3, 10]. The "simple" way we have been dealing with problems has caused many consequences so far, and the aftermath of the unknowns and uncertainties of the real world, that were left aside in previous "solutions," are becoming more evident [6].

Therefore, engineering education must be holistic just as the challenges of this century [28]. It does not mean that educators must leave the technical knowledge aside, the strong disciplinary foundation is vital, and it did and will play a crucial role in society's development. However, the engineering discipline must not remain isolated, maintaining the belief that only technical knowledge is sufficient to deal with modern problems [29].

That is why we must train our engineering students to become well-rounded professionals, teaching them how to recognize and care about the social, economic, environmental and cultural aspects embedded in every scientific and technological activity [30], while they develop a professional and individual identity, and become lifelong learners. A partnership between the humanities, arts and engineering is one way to bring a deeper awareness of these aspects, as well as improve students' critical thinking, flexibility and adaptability [31].

However, even though most universities have credits in their curricula for these courses due to accreditation requirements, and teach topics that include social, ethics and environmental issues, students are not educated to care about them, and they find it difficult to comprehend their importance [9]. Just adding courses to the curriculum has not been enough; students must understand and care about how the concepts fit together, and how to apply them to the real world scenario [8].

According to researchers, most engineers just saw the importance of non-technical courses after they graduated [31]. They argued that they could not understand the relevance and purpose of these courses. It was hard for them, while in school and studying humanities, arts, engineering and science courses separately from each other, to appreciate how non-technical aspects are critically important in their decisions [32] and day-to-day at work. Furthermore, this disciplinary method of teaching has hindered students from comprehending how critical thinking and knowledge integration are crucial [33]. Building demand for this type of content and creating this kind of awareness requires time and a cultural change [9], it is not as simple as requiring students to pay attention to class, read books and answer pre-defined questions at the end of the semester.

This compartmentalization of knowledge is what some educators, departments and even entire universities are trying to avoid by incorporating "holistic," "integrative" and "integrated" frameworks in undergraduate engineering education. These comprehensive frameworks support the formation of "well rounded" graduates who are trained to

be the future leaders and creative thinkers [34], and able to appreciate “the big picture” [35]. These advocates intend to foster the understanding, not only theoretically but also practically, of how concepts taught in distinct courses and disciplines are intertwined [8].

By reducing the boundaries between concepts, courses and even disciplines, educators have documented significant results in students’ development. When courses leave their “silos” and are allowed to interact and borrow “ways of knowing” from other areas, students retain better the material [12] and assimilate engineering concepts and theories more [8]. Researchers have also argued that, depending on how comprehensive practices are developed, students can improve their communication, teamwork [29] and leadership skills [34].

Another important aspect is that, when engineering programs integrate sciences, arts and the humanities, they attract a wider variety of students [10], increasing the diversity in the classroom and, consequentially, in the workforce [3, 16]. Additionally, students’ interest and engagement improvement have led to an increase in the retention rates [3, 8], especially between women and underrepresented minorities [36].

The philosophy of blurring the boundaries between “areas of knowledge” is the core aspect of comprehensive frameworks. It is aligned with the holistic nature of the world, and also with the complexity and ambiguity present in the challenges of the 21st century. The research has shown that comprehensive initiatives have a positive impact on students and can be considered viable approaches to prepare the next generation of engineers.

3. FINK’S TAXONOMY OF LEARNING

Educational and learning taxonomies have the purpose of taking the whole process of student development and organizing it in smaller parts. This procedure facilitates the discussion of different types of learning outcomes and educational goals, as well as behaviours and characteristics that students should develop, and how to assess students’ achievements [37, 38].

One of the most widely-known frameworks is Bloom’s Taxonomy [15]. His original version included three domains, Cognitive, Affective and Psychomotor. However, as he divided students’ development into three areas, he started by giving more attention to the Cognitive domain and making it the core of his first book *Taxonomy of educational objectives: The classification of educational goals - Handbook I: Cognitive Domain* [15], from which most of his acknowledgment came. The Affective domain was better detailed in *Taxonomy of Educational Objectives, Handbook II: Affective Domain* [39] years later after the success of the first book. However, it did not receive the same repercussion as the Cognitive domain. The Psychomotor domain, on the other hand, never received further development from Bloom.

The Cognitive of Bloom’s taxonomy has been proven an effective method to categorize student learning [11, 37] and has been the primary reference for the development of educational outcomes in many institutions, including in ABET [38, 40]. Its linear categorization of learning processes goes from remembering pieces information and mastering content to developing high-level skill and creating novel things [11, 15].

Individuals and organizations, outside and inside engineering, are expressing their desire for a new kind of learning, one that goes beyond the cognitive domain and cannot be represented easily by the language Bloom’s taxonomy provides. This call for a new kind of learning, including in engineering education, requires that students develop their lifelong learning, interpersonal and leadership skills, tolerance, adaptability, ethics and character [14]. Also, they call for the development of the student as a whole person, what encompasses fostering their intellectual, emotional, physical, social, creative and even spiritual potentials [34].

While some comprehensive initiatives and experiences within engineering education can fit into Bloom’s vocabulary, more extensive and broader efforts cannot be fully explained by the terms afforded by this framework [11]. That is, Bloom’s taxonomy does not provide a language for integration that highlights its relevance. It is crucial to clarify that there is no debate about the importance and value of what Bloom’s taxonomy helped to accomplish [14], but it is time for a more appropriate taxonomy of significant learning that can help to structure these comprehensive initiatives.

Fink’s Taxonomy of Significant Learning is an excellent framework for those who want a vocabulary and classification to develop their comprehensive experiences. It is based on the premise that there must be some change in the student in order for learning to occur. If there is no lasting change, there is no learning [14].

One of the main differences between Bloom’s and Fink’s taxonomies is that, while the former is hierarchical, where one step must be completed before moving to a more advanced level [15], the latter is relational and even interactive [14, 38]. In Fink’s Taxonomy, the learning dimensions can happen concomitantly and, according to him, significant learning experience occurs when two or more of these dimensions are in play at the same time [14].

Fink’s taxonomy can be considered an expansion of the Cognitive domain of Bloom’s taxonomy. From its six dimensions, “Foundation Knowledge” and “Application” cover all Bloom’s hierarchical categories. The other four, “Human Dimension”, “Caring”, Learning How to Learn” and “Integration”, are essential in creating a significant learning experience [14], and all the six dimensions together provide the perfect framework that can contain many, if not almost all, comprehensive initiatives in engineering education.

The “Foundational Knowledge” brings forth the elementary understanding needed for the other types of learning. It is the base for students to comprehend and remember specific ideas and information. That can be basic knowledge about history, geography, science, literature and so forth, or understanding major concepts and ideas, such as evolution, capitalism or democracy [14].

“Application” brings usefulness to other kinds of learning. This usefulness can be expressed by the social, physical or intellectual engagement of students in order to apply what they learned. It can also be in different kinds of thinking, such as creative, critical and practical. Likewise, Application can result in the development of new skills related to the type of activity engaged. For example, students can develop communication and problem-solving skills when dealing with real case scenarios in the classroom [14].

“Integration” gives students a certain intellectual power that allows them to perceive and understand the connection between seemingly disparate things. The connection can be between ideas, people, concepts, and even areas of life (personal, work and school) [14]. It is the core of any comprehensive initiative, and the key to bringing “ways of knowing” from other disciplines into the engineering education system.

“Human Dimension” helps students learn and understand more about themselves or others. It allows them to discover the human significance of what they have learned. Students can have insights and a better understanding of who they are or what they want to become, as well as a better comprehension of others. The introduction of the “Human Dimension” can be through the material (curriculum) or through the method (pedagogy) they are learning [14].

“Caring” is as essential as any other learning dimension, if not more. It is of extreme importance because it creates in the student a sense of caring about something, which can be about a grade, a subject, a profession, or maybe their mission in life. This new step in their lives may be seen in the form of feelings, values or interests [14]. The point is that students who care will have the energy and motivation to engage and learn more, making them move forward into becoming a competent student, professional and individual.

“Learning How to Learn” enables and encourages students to become “eternal learners,” where they will have the willingness and tools to continue learning throughout their lives. This can be fostered by introducing elements of the learning process itself, such as how to be more time-efficient in the studies, how to be a self-directing learner or how to inquire about a topic. Learning How to Learn is fundamental in this new age, where almost any kind of information can be easily accessed, technologies and areas of knowledge are being created and modified constantly.

4. RESULTS

After analyzing the “holistic,” “integrative” and “integrated” definitions in the selected works, it was possible to see that all of them include “Knowledge Foundation” and “Application” principles. The inclusion of these dimensions was expected because they are the foundation of any educational model, regardless of being comprehensive or not. If a system does not provide new knowledge and does not give opportunities to apply them, whether with assignments, exercises or exams, the premises of this system might be questionable.

Moreover, this work is interested in how authors defined comprehensive frameworks and what they considered to be included in them. Therefore, it focused on whether or not “Human Dimensions,” “Caring” and “Learning How to Learn” were part of the definitions. However, as “Integration” is the core of any “holistic,” “integrative” and “integrated” framework, it was given more detailing by dividing it into three layers: In-curriculum, in-engineering and out-engineering.

The in-curriculum layer is where only courses and topics from a particular curriculum participate in the integration. The engineering curriculum at Texas A&M University is a great example. There, science and mathematics courses are tied together over the program through design projects and common themes in different courses [41].

In the second layer, in-engineering, knowledge from one or more engineering disciplines (e.g. civil, mechanical, electric and computer.) are incorporated by another. For example, the Integrated Engineering Program at the University of Western Ontario composes the curriculum with fundamentals from different engineering disciplines [4].

The layer of out-engineering is where educators consider it important to bring into engineering “ways of knowing” from disciplines such as arts, humanities and social sciences. The proposal of Kasenberg et al. [10] illustrates this layer. They defend the incorporation of personal, group and professional praxis – “practices that embody this proposed new culture [10]” – in engineering programs, such as contemplative practices, dialogues and mentoring.

4.1. Holistic

The holistic approach to engineering education is probably the best-established term among the three. The publication of the book *Holistic Engineering Education* in 2010 [42] by Grasso and Burkins brought more attention to its cause and provided a consistent foundation to build upon. The book defines Holistic Engineering Education as “a more cross-disciplinary, whole-systems approach to engineering that emphasizes contextualized problem formulation, the ability to lead team-centred projects, the skill to communicate across disciplines, and the desire for

life-long learning of the engineering craft in a rapidly changing world."

However, the usage of the term before, and even after, the publication of this book has varied. Some authors have used holistic in the engineering education context to refer to a much broader model that fosters learning within and beyond the classroom [13, 34], taking into consideration co and extra-curricular experiences. More importantly, this approach intends to develop the student as a whole person, addressing the physical, intellectual, emotional and spiritual dimensions of being [32, 34] and promoting specific character qualities, affective dispositions and habits of the mind [10, 16]. On the other side of the spectrum, authors have used the term holistic more narrowly, intending to support the idea of connecting the course components throughout the curriculum [7], and to present "cross-disciplinary" (in-engineering) problems over the program [35].

Table 1 below was constructed to visualize better what other dimensions of Fink's Taxonomy, besides "Knowledge Foundation" and "Application," are incorporated by definitions of "Holistic" in engineering education.

Table 1. Holistic and Fink's Taxonomy

Reference (Holistic)	Dimensions of Fink's Taxonomy		
	Human Dimension	Caring	Learning How to Learn
[7]			
[3]		X	X
[9]			
[10]	X	X	
[13]	X	X	X
[16]	X	X	
[31]			
[32]	X	X	
[43]			
[34]	X	X	X
[35]		X	
[44]			X
[42]		X	X

Table 1 shows that more than half of the studies has "Caring" included, while nearly one third has "Human Dimension" and "Learning How to Learn." It means that the main concern of most authors, within holistic approaches, is creating a sense of purpose and meaning in engineering education, giving students reasons to pursue their careers, and teaching them to care. The presence of "Human Dimension" shows that there is a preoccupation regarding the student as a whole person, not only as an academic learner. Lastly, mentions to "Learning How to Learn" by more than one-third of the authors suggest the intention of educators to provide students with tools to become lifelong learners.

For the second part of the analysis, Table 2 was developed to show in what layer of integration authors position their Holistic definitions.

Table 2. Layer of Holistic frameworks

Reference (Holistic)	Layer of Integration		
	In-Curriculum	In- Engineering	Out- Engineering
[7]		X	
[3]			X
[9]			X
[10]			X
[13]			X
[16]			X
[31]			X
[32]			X
[43]			X
[34]			X
[35]		X	
[44]			X
[42]			X

Through Table 2, it is possible to see that the majority of authors refers to holistic frameworks as a mean to reduce, or blur, the boundaries between disciplines. The exchange of "ways of knowing" among subject areas is the core of these definitions. They intend to give students resources to analyze and synthesize solutions using not only pure technical knowledge but creating awareness of other aspects, such as social, environmental, political and economic.

4.2. Integrative

The definitions of the term integrative in engineering education literature have also been used to describe a wide range of initiatives, many of which could easily be included in one of the aforementioned holistic definitions. For example, some authors use integrative engineering education as a means to recognize the student as a whole person and promote the development of the students' personal, social and academic dimensions [25]. They describe a model that combines the practical and theoretical aspects of engineering with cultural, social and self-awareness, helping them to connect what they are studying and who they are with the context of the engineering profession [27, 45].

Also, there are those who work towards and are primarily worried about the academic dimension of the student, considering integrative education only those efforts in which "ways of knowing" of one discipline is absorbed by another [11], and equipping students with tools to look at problems from different disciplinary perspectives and to accept ambiguity and complexity [6].

Lastly, integrative is also seen as a term that describes an educational model that reinforces the core skills of the engineering profession. It includes in the learning experience the motivational and time aspects of the engineering work [46], while linking them to the societal, political, economic and environmental issues inherent to engineers' decisions [47].

To clarify these definitions of Integrative frameworks, Table 3 illustrates Integrative definitions in engineering

education literature and their relationship with Fink's Taxonomy.

Table 3. Integrative and Fink's Taxonomy

Reference (Integrative)	Dimensions of Fink's Taxonomy		
	Human Dimension	Caring	Learning How to Learn
[6]			X
[11]			
[25]	X	X	
[27]	X	X	
[47]			
[45]	X		
[46]		X	
[48]			

As shown in Table 3, approaches to "Human Dimensions" in the integrative frameworks follow the same trend as in holistic, approximately one-third of the authors mention this aspect somehow. On the other hand, "Caring" and "Learning How to Learn" fall behind when compared to Holistic, where "Caring" was mentioned by one-third, and "Learning How to Learn" had a single appearance. However, it does not mean that the initiatives themselves did not develop these dimensions on the students; what is being examined here is the theoretical framework that supports those initiatives.

Table 4 presents the trends in the layer of integration considered by authors when using the term integrative.

Table 4. Layer of Integrative frameworks

Reference (Integrative)	Layer of Integration		
	In- Curriculum	In- Engineering	Out- Engineering
[6]			X
[11]			X
[25]			X
[27]			X
[47]			X
[45]			X
[46]		X	
[48]		X	

Similar to what was found when analyzing "Holistic" frameworks, Table 4 evidences that "integrative" initiatives had almost all authors referring to the inclusion of non-technical disciplines in engineering education. This shows how these two terms, integrative and holistic, might be interchangeable when it comes to talking about blurring the boundaries of engineering and welcoming other disciplines.

Therefore, it is safe to argue that, even though integrative and holistic share some similarities, integrative definitions are not as comprehensive as holistic when it comes to encompassing "Caring," "Human Dimension" and "Learning How to Learn."

4.3. Integrated

The definition for the integrated framework is, when compared to the other two, perhaps the most consistent,

even though there still are variances. On one side, there is the concept that sees in the integrated approach a solution to educate responsible citizens and professionals, conscious of the society and environment's necessities [22]. It aims to improve students' communication and interpersonal skills, and to increase their flexibility, teamwork and ethics.

On the other side, the most common idea of integrated engineering education is one that helps students to understand the general concepts, ideas [49] and problems [29] present in engineering as a whole. For that, they defend putting together fundamentals and theories of different engineering disciplines [4, 28] and, sometimes, other disciplines outside engineering [23] in order to create an understanding of ethical, societal and financial contexts in real work scenarios [29].

The integrated approach is also often seen as a method to promote the comprehension of how concepts and ideas introduced in different courses are interrelated [8], tying together science, math and engineering courses, and making each subject become an essential part of the whole [36].

Just as Table 1 and Table 3, Table 5 intends to provide an overview of how the dimensions of Fink's Taxonomy are approached in Integrated definitions.

Table 5. Integrated and Fink's Taxonomy

Reference (Integrated)	Dimensions of Fink's Taxonomy		
	Human Dimension	Caring	Learning How to Learn
[4]			
[8]			
[12]			
[22]		X	
[23]			
[28]			
[29]			
[36]			
[49]			
[41]			

In Table 5 we see that "Integrated" had a much more unanimous definition than "Holistic" and "Integrative." None of "Integrated" definitions mentioned anything about "Human Dimension" or even "Learning How to Learn." The integrated frameworks were not focused on these "non-academic" dimensions, they were solely interested in the student as a student, and nothing more.

Here, in Table 6, analyzing the "Integration" dimension, we can see in what layer authors position the term "Integrated."

Table 6. Layer of Integrated frameworks

Reference (Integrated)	Layer of Integration		
	In-Curriculum	In- Engineering	Out- Engineering
[4]		X	
[8]	X		
[12]	X		
[22]			X
[23]		X	
[28]		X	
[29]		X	
[36]	X		
[49]		X	
[41]	X		

The study of Table 6 demonstrates that “integrated” approaches seem more concerned with developing an educational model that allows students to understand the connectedness between courses and disciplines within engineering better. While almost half of the definitions focused on connecting the curriculum and the courses within it, the other half wanted to include concepts and knowledge from other engineering areas.

4.4. Overview

Table 7 shows a better comparison between all three comprehensive terms.

Table 7. Comparison between Integrated, Integrative and Holistic frameworks

Elements of Integration	Holistic	Integrative	Integrated
Human Dimension	38.5%	37.5%	0%
Caring	61.5%	37.5%	10%
Learning How to Learn	38.5%	12.5%	0%
In-Curriculum	0%	0%	40%
In-Engineering	15%	25%	50%
Out-Engineering	85%	75%	10%

Through the analysis of Table 7, we can conclude that “Holistic” definitions have the highest chance of encompassing more dimensions of Fink’s taxonomy, especially “Caring” and “Learning How to Learn.” They are also very likely to bring knowledge from other areas into engineering. Table 7 also shows that “Integrative” definitions brought some emphasis on non-academic dimensions, but not as much as “Holistic.” Most of “Integrative” focus is on equipping engineering students with non-technical capacities, incorporating knowledge from the humanities and arts, for example. “Integrated”, on its turn, presented definitions much more consistent and in resonance with one another, where no emphasis is given to “Human Dimensions” and “Learning How to Learn.” Conversely, their primary intention is to interweave courses and topics from one or more engineering

disciplines, in order to create more consistent curricula and “general” engineering programs.

5. CONCLUSION

In conclusion, comprehensive frameworks are relevant theoretical backgrounds to support initiatives that aim to create integration within engineering education, whether that is interweaving courses in a curriculum or promoting contemplative practices.

In order to facilitate the communication and discussion around the topic, it was analyzed how “holistic,” “integrative” and “integrated” terms are being used to describe comprehensive frameworks. It was observed that “integrated” is being mostly defined as the connection of courses and concepts within a curriculum or engineering disciplines. “Integrative” frameworks seem more concerned with incorporating “ways of knowing” from other disciplines. And “Holistic,” even though welcoming elements from other disciplines in engineering, posed much more emphasis when compared to the other terms, in non-academic matters, such as self-awareness, empathy, caring and lifelong learning.

For future research within the area of comprehensive engineering education,

it is recommended that authors use the terms, as described in this work, that better correspond to their initiatives. It is crucial that engineering education researchers adopt a common language to facilitate the communication within the field, and this work helped clarify the main differences between these three terms and how comprehensive initiatives are still in need of a strong theoretical background.

The next step of this project is to explore how authors are associating each of these terms with their practices. Also, as a further step, it will analyze initiatives in engineering education that would fit one of these three frameworks but are not named after any of them.

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