Full Title

Development of a Professional Competency Framework for UK Food Science Graduates

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[END PAGE 1]

ABSTRACT:

Food science-based graduates are a significant proportion of the UK food and drink industry's workforce. Aside from technical standards, there is no cohesive competency framework to support key stakeholders; employers, students and degree providers. Clarity of desirable competencies for the range of graduate opportunities available would enable students to undertake effective career planning and personal development, and educators to refine programs to satisfy market needs.

Using a previously developed language tool, a Likert style, industry-wide online survey in UK and Republic of Ireland (ROI) was conducted involving 218 participants from a broad range of food science-related employment areas, evaluated by a combination of descriptive and multivariate data analysis. The survey outcomes indicate types of desirable competencies in a food science graduate. The tailored competency framework, Competencies for Food Graduate Careers (CFGC), is a set of 48 *elements* across 8 *themes,* outlining which are desirable for each of 14 typical initial graduate roles.

To enhance the quality of 'oven-ready' graduates entering the food industry, it is recommended CFGC be used for careers education and competency development in higher education. The framework is aimed to have further applications for job specification development and also to improve awareness of careers in the food industry.

5 Keywords: Principal component analysis (PCA), competencies, food science workforce readiness, curriculum, education.

Practical Application: *NOTE: Do not include a PA for JFS Concise Reviews, JFSE, and CRFSFS papers.* ***N/A***

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Introduction

Ensuring students of vocationally based courses have understanding of and the ability to develop the requirements of graduate employers is a duty of contemporary degree educators. This includes the broader competencies associated with success in the workplace and may vary dependent on role undertaken. Competency frameworks for graduate vocations can be used beyond curriculum development, having the potential to improve a student's awareness of the desirable skills and behaviors for specific career pathways and thus inform choice and plans for personal development.

UK degree subject standards or 'QAA' benchmark statements such as the 'Agriculture, horticulture, forestry, food, nutrition and consumer science' (The Quality Assurance Agency for Higher Education, 2016) provide specific technical skill requirements for course types under broad discipline groups. Food science degrees in the UK demonstrate reference to content of this QAA statement. Aspects of broader competencies that may be required for graduates to possess, are found in the 'generic skills' section, but are unspecific or broadly applicable to the many degree course types covered in the statement. This limits understanding of the type of desirable competencies expected in a food science graduate undertaking their first role, particularly when in reality there are a range of pathways to choose across research, development, manufacturing, retail and compliance. The relatively new UK-based IFST degree accreditation (Institute of Food Science and Technology, n.d.) makes reference to this QAA statement as part of its compliance guidelines for technical and broader competence.

The USA-based IFT standard (Institute of Food Technologists, 2016), appears to be broadly comparable to the QAA statement (2016), but more targeted to food science degree requirements. A number of educators in the USA have published work on compliance of degree curricula to the IFT standard (including Bohlscheid & Clark, 2012; Hollis & Eren, 2016; Joyner, 2016; Morgan, Ismail, & Hayes, 2006). 'Careers in Food Science: From Undergraduate to Professional', published in 2008 (Hartel & Klawitter) targets US undergraduate students (or aspiring students) and includes examples of different career pathways in small chapters provided by representatives from US industry. Whilst perhaps inspirational in style to a student audience, it does not provide a clear scaffold of desirable competencies for each role to inform students and steer curriculum designers.

European work coordinated by the ISEKI Food Association (https://www.iseki-food.net) since 2010, has identified a selection of technical and "soft" skills that may be required in food scientists and technologists at varying levels of qualification on entry to industry (Flynn, Bejarano, Wahnstrom, Echim, & Quintas, 2013; Ho, Lindbom, & Wahnström, 2011; Mayor et al., 2015). However, there is no defined tool, model or guideline available from this work outlining the broader skills that make a workplace-ready food sciences graduate. UK-based careers information is limited; for example, 'Tasty Careers', (https://tastycareers.org.uk) is not graduate or technical specific, nor grounded in formal research.

The overarching aim of the project was to construct a 'competency framework' outlining desirable qualities for typical roles undertaken by food science graduates in the UK and ROI food industry to support student 'employability' and engender clarity in graduate career opportunities for wider stakeholders. The framework can also underpin targeted curriculum development. To underpin the study, involvement of industry was critical.

In previous work by the authors, a common language or tool was developed, using an exploratory process of 'semi-structured' or 'focused' interviews, thematic analysis and consolidation by an online modified Delphi group engagement activity (Weston, Crilly, Mossop, & Foster, 2017). Competencies for Food Graduate Careers (CFGC) comprises 48 *elements* (and the associated definitions applied to them) that may be desirable in a UK food science graduate, subsequently checked for comprehension by a series of group interviews with students at three UK Universities.

The purpose of this study was to discover which *elements* in the CFGC language tool are particularly desirable for initial bachelors' graduate roles typically undertaken by food scientists in the UK and ROI. This paper commences by outlining the definition of these graduate roles in collaboration with a stakeholder group. The development, dissemination and analysis of a wider industry survey is described, aiming to establish the importance of each CFGC *element* for each graduate role. The present and future use of the finally ratified framework will be discussed.

Materials and Methods

The scope of this study does not center on the technical aspects of UK and ROI food science degrees as outlined in the QAA subject benchmark statement (2016), but on the broader behaviors, knowledge and skills that support a graduate's scientific knowledge and capability.

Stakeholders and Participants

In order to deliver a valid tool, a systematic approach utilizing a range of industry stakeholders was utilized. This included voices and views from human resource personnel, recruitment consultants, line managers/employers and recent graduates within the range of employment areas identified, such as manufacturing and retail. Sampling of these participants was purposive and through a process of snowballing via prior contacts (Braun & Clarke, 2013). Aiming to gather an industry-wide perspective, extensive efforts were made to gather representation from range of initial graduate pathways, mindful that as

some roles type are less frequently recruited to, associated participant numbers may be limited. A preferred mode of contact of direct email or using 'LinkedIn' (Microsoft Corporation, California, USA) was established.

The survey was approved by the School of Sociology and Social Policy as aligned to University of Nottingham (UoN) Code of Research Conduct and Research Ethics. Informed consent was obtained from participants before survey completion.

Design

Using the language tool previously developed (Weston et al., 2017) to frame a stakeholder survey (Flynn, Bejarano, et al., 2013; Su & Zhang, 2015), an exploratory sequential mixed methods approach to competency framework development was taken (Creswell, 2014). The process employed for this study is illustrated in Figure 1.

Preparatory work was progressed in 2016 and the survey was conducted in January 2017. Choice of data analysis reflected the nature of data gathered and development of a useful final construct (Su & Zhang, 2015; Velasco, 2012). The proposed framework was ratified by the industry stakeholder group in September 2017 as an expert forum (Joyner & Stevenson, 2017; Perera, Babatunde, Zhou, Pearson, & Ekundayo, 2016; Weston et al., 2017).

There are an assortment of terms and associated definitions used in graduate competency constructs (Suleman, 2018), so careful application of terminology was required. Table 1 outlines the key terms and definitions used in the study.

Establishing graduate roles

A draft list was compiled of typical roles and associated titles that food science graduates may undertake as they enter the food industry, to instigate discussion in a stakeholder group meeting (comprising 11 attendees) in July 2016. This discussion confirmed that whilst some roles listed were less frequently advertised or recruited to, the range of identified career pathway options should be included in the study. A further desktop review was then undertaken of relevant careers guidance, job advertisements, and specifications found on UK websites and recent employment destinations of UoN food sciences alumni. A proposed list of 14 roles with associated titles and descriptors was electronically issued to the stakeholder group for consideration. Small revisions were made and a final list confirmed for the development of the survey.

Survey development

An anonymous online survey developed using Online Surveys™ (Jisc, Bristol, UK) was considered appropriate for the large sample size and geographical spread of target participants. Communications to accompany the single URL (uniform resource locator) weblink included carefully constructed introductory messages, adapted to the participant's prior knowledge of the study (Lawless & Heymann, 1999). A draft survey was piloted with a small test group of eight and minor modifications were required to some wording of questions. The survey was launched in mid-January 2017.

The survey was constructed around the research question of 'What competencies are desirable in food sciences students for the initial roles they undertake after graduation?'

The survey presented the 48 *elements* of CFGC which participants had to rate according to their perception of the desirability of this component in the workplace for a given graduate role. The rating scale required a 'forced choice' owing to the expertise of the respondents (Brace, 2013). Participants could respond about as many roles as they were familiar with.

To aid completion, the 48 *elements* were listed within 11 zones, namely the original grouping of the *elements* (Weston et al., 2017) and appropriately sized subpages constructed. As illustrated in Figure 2, definitions were provided for each *element* within the question, and further explanatory text was provided at regular intervals by use of the 'more info' collapsible text box option, to guide and inform closed responses. To terminate each subpage, questions with free text or open responses were included, to allow the participant to provide optional qualitative information.

Core questions were structured in a five-point, ascending, unipolar Likert style scale with resultant useable scoring in the survey of '1 – not specifically desirable for the role' to '5 – essential for the role', as illustrated in Figure 2.

A series of initial, short anonymous demographic questions to facilitate data sorting, were included to establish the participant's relationship to graduates, whether: a 'recruiter', 'recent graduate', or an 'employer / line manager'. The use of the survey 'routing' feature prevented unnecessary additional questions being presented to a participant and use of the 'piping' feature allowed for their choice of role title to be cascaded into subsequent text and pages (Figure 2).

A progress bar was omitted appreciating the encouraging benefit was more suited to short surveys (Brace, 2013), however radio buttons were employed to reduce the number of clicks for the user.

Data Analysis

As data was obtained from a sample of employers, inferential statistics were applied (Sapsford & Jupp, 2006). Analysis was performed using non-parametric statistical methods, as appropriate for ordinal data from Likert style rating (Cohen, Manion, & Morrison, 2011; Dillman, Smyth, & Christian, 2014). Data were downloaded into Excel for analysis and an initial cleaning and inspection removed any errors/incomplete data.

A Chi-square test was undertaken to look for associations between variables (Sapsford & Jupp, 2006) and support further investigation by multivariate analysis. The Cronbach's alpha reliability test was also conducted, using 0.6 as an acceptable lower limit for exploratory research (Hair, Black, Babin, & Anderson, 2014). Two approaches of data analysis were applied and combined to generate the final framework of CFGC to present to stakeholders, comprising descriptive data analysis followed by principal component analysis (PCA).

Detailed descriptive analysis

This provided an opportunity to visualize data and establish relationships between variables. Desirability of each of the 48 specific *elements* of CFGC against the 14 typical graduate roles was explored by sorting data either by role or by *element* and inspecting data presented graphically in the following ways:

- Stacked bar chart of responses, presented in descending order by role or by *element*.
- Frequency counts of the more desirable responses of '5' and '4 & 5' for an *element* by role type, presented in lists of descending order.
- The combined 'score' for each *element* by role type, converted and standardised to a common sample size for comparison purposes, using a 'score' for the total survey data set.

Roles or *elements* identified as 'top' in the visual inspection for each graph or list were captured and compared. Care was taken in interpreting roles with lower sample sizes (<10 survey responses). A final list of desirable *elements* by role were compiled and a matrix generated for use in future illustrations.

Principal component analysis (PCA)

PCA, a form of factor analysis, identifies patterns of correlations amongst the original variables and resolves them into a set of sensible groupings ('components') which each have a meaningful interpretation and a basis for the desired competency framework (Lawless & Heymann, 1999). The process of identifying and choosing the best solution is not necessarily straightforward but PCA, in combination with careful inspection and comparison of the face validity of alternative solutions, offers a pragmatic and objective way forward.

Following initial pre-testing, based on a chosen number of retained components from the PCA, the configuration can be rotated so that, whilst retaining the same overall percentage of information from the complete data set, the original components are replaced by new ones each with an easier interpretation, namely components with higher positive or negative loadings on a reduced number of variables. The commonly-used Varimax procedure was used throughout in this study (Hair et al., 2014).

The alternative solutions with varying numbers of rotated components were then analyzed to select the best visualization of data. This included analysis for how many variables could be retained within each component (factor loading cut-off) assigning some meaning or identity to the construct and each component (Stevens, 2009). The terms 'factors' and 'components' are used interchangeably, also 'variables' and *elements* are equivalent in this study.

PCA was performed on standardized data using XLSTAT™ Statistical Software (Addinsoft, NY, USA). Samples (participants) were entered in rows, and 'variables' (scored *elements*) in columns, plus 'supplementary variables' comprising codes for each participant, the participant type and typical graduate role chosen to review.

Initial reliability of data were explored using the tables presented in the XLSTAT™ report. Bartlett's test of sphericity checks for correlations, having more limited value with a large data set and number of variables but was included in initial analysis (Field, 2013; Tabachnick & Fidell, 2013).

A review of factor eigenvalues greater than 1.0, and inspection of cumulative variance supported choice of the range of components to inspect following rotations (Hair et al., 2014; Stevens, 2009). Cumulative variance, although typically required to meet thresholds such as 60%, can be acceptable when lower in exploratory studies (Tabachnick & Fidell, 2013). PCA software biplots, had limited use in the study due to a likely spread of useable components beyond two.

A summary of chosen criteria to support interpretation of rotational models is summarized in Table 2.

Interpretation of each alternative rotated solution was approached in a sequential manner adapted from the steps described by Hair *et al.* (2014), enabliing choice of a final dimensional model and its most appropriate structure:

- Initial examination of each alternative rotated solution
- Factor communalities assessment

- Identification of significant loading(s) for each factor
- Reflection on models and provisional labelling of factors
- Factor scores analysis
- Choice of the final rotational model
- Refinement of factor scores and model construct

After the structure was finalized, material was prepared to illustrate the CFGC framework and also a profile for each graduate role identified. The stakeholder group meeting (comprising 12 attendees) in September 2017 ratified the final construct (Perera et al., 2016) and possible visual representations of all aspects of the final framework were agreed.

Results

Figure 3 Illustrates the 14 roles identified as typical for food sciences graduates to initially undertake when entering the UK and ROI food industry.

In total, the survey was sent directly to 250 individuals, and 218 fully completed responses were collected. Some responses included reviews of multiple roles. Following detailed inspection of data quality, the final data set comprised 226 reviews of the range of graduate roles. Focusing on the core questions, there appears general alignment between responses by types of participants (Table 3).

When sorted by responses to 14 typical graduate roles (Table 4) the data sets range from 3 to 55 participants. Appraising the lower sample sets (those with <10 responses), results generally appear to mirror the prevalence of the number roles usually on offer in the UK and ROI. This is based largely on personal knowledge of industry employment patterns and also the review of graduate role advertisements within this study, where for example the 'NPD, Development and Process roles' are one of the most common initial graduate positions to undertake. However, it is appreciated the six roles with lower sample sets (shaded in grey in illustrations) have limitations for robust statistical analysis. All data were retained reflecting stakeholder viewpoints that a full representation of the job market be included. Grouping smaller data sets would not be possible by any natural affiliation to provide meaningful outcomes, however care and sense was applied to analysis of these data sets and any judgments or comparison with other roles to prevent creation of bias.

Comparing the medians, there was little to differentiate between *elements* in the total data set, however visual inspection in graphical format provided some initial observations, for example the spread of results for the *element*, *acceptance of ambiguity* (Figure 4a) indicated relatively high desirability in the 'PhD or Other Postgraduate Research' role (Figure 4b).

Cronbach's alpha reliability test results provided scores of >0.8 with the exception of the role, 'Research or Materials Technologist', at 0.59 (a lower sample set role). However with closeness of the recommended threshold of 0.6 for exploratory research (Hair et al., 2014), all results were accepted. Chi-square test results confirmed that some correlations are significantly different, and thus the null hypothesis was be rejected and testing progressed.

Detailed descriptive analysis

Figure 5 provides an example of data presentation by a single *element*. In general *elements* scored more highly were positioned at the top or left area of the 48 *element*s for each representation. Decisions were supported by use of printed copies, to compare results effectively.

Table 5 provides a matrix summary of the descriptive analysis, illustrating between 10 to 14 *elements* with high desirability to each specific graduate role.

Principal component analysis

Bartlett's test of sphericity results confirmed suitability for progression. Retaining factors with eigenvalues >1, up to 12 factors were considered for future analysis with a total cumulative variance of 61.4%. Observing the contribution of variability of each eigenvalue, PCA analyses were run to create four separate solutions by comprising six, seven, eight and nine dimensions and varimax rotations. After full analysis of these four dimensions based on the steps presented earlier, the eight varimax solution was determined to present the data most appropriately; the rationale is now summarized.

The variance data each rotational set in ascending order produced cumulative variances of: 45%, 48%, 51% and 54% respectively. Analysis of the factor matrix of four rotational sets commenced as described previously with the associated threshold and cut-offs summarized in Table 2. Initial inspection of the content (*elements*) of components within each set were inspected allowing for practical reflection of each model with regard to the study context. For the nine rotational solution, the groupings did not appear rational or simple in terms of where the *elements* were found, which reflected in the sensibility of a final model, so this option was discarded.

Communalities were assessed for the remaining three rotational sets with a nominal threshold of 0.4. For the eight rotational set average communality was 0.51. Three variables (*elements*) had communalities of <0.4: *acceptance of ambiguity* (0.37), *personable* (0.36) and *self-development* (0.38). Reflecting on literature guidance, a decision was made to include all variables. For sets with six and seven dimensions, average communalities were lower at 0.45 and 0.48 respectively, with a greater number of individual communalities at <0.4, at 12 and 7, respectively.

With data sorted in each component by descending order of variables' (*element*), factor loadings for each rotational set were compared using initial factor loading cut-offs of 0.32 and 0.35, to view which *elements* remained in each component. Using both cut-offs the *work experience element* was excluded the six rotational set, having a maximum factor loading of 0.207. Aligned to stakeholder agreement that all 48 *elements* should remain, this set was therefore rejected. Using a 0.35 factor loading cut-off, all *elements* were included for eight rotations, but for seven rotations, two variables were excluded; namely *self-development* (D6, 0.337) and *questioning approach* (D6, 0.328). However using a 0.32 factor loading cut-off for both dimensional models, all *elements* were included. Further work proceeded with the seven and eight dimensional models.

Reviewing cross-loadings (an *element* found in two components) with a factor loading cut-off of 0.35, 9 cross-loadings were found with the seven dimensional model, and 12 cross-loadings for the eight dimensional equivalent (presented later in Figure 8). Using a 0.32 cut-off, the number of cross-loadings increased further (total of 17 for seven, 15 for eight rotated solutions). On this basis, factor loading cut-off was most appropriate at 0.35. Reviewing each cross-loaded *element* against their provisional component labels, their double inclusion appeared justified. As such each *element* remained cross-loaded with affiliation to two components. With varimax rotation, the components are independent, so any future framework illustrations for CFGC should not demonstrably associate components or *themes* where an *element* is cross-loaded.

Draft names and definitions for each of the components in the two remaining rotated solutions were assigned, for stakeholder group agreement. Following the project stakeholder meeting in September 2017, components or 'groups' became known as *themes*, so terminology henceforth reflects this and the resulting model with eight *themes* and draft titles is illustrated later in Figure 8.

Factor score data for each rotated solution provided in the PCA test reports were grouped by role type, and the mean scores calculated for each *theme.* Initial cut-off points were applied, whereby factor scores of ≥ 0.40 or ≤ -0.40 were considered significantly positive or negative. This provided for each dimensional model, initial indication of relative affinity of a *theme* to each role assisting the final choice of construct.

PCA reduces variables to provide meaningful groupings, chosen by balancing empirical criteria with theoretical basis (Hair *et al.*, 2014), so a judgement of the 'meaning' of each model was made. Preserving a discrete component relating to business aspects was concluded as useful when characterizing graduate roles, along with the inclusion of all *elements* in the final framework, so the final model of eight dimensions was chosen with an associated factor loading threshold of 0.35. Although a small proportion of cross-loading and lower communalities were detected, contextual understanding of the subject under scrutiny can be included in exploratory research interpretation and the framework was meaningful for the study context.

Data for the final model was transposed and split into the 14 role types with further refined factor score thresholds, providing details of the relative desirability of a particular *theme* for a particular role (example in Figure 6). Identification of levels of desirability by (blue color) shading provides the ability for simple visual, interpretation mechanism.

Culmination of survey data analysis

After completion of data analysis, information was assembled for each of the 14 role types with regard to desirable *elements* (descriptive analysis) and also relative affinity to the new eight *themes* (PCA). A report was developed in advance for review and approval in a roundtable session with the stakeholder group and representation from IFST.

The draft names and definitions for the eight *themes* derived from PCA were presented and reviewed to ensure appropriate definitions were developed with the student as target audience. The final construct is presented in Table 6.

From the stakeholders' experience, the resulting desirability of *themes* to each role appeared appropriate. For example, a 'PhD' pathway may require a particularly high level of some specific competencies, whereas for a 'Company Graduate Scheme', employers may require graduates to possess a more balanced set of competencies. A new pictorial illustration was proposed and approved, indicating relative importance of a *theme* by the darkness of blue shading (Figure 7).

Thus, a new grouping of eight *themes* to replace the original 11 *zones* (Weston et al., 2017) was ratified by the project stakeholder group. Consideration was made to appropriate treatment and display of the 12 cross-loaded *elements* using the diagram provided (Figure 8). The prevailing view was to provide simplicity and ease of understanding of CFGC to priority audiences, namely undergraduate students and employers.

A new pinwheel design was constructed (Figure 9) to illustrate the eight *themes*. In summary CFGC, now comprised:

- A language tool of 48 *elements* grouped into eight *themes*.
- 14 typical graduate roles for food scientists.
- An industry informed framework of the desirable *elements* and *themes* for each of the 14 roles.

Discussion

CFGC is aimed to ensure program provision by educators meets the professional requirements of employers and in turn, students are able to understand more about job opportunities, their suitability and how to prepare for application and selection processes. These aims will be discussed later. However it is interesting to review the variation in *element's* frequency of inclusion (Table 5) where *questioning approach* and *verbal communication* are considered desirable in half of the 14 roles, and three *elements, digital capability, global supply chain* and *work experience* are only included once. It could be suggested that some *elements* with lower occurrences may increase in desirability for the workplace in future. As noted earlier, Figure 7 highlights the differences in relative desirability of *themes* to roles, such as where *D7 - dependability and experience* is highly prized for laboratory-based or regulatory roles. Overall the role profiles generated (see Supporting Information as an example) are judged suitable as targeted descriptors for these graduate roles.

Review of methodology

The use of the ordinal survey scale was most applicable for the intended use, but limited data handling options. As target survey participants were 'untrained participants' remotely spread across the UK and ROI, assurance was not possible that defined equidistant scale intervals would be used correctly. The inclusion of more points on the scale e.g. seven, may have created more differentiation, but also participant burden (Dillman et al., 2014) and clutter on a text labelled scale.

Suleman's (2018) recent comparison of past approaches to building competency frameworks suggests caution in providing a predefined list of skills to employers or graduates; however this study utilized the viewpoints of employers themselves to build the lexicon and associated definitions (Weston et al., 2017), also suggested by Suleman. This is hoped to provide the required validity.

The relatively low sample size (<10) for six of the typical graduate roles (sizes ranging from three to eight) is a limitation, however fewer survey participants were captured for roles less commonly recruited to. As all data was retained, analysis and interpretation was undertaken with careful consideration, and roles with low sample sizes identified in all outputs and published material to highlight possible limitations.

Selected approaches to data analysis have developed discrete role profiles and an exploratory PCA of survey data has enabled the generation of meaningful *themes* from the CFGC language tool. Splitting the original data set, and retesting did not indicate the final framework has significant generalizability (Field, 2013; Hair et al., 2014). The study and criteria applied is suggested to be treated as a discrete experiment, and studies with alternative context, such as another employment sector should be approached as new. However if the same survey was undertaken with the same population type of UK and ROI food industry employers, there is a likelihood for repeatability. CFGC is a credible indicator to students and HEIs of which desirable *themes* are aligned to different food science graduate roles. Exploration of responses during PCA has not indicated grouping of responses by the 14 subpages and thus influence on *theme* construction, for example, t*heme* D2 - *appreciation of the wider world* contains *elements* from two different subpages.

As for studies of this nature, CFGC captures a time-framed view of UK and ROI recruitment in 2017 and will not account for any significant future change. However with no equivalent research-based framework of any age in the UK and ROI it is reasoned that having a tailored framework in place for food sciences students to utilize, is more beneficial than none.

Current use of CFGC framework

Opportunities for use of CFGC following the study have been discussed with the stakeholder group and sessions with students and other wider industry audiences. Material created from the study was compiled into role profiles, highlighting the key desirable *elements* and *themes* in a simple 'infographic' poster. The widely recruited 'NPD, Development or Process' role as an example, is found in Supporting Information. In collaboration with the stakeholder group, a report was created and published in October 2017 on the IFST website (Weston, 2018) . Freely accessible to other degree educators, students and employers, it includes an outline of the framework and access to all 14 infographic posters. A simple interactive open access online tool, has also been created (University of Nottingham, n.d.) aiming to provide careers guidance for students and new graduates and support personal development and job application preparation.

CFGC has direct use in undergraduate career education and personal development. Feedback from surveys and group interviews, following integration into student teaching at UoN has been encouraging. By accessing open access CFGC resources, other UK higher education institutes (HEIs) have introduced the framework to support careers education and research.

Comparison of data to previous studies

Using the frequency of inclusion of a CFGC *element* into one of the 14 typical graduate roles (see Table 5) those with a higher count and thus most likely to be desirable are illustrated in Table 7. For general employability frameworks some 'skills' appear in most studies and include technical (IT), analytical, communication and teamworking as well as 'personal traits' (Suleman, 2018). These all (aside from the IT skills) appear to correlate well with Table 7.

There is limited cohesive previous work to define and describe typical roles for food sciences graduates. Hartel and Klawitter's book (2008) does provide variable levels of detail on required competencies for some USA-based graduate roles. The 10 pathways (chapters) authored by specialists from the field are largely similar to the 14 typical roles established in this project, which is encouraging. However the CFGC framework is built on extensive industry research and material produced allows for ease of review or comparison of all graduate roles for food scientists. With respect to generic graduate requirements, at the time of the study, the IFT standard (2016) in the USA had a 'success skills' domain, less technical in focus, appearing to include five CFGC *elements*. However a newly published IFT requirements (2019) includes 11 standards of which four encompass at least 13 CFGC *elements*, including explicitly *written and verbal communication, leadership, critical thinking* and *independence*. One US institute (Morgan et al., 2006) engaged their Industry Advisory Board in a survey, to establish relative importance of constituents in the entire IFT standard. Whilst acknowledging the restricted number of participants, results demonstrate 11 of the 13 'outcomes' of the success skills group in the standard are rated relatively highly.

No previous work has been undertaken in the UK or ROI to explore specific detail for food science degrees. The labels of the seven sections of 'generic skills' in the UK's QAA benchmark standard (2016) for Agriculture, Horticulture, Forestry, Food, Nutrition and Consumer Sciences are not opposed to the *elements* in CFGC but are essentially a general list. For both UK (QAA) and USA (IFT) contexts it is unlikely anyone would question the advantage of possession of the 'skills' listed in both documents, but no research-based detail has been given with weighting of these specific competencies required against different food science graduate roles.

The list of 'soft skills' for food scientists and technologists generated by ISEKI within Europe (including the UK) has no specific profiles for graduates (Flynn, Wahnström, Popa, Ruiz-Bejarano, & Quintas, 2013; Mayor et al., 2015). Flynn ***et al's.*** study established 'communicating' as the number one sector or non-sector (soft) skill which aligns well to high counts of *verbal* and *written communication* in CFGC (Table 7). Some regional variation was observed; with 'working with others' reaching the top three only in southern Europe (aligned to CFGC), whilst a technical skill, 'product development' is rated more highly in the north (Flynn *et al.*, 2013b), however this possible variation has not been subsequently explored or verified.

Recent and future work

With regard to careers education, collaboration is planned from autumn 2019 with a selection of HEIs exploring the use of CFGC. Food science educators Joyner and Stevenson (2017) observe the 'trend' is to teach to enable students to perform well in specific career pathways. The frequency of particular *elements'* appearance in the 14 role profiles (Table 5) is of interest, and may provide some context to relative priority for development of *elements* in student cohorts. Curriculum mapping of CFGC against UoN food science degree programs was conducted from 2017 to 2018 with subsequent reflection and program development; this will be presented in a future paper.

The encouraging level of industry engagement in the process reflects employers' interest in ensuring degree providers develop 'oven-ready' graduates. CFGC has been introduced to industry at a number of opportunities, to inform and test development of the framework. By employers using CFGC to improve the accuracy of recruitment and selection processes there could be significant value in securing the right candidate, so initial exploration in developing targeted content in job specifications and advertisements has commenced.

Ideally the industry survey should be repeated a few years hence, using the same approach, to test repeatability and gauge if employers' have altered opinions of the desirable competencies for food science graduates (as suggested earlier).

It is suggested CFGC could support compliance in IFST degree accreditation (n.d.) for aspects such as employability, competency development and careers education. It is anticipated inclusion of CFGC into criteria will be approved in due course, resulting in consistency of competency development in UK degree courses beyond compliance to the technical aspects already outlined in the appropriate QAA benchmark statement (2016). Finally CFGC could support initiatives to inspire and inform pupils in compulsory education to choose food science based courses.

Conclusion

A framework, supported by an appropriate language tool was developed, to illustrate the relative importance of specific competencies to the types of jobs food sciences students typically undertake after graduation in the UK and ROI. In shaping a suitable survey and ensuring wide industry participation, a unique data set was acquired. Following suitable data analysis and stakeholder ratification, a framework of desirable competencies for 14 typical roles has been produced highlighting there is no general blueprint for an ideal food science graduate. In this region, CFGC fills a novel gap in knowledge, superseding only general profiles. CFGC has been disseminated in open access resources (ttp://bit.ly/foodgrad and http://www.nottingham.ac.uk/go/foodcareers) and provides an objective and useful reference for educators, students, graduates and employers.

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Author Contributions (required for *JFS* original research manuscripts)

Emma Weston was responsible for the design, implementation and data analysis for the project and drafted the manuscript. Liz Mossop contributed to the design of the survey and manuscript revision. Tim Foster and Jim Crilly engaged industry support for survey completion and contributed to the final construct of the framework, and Tim also the manuscript revision.

Nomenclature or Appendix

N/A.

Supplemental Information – 1 of

Title

Example graduate role infographic – NPD, Development or Process role

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LIST of CAPTIONS FOR TABLES AND FIGURES

Tables *All attached as excel files*

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Table 2 - Summary of the chosen criteria for PCA initial data interpretation.

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Figures *All attached as TIFF or pdf files*

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Figure 9 - Illustration of eight *themes* in CFGC.