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Identifying Nanotechnology Professional Competencies for Engineering Students Using Q Methodology*

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This study aimed to introduce a new approach to identifying nanotechnology competence for college engineering students' career preparation based primarily on competence-based perspectives. While Q methodology is a powerful pattern analytic for expressing opinions of specific group and gives consideration to both qualitative and quantitative advantages, it was employed as a tool to explore and highlight the unique viewpoints and patterns of nanotechnology competencies expressed by stakeholders in the industry. Forty-seven competence statements were selected as contributing to the final Q set based on the university professors and post-doc fellows' evaluation and post interviews. Then twelve professional experts in the nanotechnology industry in Taiwan were recruited to be the Q participants. Based on the results of Q sorting and discourse analysis, two factors of the subjective viewpoint toward the expected general nanotechnology competencies of university graduates were presented, namely, personal-attributes oriented and professional-skills oriented. Although the emphases were placed on dissimilar statements by different factors, it was clear that innovation, activeness and ambition, applied chemistry, and nano-optoelectronics together constructed the core nanotechnology competencies. The results provide practical and theoretical implications for engineering education in students' training and professional development.

Keywords: discourse analysis; electro-optics; nanotechnology; professional competencies; professional development; PQMethod; Q methodology

1. Introduction

The preparation and development of a nanotechnology workforce represents a major challenge to progress in new technology in the coming decades, for much of the recent research of all varieties is directly related to nanoscience. To prepare skilled and qualified workforces, universities around the world have been establishing undergraduate and graduate nanotechnology programs since 2000. While nanotechnology is experiencing considerable growth due to its significant impact on society, the demand for nanotechnology experts may far exceed the number of students pursuing academic paths leading to careers in nanotechnology [1]. For satisfying the requirements of well-trained workforce, it is important to determine if the programs or courses put in place have an effect on students' intentions to pursue the study of nanotechnology. Therefore, researchers [2] developed a nanotechnology awareness instrument to measure the constructs of nanotechnology awareness, exposure, and motivation of university students.

Meanwhile, in addition to examining what essential skills are required for new graduates upon entering nanotechnology industries, many studies have focused on addressing the instructional design concerns related to the development of effective nanotechnology courses [3–6]. However, most studies have merely explored how to teach competence, while little attention has been focused on the competencies that the instructors and employers want students to possess [7, 8]. There is a clear need to define what exact competencies are needed by the nanotechnology workforce from a practical perspective.

One of the major focuses of the nanotechnology plan was to prepare as many qualified nanotechnology scientists and engineers as possible. For this purpose, interdisciplinary nanotechnology programs featuring collaboration by departments at major universities have been established to re-educate researchers who were trained in traditional disciplines [9]. Experience in developing nanomaterials reveals the necessity of strengthening the collaboration between research units and industrialization expertise in order to stimulate the transfer of laboratory techniques to production [10]. As

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mentioned above, the importance of nanotechnology development is reflected in the sufficient financial resources allocated to nanotechnology R&D and the preparation of a qualified nanotechnology workforce. Roco's research [1] predicted that the job market and related careers in nanotechnology would reach approximately 5 million by 2015 globally, which means the demand for a practical and competent workforce is becoming urgent.

To bridge the gap between what the employers expect and what the graduates possess, institutes of higher professional education and several universities in Australia, New Zealand, Europe, and other places have adopted the concept of competence to guide the development of educational programs [8]. Competence-based training means training geared to the attainment and demonstration of skills to meet industry specified standards [11]. Australia introduced competence-based training in 1992 to provide vocational education and training. The results of case studies of enterprises have shown that competence-based training is not a singular, universal model of vocational education and training. Rather, such training is performed in particular and specific situations (e.g. in particular industry sectors or enterprises), and when re-situated, it also needs to be re-constituted or transformed [12].

Since nanotechnology research is still developing and the field is not as mature as others, the professional education and training provided by universities seems somehow insufficient [13]. While instructors in the nanotechnology field pay more attention to the development of observable skills and the knowledge dimension, and provide students with more theoretical knowledge than operational skills, there exists a gap between what is taught in schools and what is needed by industry. To bridge the gap between what academia and industry expect in terms of nanotechnology workforce requirements, this study aimed to define the professional competencies of the nanotechnology workforce by adopting Q methodology to explore the competencies of nanotechnology careers from the standpoint of professional experts. It is expected that results of this empirical research should serve as a valuable resource and reference for planning future curricula or programs in nanotechnology and developing a nanotechnology workforce.

2. Methodology

2.1 Q methodology

Q methodology is a population of different tests (or essays, pictures, traits or other measurable materials), each of which is measured or scaled by individuals. It is a behavioral research technique that is fundamentally qualitative, although it may more accurately be described as qualiquantological, as it is a qualitative methodology with strong quantitative features [14].

Q methodology is a powerful pattern analytic for expressing the ensemble of discursively organized positions or voices around an issue [15]. It is a gestalt procedure, which means that it can never break up its subject matter into a series of constituent themes. What it can do is to show the particular combinations or configurations of themes that are preferred by the participant group. All these overall configurations (not test results or measures) are then intercorrelated, and factors are analyzed with a Q study [16]. The meaning and significance of these configurations must then be attributed through a posteriori interpretation, rather than through a priori postulation [17].

Q methodology generally can be explained with five stages [18]. The first stage is selecting a Q set, which is the collection of heterogeneous statements that the participants will sort. It must broadly represent the opinion domain of the issues. The selection of statements can be either unstructured or structured. In the former case, the chosen statements are presumed to be relevant to the study, but the emphasis is on representation. In the latter case, sample statements are chosen to represent points in a theoretical matrix [18]. Statements for the Q set can be gathered from various sources.

The second stage is selecting Q participants. Q methodology adopts a multiple-participant format and is most often deployed in order to explore highly complex and socially contested concepts and subject matters from the point of view of the group of participants involved [19]. The aim in selecting participants in Q methodology is to achieve representativeness of a cross-section of the stakeholders [18, 20]. The participants do not need to be evenly distributed across different backgrounds or interest groups, but all backgrounds and interest groups must be represented [21].

The third stage is Q sorting. The research target of Q methodology is the configuration from participants' completed Q sorts [22]. Fundamentally, Q sorting calls for a person to rank-order a set of statements or measurable stimuli according to an explicit rule (the condition of instruction). Each statement is numbered and written on a separate card, and participants assign each statement a ranking position in a fixed quasi-normal distribution, usually from disagree (-5) to agree (+5), which helps the participant in thinking about the task. After completing the Q sorting, a postsorting interview is generally conducted. The open-ended questions in the interview collect responses that inform the interpretation of the sorting configuration [23].

The fourth step is Q analysis. The factor analysis is carried out on a by-person rather than a by-item basis. In Q analysis, each Q sort is correlated with other Q sorts (but not the relationship of each item with every other item) to identify a small number of factors that can represent shared opinions among participants [23]. The Q sorts of all participants that load significantly on a given factor are merged together to yield a single Q sort, which serves as an interpretable best estimate of the pattern or item configuration which characterizes that factor.

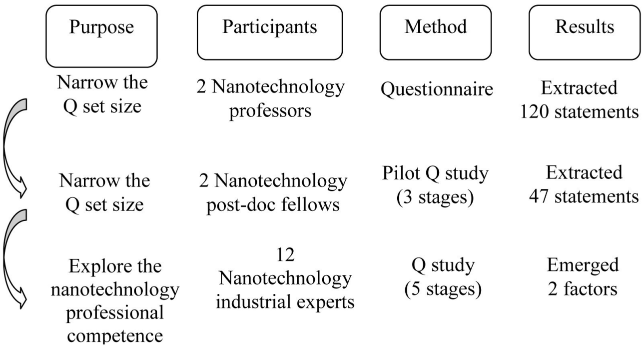
The final stage is performing Q interpretation, also called factor interpretation. Factor interpretation is based on an examination of the ranking assigned to each statement together with participants' comments from the postsorting interview, which are integrated in narrative accounts of each factor [23]. While the Q methodology can bridge and maintain the advantages of both qualitative and quantitative research, and the statements collected from Q participants can represent opinions of a specific group, it is an innovative approach to be used in the investigation of core competencies in a specific profession (i.e., nanotechnology) like the current study.

2.2 Research procedure

The research procedure of this study is illustrated in Fig. 1. In order to obtain the most core and representative competence descriptions for the Q set, this study adopted the research results conducted by [13], in which 410 nanotechnology competencies were discovered from thorough analysis of curriculum mapping of nanotechnology programs in Taiwan. The courses provided by these nanotechnology programs were viewed as the required or selective competencies that graduates needed in the future nano-industry. To collect responses from and the opinions of nanotechnology-related professional personnel concerning these competencies in order to narrow the size, a questionnaire on a 5-point (1 = not important at all, 5 = very important) Likert-like scale was distributed to two experts who are university engineering professors teaching nanotechnology courses at a comprehensive university in Taiwan. The questionnaire was composed of 410 items for evaluating how essential the instructor thought those competencies would be to practical nanotechnology-related work tasks. In addition, interviews were conducted to collect feedback from the instructors on these competencies and the future application and development of nanotechnology.

A total of 120 of the 410 competencies were rated relatively high, and these 120 were selected as the Q set for the pilot Q study. The extracted statements were then evaluated by two post-doc research fellows affiliated with a nationally-funded center for nano-electro-mechanical-systems as multi-raters to confirm the appropriateness of the statements. The response matrix ranged from not important at all (-5) to very important (+5), and the 120 statements were given to the Q participants separately. Then the Q participants were informed of the purpose of the pilot Q study, which was to examine their subjective opinions on the general competencies that graduates should possess when dealing with nanotechnology-related jobs, and the detailed Q sorting procedures were explained. After the Q sorting, postsorting interviews were conducted. Each participant was asked to comment on the statements, the sorting procedure, the relevance of each statement, and the statements that were not clear, and each was asked to provide suggestions to the Q study.

After completing two pilot Q studies, the Q sorting results and interviews were integrated as a foundation for further clarification of the competencies. In the beginning, all the statements that were rated equal to and above 0 by both Q participants were selected. Sixty-six statements met that requirement, and the others were deleted due to unclear phrasing or insignificance. After consideration of the completeness, explicitness, and representativeness suggested by the participants, some similar statements were integrated into a more



Purpose	Participants	Method	Results
Narrow the Q set size	2 Nanotechnology professors	Questionnaire	Extracted 120 statements
Narrow the Q set size	2 Nanotechnology post-doc fellows	Pilot Q study (3 stages)	Extracted 47 statements
Explore the nanotechnology professional competence	12 Nanotechnology industrial experts	Q study (5 stages)	Emerged 2 factors

Fig. 1. Research procedure of this study.

Table 1. Q Statements of This Study

No.	Statement	No.	Statement	No.	Statement
1	Classical physics	17	Nanostructures	33	Nanophotonics
2	Modern physics	18	Solid structures	34	Liquid crystal displays
3	Basic chemistry	19	Electronic structures	35	Bionanotechnology
4	Applied chemistry	20	Nanobiology structures	36	Nanofood technology
5	Circuit Theory	21	Engineering mathematics	37	Solar cells
6	Nanoscience	22	Nanometrology	38	Environmental nano technology
7	Nanotechnology	23	Calculus	39	Biochips
8	Nanomaterials	24	Microelectromechanical systems	40	Lab-on-a-chip
9	Nanodevices	25	Nanoelectromechanical systems	41	Microsystem chips
10	Plasma engineering	26	Nanoelectronics systems	42	Innovation
11	Electronic equipment	27	Integrated circuit fabrication	43	Independent thinking ability
12	Electronic manufacturing	28	Integrated circuit design	44	Flexibility
13	Electronic packaging	29	Nanotransport	45	Understand market trends
14	Optical packaging	30	Vacuum technology	46	Problem solving abilities
15	Nano-optoelectronics	31	Clean room technology	47	Activeness and ambition
16	Nano-scale	32	Measurement techniques		

comprehensive representation. Finally, forty-seven statements (Table 1) were selected for the final Q set.

Three researchers with backgrounds in engineering education helped to execute the Q study. Twelve professional experts who are managers and practitioners (2 female and 10 male) in the nanotechnology industry (mostly from electro-optics related departments) in Taiwan were recruited as the Q participants. All of the participants were selected by the researcher for the representativeness and views they might express on the basis of their unique positions.

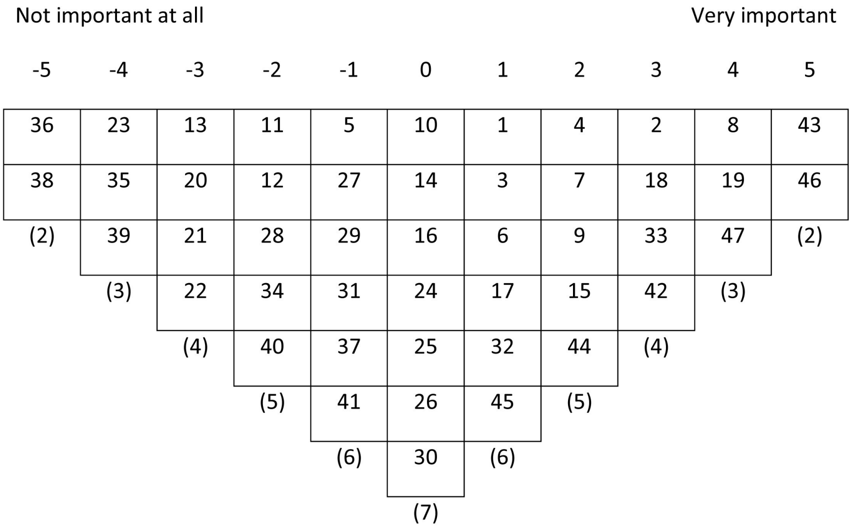
A response matrix from not important at all (–5) to very important (+5) was provided to demonstrate the distribution and number of items that could be assigned to a ranking position. The task of the Q participants was to sort all statements according to their relative importance when engaging in nanotechnology careers. Postsorting interviews were conducted to encourage the Q participants to express their subjective opinions about key issues. The interviews included questions on whether any statements were vague or unclear, what points they considered while doing the sorting, whether the nanotechnology industry existed, whether it was necessary to have specific nanotechnology competence descriptions, and from their practical perspective, what competencies students needed to develop before entering the nanotechnology industry. Finally, the Q sorting results of the twelve participants were analyzed by the PQMethod, and the discourse analysis of the interviews showed similarities and differences among the different categories.

3. Results

3.1 Factor analysis and interpretation

The data from the twelve participants were statistically analyzed with the PQMethod. The PQMethod is a factor analysis program that quantifies subjectivity and reveals patterns of perceptions in any situation. Previous research [17] recommended that researchers run from a seven-factor to a two-factor solution before accepting a final solution. First, centroid factor analysis was performed, since it is a simple and economic solution that can produce smaller numbers of factors [24]. Then those factors were rotated using varimax rotation, which can result in higher levels of explained variance and a simple structure that maximizes the similarities within factors and the differences between them [14]. [25] proposed that a factor with a loading of $\pm 2.58/\sqrt{n}$ (n = number of Q statements) will be considered significant and indicative of a meaningful relationship between the Q participant and the factor type. In this current study, $2.58/\sqrt{47} = 0.376$ was viewed as the judgment criteria. Those rated factor loadings greater by 0.376 or lower by –0.376 were categorized into the corresponding factor. After the varimax rotation, two factors emerged from the analysis. These two factors explained 51% of the variance and accounted for eleven of the twelve participants.

Previous research [26] has recommended that researchers interpret the results of factors in three ways: (a) point out and illustrate the consensus statement among all factors; (b) provide mixed explanations for the extreme statements, such as statements to be assigned to ±5, ±4, and ±3; and (c) compare one factor with the others to display the key differences. According to the results of the PQMethod analysis, no statement was selected as the significant consensus statement. However, innovation (42; +3, +3) (the first number in the bracket represents the item number, and the following two numbers represent the scores of two factors), understanding market trends (45; +1, +1), applied chemistry (4; +2, +2), activeness and ambition (47; +4, +4), and nano-optoelectronics (15; +2,



Not important at all | Very important

-5	-4	-3	-2	-1	0	1	2	3	4	5
36	23	13	11	5	10	1	4	2	8	43
38	35	20	12	27	14	3	7	18	19	46
(2)	39	21	28	29	16	6	9	33	47	(2)
	(3)	22	34	31	24	17	15	42	(3)	
		(4)	40	37	25	32	44	(4)		
			(5)	41	26	45	(5)			
				(6)	30	(6)				
					(7)					

Fig. 2. Factor array of factor A.

+2) showed the same positive scores. Participants generally expressed their opinions that a proper attitude was crucial in one's career [27], even though soft skills are not easy to teach in formal education [28].

> *"In industry, we put more emphasis on the attitude and thinking of new employees."* (s6)
>
> *"Understanding market trends is important. You can attend conferences or search for and analyze the products of other companies. Because the goal of the company is to make money."* (s11)

On the contrary, bionanotechnology (35; –4, –4), liquid crystal displays (34; –2, –1), biochips (39; –4, –3), nanofood technology (36; –5, –5), and nanobiology structures (20; –3, –2) displayed the same negative scores. The Q participants tended to sort the statements according to their learning and work experience, as reflected in the importance given to optoelectronics and chemistry, and the de-emphasis on biology-related competencies.

> *"No doubt, I will put the statements with the term of optoelectronics in the right (important) side."* (s1)
>
> *"(The knowledge of) food and biochips will not be used in the industry I am involved in. Maybe we will use them in daily life, but they are not important in my career."* (s8)
>
> *"(The sorting procedure) depends on what the basic science (knowledge) I really use right now, and I will search for what kind of knowledge is required when encountering the problems. The starting point is on how to solve problems. For a long time, science has developed its solid foundation, which makes it truly difficult to achieve a breakthrough. Nothing new will come out unless fundamental changes are made in basic scientific theories."* (s11)

3.2 Factor A: Personal attributes oriented

Factor A explained 38% of the study variance and had an eigenvalue of 4.59. Six participants loaded significantly on this factor. One of them was a female and five were males. Three participants were in management positions and three were not. In terms of the degree of familiarization with nanotechnology knowledge, half of them tended to "average" knowledge of nanotechnology and the other half expressed familiarity with it.

The factor array of factor A is shown in Fig. 2. This factor was termed Personal-Attributes Oriented, since the Q participants categorized into this factor focused more on the competencies related to personal features, such as independent thinking ability (43, +5), problem solving abilities (46, +5), activeness and ambition (47, +4), and innovation (42, +3), followed by basic knowledge such as electronic structures (19, +4), modern physics (2, +3), and solid structures (18, +3). Moreover, nanotechnology-related competencies, such as nanomaterials (8, +4) and nanophotonics (33, +3), were also emphasized.

From the results of Q sorting and postsorting interviews, the Q participants in factor A had a greater tendency to view personal attributes as the basic and required competencies, regardless of the industry and position. In contrast, the participants in factor B gave greater values to independent thinking ability (43; +5, +3) and innovation (42; +3, +3), which indicated that those two attributes were the driving forces in personal and professional development. Also, the score on problem solving abilities (46; +5, +4) implied that instruction should focus not only on the transmission of knowledge but also on the ability to transform internalized knowledge into a flexible and applicable ability. Generally speaking, the development of industry and the required workforce competencies changed rapidly, so graduates were expected to possess the appro-

Not important at all Very important

-5	-4	-3	-2	-1	0	1	2	3	4	5
22	29	16	6	9	1	10	2	5	3	14
36	35	17	7	24	8	11	4	30	46	32
(2)	41	38	20	26	18	21	12	42	47	(2)
	(3)	39	25	33	19	23	13	43	(3)	
		(4)	37	34	27	31	15	(4)		
			(5)	40	28	45	(5)			
				(6)	44	(6)				
					(7)					

Fig. 3. Factor array of factor B.

priate attitude to cope with various job challenges [29].

> *"Innovation and independent thinking are the most important. When you have learned those technologies, you can innovate and think by yourself. Make a new start. Those two features are the driving forces."* (s9)

> *"Engineering students can do many various jobs that are not restricted to engineering-related jobs. However, the competencies which all the jobs need are innovation, independent thinking ability, and autonomy. I think these competencies are more important for jobs, rather than what you actually have learned."* (s10)

> *"The students need to be equipped with problem solving abilities. It is better to know how to solve problems than to teach and give you something. The (knowledge in) books is dead; it is more important to know how to find problems and directions."* (s11)

In basic science and nanotechnology fields, the core concepts of fundamental knowledge underpinned the domain. The focal point was not on how well employees could utilize those abilities in various fields, but on the degree of familiarity with core concepts of basic subjects. This explanation also implied that a shortage of crucial competencies would strongly influence the regular execution of work.

> *"Basic skills, similar to most knowledge are repeating, are the foundation of learning and are to be utilized on job in the future. Primary subjects and theories were of high priority when I sorted. If I can learn those subjects well, I can comprehend other applications and subjects faster."* (s6)

> *"I decided the degree of importance based on the basic concepts. Basic science is the standard. Most of the academic statements were assigned as more important, followed by applied fields. That's my sorting process for nanotechnologies."* (s9)

> *"I put physics and chemistry as the most important subjects, because I think if you understand these, you can learn or infer newer theories based on them. In addition to the importance of independent thinking ability and attitude, basic knowledge is more important than newer knowledge."* (s10)

3.3 Factor B: Professional skills oriented

Factor B explained 13% of the study variance and had an eigenvalue of 1.54. Five participants, all male, loaded significantly on this factor. Three of the participants were in management positions and four of them had "average" familiarity with nanotechnology.

Figure 3 shows the configuration of factor B. This factor was termed Professional-Skills Oriented because the Q participants categorized into this factor tended to focus on the competencies related to professional operation skills, such as optical packaging (14, +5), measurement techniques (32, +5), and vacuum technology (30, +3). This different focus the main difference between factors A and B. The statements about personal attributes, including problem solving abilities (46, +4), activeness and ambition (47, +4), innovation (42, +3), and independent thinking ability (43, +3), were also stressed, as in factor A.

In the opinions of the Q participants, the essential ability of nanotechnology graduates was to understand how to measure on the nano-meter scale, as evident from the importance given to measurement techniques (32; +1, +5). The results revealed that graduates should be proficient in fundamental skills that are replicable and can be applied across disciplines. In addition, optical packaging (14; 0, +5), vacuum technology (30; 0, +3), and circuit theory (5; –1, +3) were given higher scores because they were currently being used by the participants.

> *"I put the statements in the important side according to what I have learnt or the skills our company needs, such as vacuum techniques and circuit knowledge."* (s3)

As seen in the previous analysis, problem solving abilities (46; +5, +4) were important to participants under both factor A and B. In addition, activeness and ambition (47; +4, +4), innovation (42; +3, +3), and independent thinking ability (43; +5, +3) were widely viewed as important by the participants. As [30] contended, it is critical that college students should have higher involvement to be able to develop the important generic skills of analytical thinking and problem-solving. Besides, the results revealed once again that personal attributes were crucial competencies that employees needed to possess.

> *"Problem solving abilities are the most important competence in industry. If the question were about the academic environment, the answer would be different. I had a job in the Industrial Technology Research Institute of Taiwan before; (at that time) maybe I would have put innovation on the right (most important). Depending on the circumstances, there exist differences."* (s1)
>
> *"No matter the industry, problem solving abilities and activeness and ambition are helpful to jobs. Others are the technical skills that can be learned. Skills can be trained, while personal attributes cannot. It is hard to change personal attributes."* (s4)

4. Discussions

The purpose of this study was to identify the core competencies in nanotechnology that university graduates should have. Although professional knowledge and skills are important for students to learn, a person with the proper personal attributes is considered more crucial in the workplace. The identified personal attributes are soft skills that can be applied across disciplines. These soft skills were further categorized into four types in this study. The first type is abilities that can bring into full play the professional knowledge and skills employees have learnt, such as the decision-making ability and interdisciplinary research ability. The second type is abilities that can be exercised by employees to foster work efficiency and can be learned easily in an educational context or the workplace, such as communication skills and negotiation abilities. The third type is attitudes that employees have inherently, such as enthusiasm and flexibility. The fourth type is abilities that affect the long-term career development of employees, such as emotional intelligence and pressure management.

The results of this study also showed that the soft skills related to type one (i.e., independent thinking ability, problem solving abilities, and innovation) and type three (i.e., activeness and ambition) are essential nanotechnology workforce competencies. However, graduates who have only proper soft skills cannot meet the requirements of the nanotechnology workplace. Consequently, those who can integrate both hard skills (professional knowledge/skills) and soft skills well are considered competent for nanotechnology practice. This result is consistent with the viewpoint of [31] that engineering curricula should place more emphasis on the humanistic aspects, and it is consistent with the findings of [32] that competencies within the flexibility and creativity cluster are the most significant abilities in engineering. Even so, few competencies related to soft skills are mentioned in the course syllabi of nanotechnology programs in Taiwan [13]. This significant difference in the importance given to the personal attributes reveals that what professionals expect is inconsistent with what university courses provide. It also reflects the industrial opinion that the preparatory education provided by universities is disconnected from the requirements of the industry workforce [33]. Although personal attributes are, by nature, not easy to alter, they can be changed and influenced unobtrusively and imperceptibly through proper instructional design and strategies.

To teach students both soft skills and professional knowledge, different instructional strategies can be adopted to supplement the traditional engineering education. For example, project-based learning is a widely used approach that allows students to apply learnt knowledge and acquire new hard/soft capabilities through designing, planning, and producing a product on their own [34]. Final-year projects required for the completion of a college degree have also proven to be efficient in developing the competencies of engineering students. Such projects are considered beneficial to enhancing problem solving abilities, providing realistic engineering exercise opportunities, and developing students' personal qualities [35]. And as [28] further suggested, in addition to offer specific courses to improve skills attainment, it would be better to embed soft skills in any academic curricula as the foundations of learning that should help prepare students for future employment or professional career development.

5. Conclusion

This study employed Q methodology as an innovative tool to explore and highlight the unique viewpoints and patterns of nanotechnology professional competences expressed by stakeholders in the industry. Two factors of the subjective viewpoint toward the expected general nanotechnology competences of university graduates were presented, namely, personal-attributes oriented and professional-skills oriented. It was found that innovation, activeness and aggressiveness, applied chemistry, and nano-optoelectronics together constructed the core nanotechnology competences. Moreover, four types of soft skills were identified, including abilities for develop professional knowledge and skills (decision-making ability and interdisciplinary research ability); work efficiency (communication skills and negotiation abilities); attitudes (enthusiasm and flexibility); long-term career development (emotional intelligence and pressure management).

No matter the industry or field, the focus of competence research is on the discovery of practical hard/soft ability requirements for employees. Q methodology has proven to be a beneficial approach to constructing and extracting focal concerns pertaining to the nanotechnology competencies of the experts in this study. Generally, the definition of competence consists of four elements: knowledge, skill, attitude, and other attributes. The Q statements utilized in this study also include those four aspects. Even though the mixed usage of Q statements helps researchers to understand the relative importance of varied competencies, it is somehow confusing for participants to make decisions at different levels of sorting. Given that one's attitude or other attributes are also important aspects of competencies, this study suggests that the participants be allowed to conduct Q sorting in two rounds so that the statements on knowledge and skill can be separated from those on personal characteristics.

As this innovative approach seems new for most of the engineering educators and professionals, the current research has presented useful information associated with the competence needs of Taiwan nanotechnology industry. Although the inputs from university engineering faculty teaching nanotechnology were also included for analysis at the beginning, final Q study stages were merely based on standpoints or industrial experts to reflect the realities of professional practice. This may be subject to bias, thereby resulting in the identified competencies limited to one of the facets of professional perspectives in the present study. The research has also explored core competencies using Q methodology that highlights the need to include as many sources as possible for ensuring thoroughness of Q statements and achieving data triangulation. In this study, the Q statements were extracted from the course syllabi of all nanotechnology-related programs of the colleges and universities in Taiwan. Although it was a thorough research, however, it is worth noting that future researchers should be aware of the possible limitations of use of research results.

In comparison with the questionnaire-type survey, Q methodology gives consideration to both qualitative and quantitative advantages. The viewpoints expressed by Q participants represent the subjective opinions of a specific group, while Q statements enlist all the diverse points at issue as thoroughly as possible. With this practice, the results of analysis may be essentially different from those produced by examining the opinions of the general public or investigating a large number of opinions possessed by a particular group. However, a follow-up questionnaire survey of a larger sample of nanotechnology professionals is advisable if we are to better understand and contrast the same and dissimilar competence requirements of that workforce, and in turn, to build up reference materials contributing to the establishment of a nanotechnology competence map or career development path.

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