This document is a pre-print that is currently being submitted as (1) a scoping review, which refines the “methods” section, and (2) a discourse analysis which refines the remainder of the paper.

Developing a Career Skills Framework for the Science University Curriculum Using Network Analysis

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Keywords: skills framework, career skills, employability skills, curriculum mapping, network analysis, Gephi

Abstract

To be successful in their careers, science students need to manage not only their disciplinary learning, but also skills that are referred to as career, employability, transferable, generic or soft skills. The growing literature on the subject has resulted in several frameworks and lists of relevant skills. However, existing frameworks present unique terminologies and structures and do not comprise a coherent map of career skills that could be seamlessly integrated into the university curriculum. Educators are therefore faced with a continuing deficit of key skills that could enable students to develop more productive careers.
In this pre-print, we present the initial findings from our project to design of a Science Career Skills Framework. We begin with a preliminary review of literature and a harmonisation of extracted skills. We then apply network analysis to define the structure of a new Career Skills Framework. Finally, we present a draft version of the new framework.
This pre-print is currently being submitted for publication as a (1) scoping review and (2) a discourse analysis paper.

Introduction

Among the key strengths of science university graduates that are valued by employers are their disciplinary knowledge and the skills relevant to core scientific knowledge, such as mathematical and statistical methods, data analysis and a methodical approach to problem solving (Hume et al., 2024; Rayner & Papakonstantinou, 2015). However, employers also seek high competency in generic skills relevant to career development (Lamri & Lubart, 2023; Sarkar et al., 2016). Currently, employers report that graduates have notable gaps particularly in career skills such as commercial awareness and self-efficacy (Sarkar, Overton, Thompson, & Rayner, 2020).

To improve and demonstrate the attainment, and performance of career-relevant skills, such skills need to be explicitly integrated within the curriculum and assessment regime (Succi &

Canovi, 2020; Nester, 2022; Gouda-Vossos & Sarkar, 2023). However, as Sarkar et al. (2016, 2020) have pointed out, they are seldom explicitly taught and assessed. When career-relevant skills are taught, they are usually presented within the context of specific disciplinary settings and neither academics nor students may be explicitly aware that they are teaching, assessing and performing a range of career-relevant skills (McArthur, et al. 2017). As a result, graduates are often unaware of their lack of career-skills mastery until they enter employment, and when queried, tend to rate their abilities more highly than their employers do (Tsirkas et al., 2020). Moreover, graduates also tend to perceive such skills as less important than discipline-specific skills are to define their career identities (Nester, 2022; Succi & Canovi, 2020). This lack of awareness of obtained and unobtained career skills, combined with a traditionally narrow framing of career options, poses a barrier to recognising professional opportunities and to succeeding and progressing in the workplace.

A major challenge in making the teaching and assessment of career skills explicit is posed by the absence of a coherent framework and taxonomy that could be meaningfully integrated into the Science university curriculum. The proliferating literature on career-relevant skills includes skill taxonomies (e.g. Brüning & Mangeol, 2020; Fotiadou, 2022; Kamaroellah et al., 2021; McGunagle & Zizka, 2020; WEF, 2023a; Jobs and Skills Australia, 2023), continuously updated lists of future or top desirable skills sought by employers (e.g. WEF, 2023b; Indeed, 2023), as well as deficit-based lists of skills not explicitly taught in the curriculum (e.g. Sarkar et al., 2016). Although most sources share some identified skills, e.g. communication or teamwork skills, the naming and grouping of the vast array of skills learned and applied in professional contexts, are incomplete and idiosyncratic. Moreover, some of the best-resourced skills frameworks (e.g. WEF, 2023a; Brüning & Mangeol, 2020) present skills and skill groups relevant to all careers, including trades and vocational careers out a scope for university teaching in science. It is therefore not surprising that academic staff in science struggle to connect them to the core principles of science teaching and to integrate them meaningfully into their curricula (Collins, 2010; Scott & Willison, 2021).

This pre-print provides a preliminary report on our project to design and validate a Science Career Skills Framework based on a synthesis of current literature. The first part of this paper is currently being submitted as a scoping review. The refined second part of this paper is currently being submitted as a discourse analysis.

In this pre-print we have chosen the term “career skills,” following the language used by Heather Nester, Dennis Ray, Bonnie Dean and others (Dean et al., 2022; Nester, 2022; Ray et al., 2017). Our intention is to capture the more lifelong-learning and future-oriented connotation of the term “career” in contrast to the more utilitarian term “employability.” With students in mind, we also avoided the terms “generic” and “transferable” as too vague and potentially distracting from the significance of career-relevant skills.

The Science Career Skills Framework draws on a scoping review of literature and also considers the specific needs of the science university curriculum. It does this in three ways. First, it comprises easily comprehensible skill groups that lower the cognitive load of engaging with the framework. Following the Adaptive Character of Thought-Rational learning theory (ACT-R), we limited the skill groups to nine in order not to exceed the capacity of short-term memory when teaching staff maps the skills and when students encode and remember them (Belland, 2017, pp. 32-39). Second, consistent with the principles of Universal Design for Learning (UDL, 2024), we aimed to make the skill names easily relatable to students’ existing experience (engagement), connect them to activities and assessments performed in the curriculum (representation) and order skills within groups in such a way that they follow meaningful storylines or narrative arcs that correspond to authentic performances of their learning in their careers (action and expression). This would enable the skills framework not only to be yet another spreadsheet to be filled out by academics, but a tool that could enrich teaching and learning. Third, the design is informed by an approach to skills and skill groups as interconnected, dynamically evolving relationships. Using the network analysis software Gephi, we formulated the skill groups to be broad enough to encompass future developments. Similarly, individual skills within groups can be amended to suit emerging needs and maintain relevance to both students and educators.

Method

Our approach to designing the framework followed three steps:

- scoping review to create a body of skills and skill groups
- harmonisation and network analysis of skills and groups
- developing a set of principles to guide the design of the new framework.

Scoping review

We performed a scoping review of the literature with a focus on broad career-skills-focussed frameworks and reviews that could be adapted for the science curriculum, and on literature that specifically addresses career skills of science students. Our source selection was based on the following criteria: (1) include recent skills frameworks with a global scope and applicable to university students, (2) include reviews of comprehensive global skills frameworks, (3) include studies that explicitly identify career skills relevant to science university students, (4) include a skill framework (or frameworks) used by a major online job advertising portal. After reviewing relevant literature, we selected ten sources that together satisfied the four criteria. Their rationale for inclusion, strengths and limitations are outlined below.

Table 1: Included sources, with rationale for inclusion, key strengths and limitations

Source	Rationale for inclusion	Strengths	Limitations
WEF (2023a)	Recent, comprehensive, future-oriented analysis with a global scope. Well-structured, highly intuitive skills taxonomy and framework.	Data based on reports from 803 companies representing over 11.3 million workers globally. Complex, wide-ranging skills framework spanning 81 different skills.	Some skill groups are framed too broadly or abstractly and their relevance to graduate careers is not explicit. The breadth of scope means many skills are not directly applicable to the university science curriculum.
Brüning & Mangeol (2023)	Similar in scope to the WEF taxonomy, with a focus on graduates' skills sought by	Big-data analysis based on the analysis of online job postings. A skills framework of 67 skills based on a synthesis and	Same as the limitations of the WEF framework above.

	employers.	harmonisation of over 14,000 unique skills found in job ads.	
García-Álvarez et al. (2023)	Systematic review of 52 global employability-skills-focused studies.	Structured framework of 41 competencies, with weighing based on frequency of occurrence of relevant skills in the literature.	The framework has only five broad unevenly distributed skill groups called dimensions, ranging from 3 to 16 competencies per group.
Sarfraz et al. (2018)	Systematic review of 43 global employability-skills-focussed studies.	Structured framework of 78 skills, with weighing based on frequency of occurrence of relevant skills in the literature.	The skills taxonomy is based on frequencies of mention in literature, and is not easily translatable as a teaching or curriculum mapping tool.
Sarkar et al. (2016)	Study focused specifically on science students and graduates, and the gaps between training, employer needs and skill mastery self-perception by students.	List of twenty employability skills with a specific focus on science students, based on a review of 12 sources.	List of skills, rather than a framework.
Jobs and Skills Australia (2023)	Synthesis of core employment-relevant competencies for the Australian context.	Aims to provide a common language of skills across occupations, sectors and contexts.	Will be superseded by the National Skills Taxonomy.
Inner Development Goals (Ankrah et al., 2023)	Well-researched and visionary skills frameworks directly connected to Sustainable Development Goals as defined by the UN.	Twenty-three skills with a strong focus on empowering individuals.	Limited coverage of career skills specifically relevant to science students.
McGunagle & Zizka (2022)	Focussed on STEM and based on a review of literature and surveys of hiring managers in USA.	Highlights skills most frequently mentioned by managers who hire STEM university graduates in USA across several manufacturing	Skills list, rather than a framework; data based exclusively on US sources.

		industries.	
Perkins (2020)	Well-researched initiative supported by the U.S. government.	Skills framework with simple, intuitive categories.	Primarily focussed on US context; limited scope of skill groups.
Indeed (2023)	Skills lists based on data in tens of thousands of online job postings and ads on Indeed.com	Skill names and groupings directly reflect the ways skills are represented in a major job advertising portal.	Inconsistencies and overlaps between skills and categories.

We found the WEF (2023a) and Brüning & Mangeol (2023) skills frameworks the most complex and best-evidenced syntheses and skills frameworks. Together with the reviews by García-Álvarez et al. (2023) and Sarfraz et al. (2018), these four sources provided a rich database of skill names, as well as weighing based on the prominence of different skills across the wider literature. The limitation of these sources was in their abstractly defined and idiosyncratic skill groups (Table 2), which would require adjustment to be useful as a tool for mapping the science curriculum.

We complemented the four major syntheses with context-specific skills lists and frameworks. Indeed (2023) is a popular open-access source readily accessible to job seekers. The Australian Skills Classification (Jobs and Skills Australia, 2023) is a skills taxonomy designed to provide a common language of skills for Australian context. Perkins Collaborative Resource Network (2022) provides a similar perspective for the US. We also included the Inner development Goals (Ankrah et al., 2023), which inform the United Nations' Sustainable Development Goals, and which add a visionary perspective relevant to the development of students' personal strengths. Finally, in order to make the career skills framework more relevant to science students and educators, we included lists of key employability skills relevant to science students as identified by Sarkar (2016) and by McGunagle and Zizka (2022).

The ten sources provided us with a total of 347 uniquely expressed skills, distributed across 76 uniquely expressed skill groups. The skills comprised a sufficiently broad range to be representative of the discourse on employability, transferable skills, future skills, core competencies and development goals, and also addressed the specific needs and gaps relevant to career training of science university graduates.

Table 2: Included sources with framing, skills terminology, and number of skills and skill groups

Source	**Framing of skills representation**	**Term to identify skills**	**Number of skills**	**Number of skill groups**
WEF Global skills taxonomy (2023)	Skills taxonomy	Future job skills	81	8 top-level, 26 lower-level

Brüning & Mangeol (2023)	Skills taxonomy	Transferable skills	67	4 top-level, 15 lower-level
García-Álvarez et al. (2023)	Weighted list of skills divided into five dimensions	Transversal competencies and soft skills used interchangeably	41	5 dimensions
Sarfraz et al. (2018)	Systematic review of skill frameworks and taxonomies	Employability skills	78	10
Sarkar et al. (2016)	Skills gap review	Employability skills	20	none
Jobs and Skills Australia (2023)	List of skills	Core competencies	10	none
Inner Development Goals (Ankrah et al., 2023)	Individual development goals framework	Development goals	25	5
McGunagle & Zizka (2022)	List of skills	Employability skills	16	none
Perkins (2020)	Skills framework	Employability skills	42	3 top-level, 9 lower-level
Indeed (2023)	Skills companies value	Employability skills	39	11
Total number of uniquely expressed names for skills and unique next-level skill groupings			347	76

Harmonising skills and applying network analysis to skill groups

The large number of uniquely expressed skills we identified, and the variation in the allocation of skills to different skill groups across frameworks, confirms previous observations of the lack of coherence in the literature relevant to employability and careers by (Binkley et al., 2012; Sarfraz et al., 2018). However, we found that much of the lack of coherence is relatively superficial, as many skills and skill group names are near synonymous (e.g. “critical thinking” vs. “critical thinking skills”, “relationship management” vs. “working with others”, or “technology use” vs. “technology literacy” vs. ICT skills).

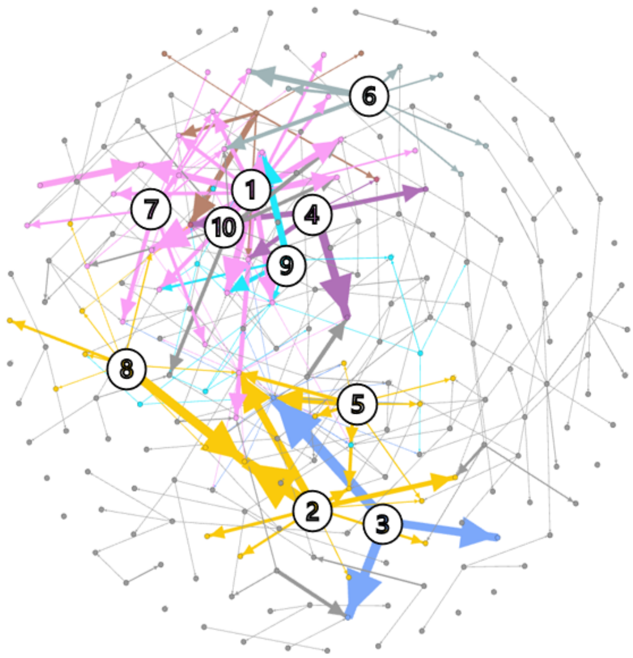
It was therefore possible to simplify or harmonise the skill map by clustering skills expressed in similar or near-synonymous terms in different sources, in an approach similar to Brüning & Mangeol (2020) and Sarfraz et al. (2018). As a reference, we used the extensive skill vocabularies provided by the WEF and OECD taxonomies, complemented by by García-

Álvarez et al. (2023) and Sarfraz et al. (2018). This resulted in a simplified skills list with 133 unique skills.

In order to avoid oversimplification and to recognise the variety of skill groups in the original sources, we avoided a synonym-based harmonisation when simplifying skill groups. Instead we analysed skill groups as a network of unique relationships in which the same skills could have multiple connections across different groups. We redistributed the 133 skills of the simplified skills list into the 76 original skill groups found in literature, and transformed the overlapping relationships into data that could be analysed through network analysis software.

Using the software Gephi, we entered all unique simplified skills and original skill groups as relationship *nodes*, and all relationships as directed *edges*, leading from the parent (skill group) to the child (skill). To visualise the frequencies of different skills' representation in the literature, we also included the weighing from the systematic reviews by Sarfraz et al. (2018) and García-Álvarez et al. (2023) who quantified the distribution of skills across their sources.

Utilising Gephi's graphing layouts we visualised the data through the force-directed Fruchterman-Reingold network projection algorithm, which arranges *nodes* (skills) and *edges* emanating from central clusters (skill groups) in a circular pattern depending on their relative weight and mutual relationships (Cherven & Magdy, 2015). In our visualisation, the skill groups with the most heavily weighted skills create their own centers of gravity, and the cross-links between individual skills contribute to the final arrangement of the graph layout. The relative weight of a skill represented in the systematic reviews is represented by a thicker line with an arrow pointing from the sources' skill group to the individual skill. Skills presented in our sources as a part of a list without explicit skill grouping appear as isolated points. The top ten skill groups with the greatest weight are identified by numbers (Figure 1).



#	Original skill group name (top 10 only)	# skills in a group	Combined weight
1	Self-management skills	19	279
2	Socio-relational skills	9	140
3	Job-related basic skills	3	108
4	Entrepreneurship skills	5	91
5	Interpersonal and collaborative skills	10	87
6	Social and professional responsibility skills	8	72
7	Personal attributes and individual differences	18	68
8	Relationship management skills	11	66
9	Cognitive and problem-solving skills	5	59
10	Productive self-management skills	9	59

Figure 1. Left: Gephi visualisation, using the Fruchterman-Reingold network projection, of the 133 simplified skills distributed into their original skill groups. Arrows point from the group name to individual skills, with thicker lines and larger arrows indicating skills have more weight based on their occurrence in the literature. Similar colours indicate groups with similar

naming. **Right:** Table of top ten original skill group names, with number of simplified skills and combined skill weight for each group.

Clusters of skill groups with widely cited skills

The visualisation in Figure 1 highlights the diversity of skill groups, with the top 10 groups covering only a portion of the total number of simplified skills. It also reveals two prominent clusters of skill groups whose proximity and thick edges indicate they share a number of widely cited skills. The first cluster is related to self-management skills (1), productive self-management (10), personal attributes and individual differences (7), as well as entrepreneurship (4) and cognitive and problem-solving skills (9). The social and professional responsibility skills group (6) also shares several skills with this cluster. The second cluster is formed around socio-relational skills (2), job-related basic skills (3) and interpersonal and collaborative skills (5). Relationship management skills (8) are positioned between the two main clusters.

Each cluster confirms that the near-synonymous naming of skill groups like "self-management" (1) and "productive self-management," (10) also means those groups contain the same or similar skills. At the same time, however, the visualisation also confirms the different conceptualisation of skills across our sources. The proximity of entrepreneurship (4), cognitive and problem-solving (9) and self-management (1) skills indicates that while the category names may be conceptually different, they share some of the same skills. Similarly, one source presents relationship management skills (8) as containing not only interpersonal and teamwork skills shared with the second cluster, but also adaptability and following instructions, which are shared with the first cluster of skill groups. This results in this group's placement between the two clusters (Figure 2).

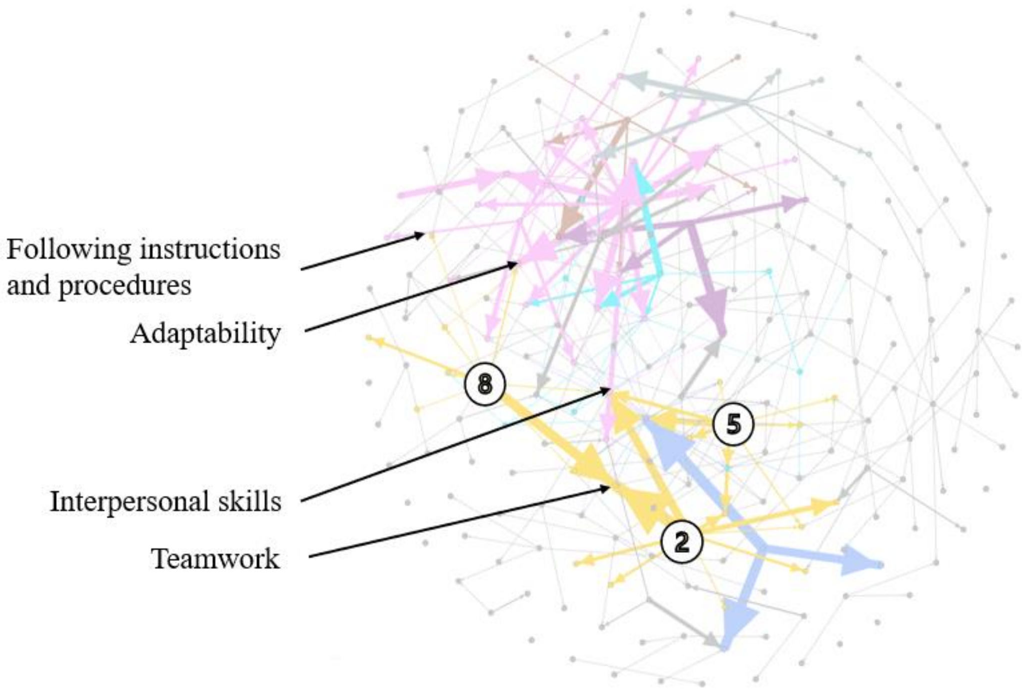


Figure 2. Visualisation adjusted from Figure 1, with a focus on groups relevant to relationship management. Group 8 (Relationship management skills) is placed further from group 2 (Socio-relational skills) and 5 (Interpersonal and collaborative skills) due to its inclusion of

adaptability and following instruction and procedures, in addition to including interpersonal skills and teamwork shared with groups 2 and 5.

Same skills in multiple skill groups

The Gephi mapping allowed also allowed us to further explore the instances where the same skill is conceptualised as part of different groups. Thus adaptability, for example, can be considered as part of skill groups concerned with self-management (García-Álvarez et al., 2022), personal qualities (Perkins, 2022) but also relationship management skills (Sarfraz et al., 2018), as well as interpersonal skills (Indeed, 2023) and resilience, flexibility and agility (WEF, 2023a). On the other hand, creative thinking can be considered as part of several groups, including creative and innovative skills (Sarfraz et al., 2016), entrepreneurship skills (García-Álvarez et al., 2022), creativity and problem-solving skills (WEF, 2023a), problem-solving (Brüning & Mangeol, 2023) and acting (Ankrah et al., 2023).

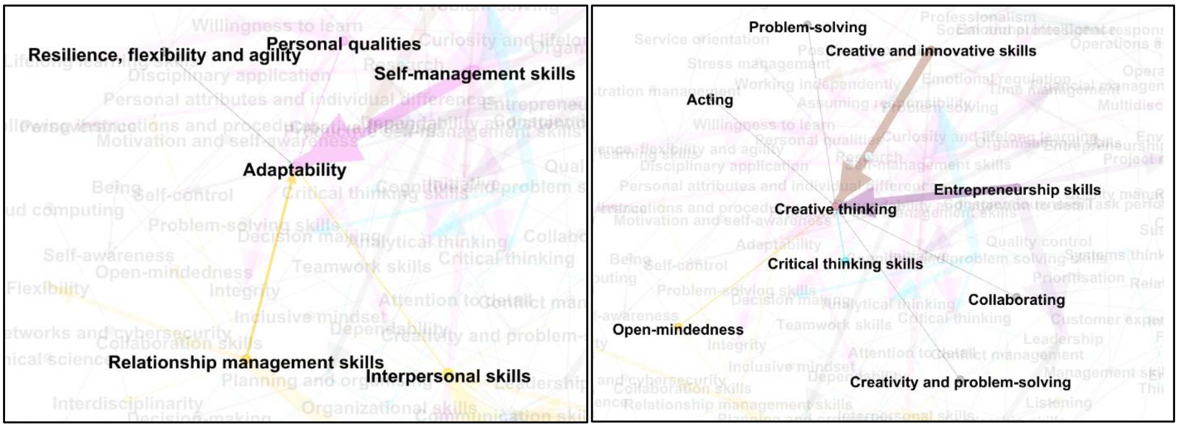


Figure 3. Examples of a skill being part of different skill groups. Left: Adaptability can be considered as part of skill groups concerned with self-management, personal qualities but also relationship management skills, as well as interpersonal skills and resilience, flexibility and agility. **Right:** Creative thinking can be considered as part of several groups, including creative and innovative skills, entrepreneurship skills, creativity and problem-solving skills, problem-solving and acting.

Skills as skill groups

At the same time, different frameworks can consider a skill also a grouping (Figure 4). For example, teamwork is a skill included in socio-relational skills (García-Álvarez et al., 2022), relationship management skills (Sarfraz), as well as interpersonal skills (Perkins, 2022), communication skills (Indeed, 2023) and collaboration/engagement with others (Brüning & Mangeol, 2023). At the same time, teamwork features as a skill group name that includes the skills of collaboration, communication and integrity (Indeed, 2023).

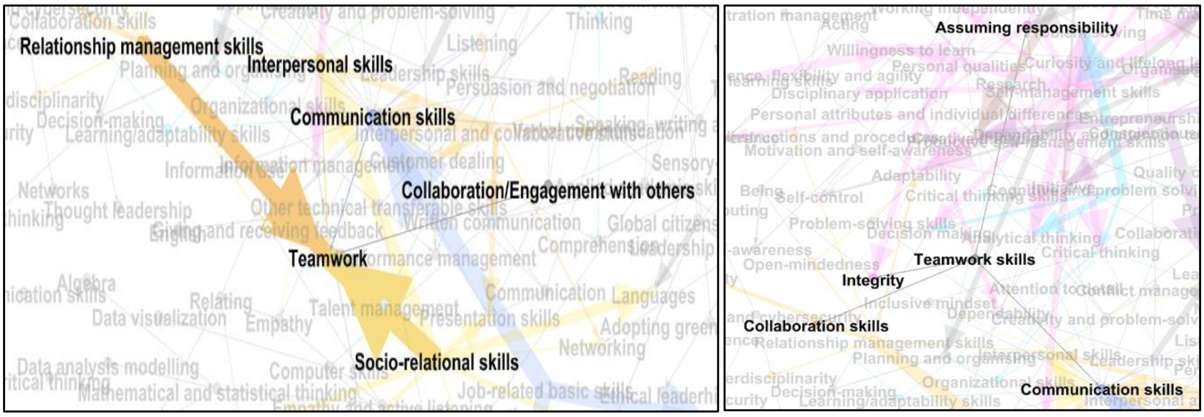


Figure 4. Examples of a skill name being also used as a skill group name. **Left:** Teamwork as a skill within a number of different skill groups: socio-relational skills, relationship management skills, as well as interpersonal skills, communication skills and collaboration/engagement with others. **Right** Teamwork skills as a skill group name that includes the skills of collaboration, communication and integrity.

Principles of designing the new skills framework based on network analysis

The network analysis of highlighted that the top career skill groups prominently featuring in literature only cover a portion of all relevant skills, and that none of our sources comprises a simple, intuitive skills framework that would encompass the broad spectrum of skills relevant to career development.

Importantly, the network analysis convinced us that rather than seeking a “perfect” career skills framework, we should conceptualise it as a dynamic network of relationships between skills and groupings. The new framework would be an artefact whose form and structure would reflect a choice of framing specific to a purpose and time. This approach would also allow for the framework to be designed for adjustment in the future, corresponding to changes in education and the job market.

Based on the observations from network analysis, we set up the following principles to inform the design of the new framework:

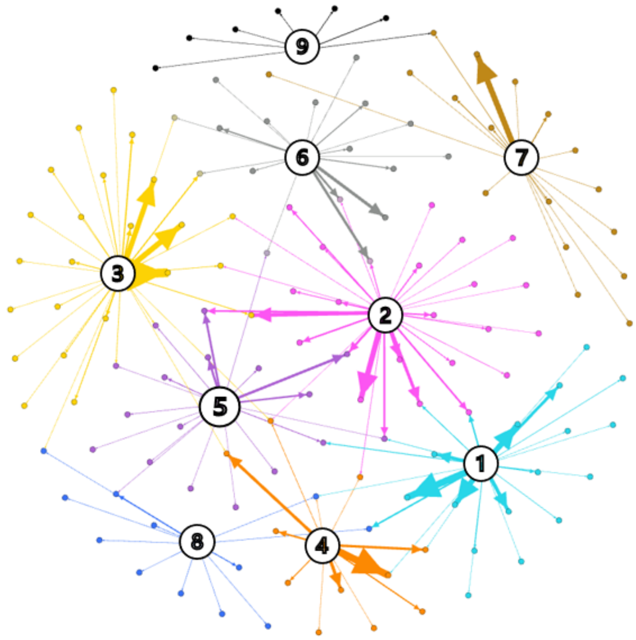
- The framework should reflect in a coherent way the prominent skill groups clusters identified through network analysis of the literature.
- The names of skills and skill groups should respect the frequencies and weightings of skills as represented in the literature.
- The names of skills and skill groups should be simple, intuitive and consistent with terminology used in the science curriculum.
- The number of skill groups should be around eight.
- The number of skills within a group should not be overwhelming.
- The arrangement of skills within a group should be conducive to recognition, comprehension and recall (consistent with UDL).
- The framework should be designed with a mindset of acknowledging it is an artefact designed for a specific purpose and time, based on the dynamic network of skill and skill group relationships as found in sources.

Results

New skill group names

Following the principles outlined above, we refined the skill groups to nine broad categories into which we distributed the simplified skills. To test our new skill group names, we applied the Fruchterman Reingold projection in Gephi on the refined skill groups (Figure 5).

The more even distribution of the major skill groups around the circular layout compared to the earlier visualisation (Figure 5) reflects their more balanced weighing and gravity. On the other hand, the new arrangement respects the need to accommodate interconnections between different skill groups. For example, the central group 2 (personal strengths and skills) with the most weight, contains skills that are also included in some mappings of group 1 (thinking, problem solving and innovation), as well as groups 3 (people and leadership), 4 (communication), 5 (professional integrity) and 6 (projects and entrepreneurship).



#	New skill group name	# skills in a group	Combined weight
1	Thinking, problem solving and innovation	24	316
2	Personal strengths and skills	29	306
3	People and leadership	29	281
4	Communication	13	186
5	Professional integrity	16	104
6	Projects and entrepreneurship	16	100
7	Digital tools	15	81
8	Lab, field and internship	11	26
9	Data and coding	8	18

Figure 5: Network map of simplified skills clustered in simplified groups. Left: Gephi visualisation, using the Fruchterman-Reingold network projection, of the 133 simplified skills distributed into new skill group. Arrows point from the group name to individual skills, with thicker lines and larger arrows indicating skills have more weight based on their occurrence in the literature. **Right:** Table of the nine new skill group names, with number of simplified skills and combined skill weight for each group.

The persisting mutual interconnection between skill groups is a reminder that just as human interactions need to create space for multiple interpretations and meanings in different contexts, any taxonomy of career skills will not have one unique solution. As an example, the discussion of communication skills in the academic context often focuses on written and oral presentations in a relatively formal setting. In a business setting, however, the primary meaning of communication will relate to interpersonal communication and negotiation. In our skills framework, the first meaning is captured under the skill group "communication skills" and the second by "people and leadership" group. In addition to using the refined skills titles, our skills framework would therefore also need to address these interconnections. A simplified visualisation of the new skill groups is presented in Figure 6.

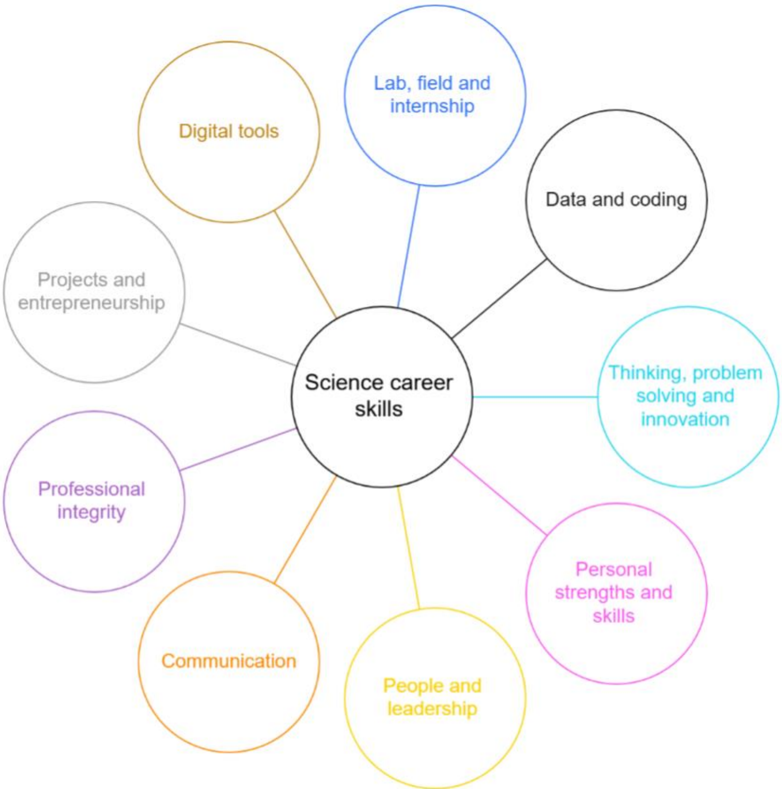


Figure 6. A simplified visualisation of the skill groups of the new Science Career Skills Framework.

Arrangement of new skills

To complete the new career skills framework, we structured the individual skills into a storyline or narrative arc. This would prevent the framework from becoming too abstract, and enable meaning-creation and heuristic recall similar to a mind map (Zarzo, 2015). A skill group with an intuitive name and an easy-to-grasp set of skills that "move" the reader through its content in a meaningful way would provide a way to easily associate the skills with authentic learning activities and assessments. It would also allow educators the freedom to introduce variety and choice, consistent with the principles of Universal Design for Learning (Dalton, 2019). Moreover, a meaningful storyline would enable us to make informed choices to reduce skills: rather than focusing solely on harmonising synonyms in the original sources, we could choose skills that were suitable for different stages in the story. For example, the "Thinking, problem solving and innovation" skill category roughly follows the arc that begins with initiating investigations and concludes with creating solutions, transforming them into actions (Table 3).

Table 3: Transforming relevant simplified skills to new skill names using a narrative arc

Unique simplified skills relevant to the new category	The narrative arc of organising skills	New skill names following the narrative arc

Ability to synthesize Analytical thinking Change initiative Communication skills Comprehension Creative thinking Critical thinking Decision making Design mindset Disciplinary application Disciplinary content Entrepreneurship Information management Initiative Long-term visioning Meta-cognition Planning and organising Problem solving Research Scientific thinking Strategic thinking Systems thinking Thought leadership Working independently	1. Initiating investigations 2. Understanding the context and asking relevant questions 3. Methodical, critical approach to solving problems 4. Creating solutions, transforming them into actions and reflecting on them	Planning and strategic thinking Awareness of complexity Information research and management Defining problems and asking questions Conceptualisation and/or modelling Critical analysis and evaluation Synthesis of ideas Developing solutions and making decisions Creativity and innovation Reflection and metacognition

The new framework

Table 4 below provides an overview new Science Career Skills for science framework with its new skill group and skill names.

Table 4: Science Career Skills Framework

New skill group name	**New skill name**
Thinking, problem solving and innovation	Planning and strategic thinking Awareness of complexity Information research and management Defining problems and asking questions Conceptualisation and/or modelling Critical analysis and evaluation Synthesis of ideas Developing solutions and making decisions Creativity and innovation Reflection and metacognition
Personal strengths and skills	Self-awareness and authenticity Self-motivation and initiative Dependability and attention to detail Continuous self-development

	Openness to uncertainty or ambiguity Adaptability and resilience Empathy and compassion
People and leadership	Interpersonal communication Teamwork and collaboration Inclusive mindset Networking Influencing Negotiation Managing up Managing people or clients Leading others
Communication	Scientific and technical writing Communicating to non-expert audiences Developing and communicating arguments Oral presentation Creating visual content Multimedia communication Providing and learning from feedback Foreign language skills
Projects and entrepreneurship	Commercial awareness Pitching and funding Project planning Project management Budgeting Time management Marketing and promotion Entrepreneurial thinking Outcomes evaluation
Professional integrity	Integrity and ethical conduct Regulatory compliance Professional guidelines Intercultural competence Indigenous cultural awareness
Digital tools and skills	Office, Google suite, LaTex or Wolfram notebooks Lab, project or client management software Collaboration and teamwork tools Social media tools Web design or development Graphic design software Dashboard software Artificial intelligence tools
Lab, field and internship	Occupational health and safety Risk assessment

	Quality control and assurance Equipment handling Physical fitness and manual handling Lab experience and techniques Local field experience and techniques Remote field experience and techniques Internship experience Licenses and certificates
Data and coding	Data collection and management Cleaning and structuring datasets Data analysis and evaluation Coding language skills Database management skills Interpreting data and providing insights Visualising data

Discussion

Our design and validation of a Science Career Skills Framework demonstrates that it is possible to design a skills framework that bridges existing research while providing a meaningful tool for particularly mapping a university science curriculum. The successful validation of the framework by mapping into the entire undergraduate curriculum of the Faculty of Science at Monash University indicates it can be a meaningful tool for bringing out the hidden curriculum and developing a more programmatic approach to teaching career skills in other institutions.

Overall, we found that network analysis has not only resulted in our framework being more robust and coherent, but also that it can be a useful tool for approaching the literature on skills in the future. First, network analysis allowed our skills framework to acknowledge the interconnected relationships between skills and groups presented in our sources, and prevented our synthesis from flattening the data by using synonym- or concept-based harmonisation alone. Second, identifying prominent clusters of skills in the literature through network analysis helped us to create more intuitive, simple skill group names that are not only more cognitively approachable, but also more resilient to change due to their general scope. Third, the data used for network mapping can be easily updated to incorporate emerging literature without jeopardising the existing framework. Finally, approaching skills and groupings not as a static set of data but as a dynamic network of relationships whose interactions change over time, led us to conceptualise the new career skills framework as an artefact designed for adjustment in the future, corresponding to changes in education and the job market. This approach avoids approaching skills as continuously changing lists of deficits or skills of the future (Sarkar, 2016; WEF 2023).

The new Science Career Skills Framework has a number of limitations. The simplification of skills means many are open to interpretation, and will require descriptions and translation, both for academic staff and for students. While the group names do correspond to clusters of groups found in literature, the decision to include “Lab, field and internship skills”, and “Data and coding skills”, was made based on curriculum specifics that may not be relevant to other contexts. We plan to address these limitations by developing student- and academic-facing resources, and a Moodle-based plugin to enable students and teachers to explore how skills are taught across the semester.

This pre-print is the first dissemination of the preliminary findings from our project to develop a Science Career Skills Framework. We are currently submitting the refined findings for publication. Our immediate goals are to use the framework as the foundation for a more programmatic approach to teaching and assessment, and to find better ways to enable students to use their university training as a powerful springboard to self-guided career development and life-long learning.

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