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Interdisciplinary Teaching and Learning within Molecular Gastronomy Education: Does it Benefit Students?

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Abstract:

Since the creation of Molecular Gastronomy (MG) as a scientific discipline in 1988 a variety of higher education modules and programmes in that discipline have developed around the world. At the Dublin Institute of Technology, MG has been taught using an interdisciplinary approach since the academic year 2012/2013. A Culinary Science lecturer and a Culinary Arts lecturer work in synergy and teach an interdisciplinary group of Food Science (FS) and Culinary Arts (CA) students. The students' work is assessed, in each academic year, using summative methods i.e. written exam and a project assignment. In the academic year 2016/2017 the assignment reports were, for the first time, jointly written by a member from each student group. The exam results in that academic year were compared and the discussion sections of the assignment reports were analysed for word frequencies. An open-ended questionnaire was also given to the students (n = 28) to get their opinions about the structure and organisation of the MG module. There was no significant difference in the total (exam + assignment) results of the FS and CA students ($p \geq 0.05$). An analysis of results for the module, pre-interdisciplinary vs. interdisciplinary, shows that the CA students benefited significantly ($p \leq 0.05$) from having FS students in the group whereas there was no significant difference in the FS results when there were CA students in the group ($p \geq 0.05$). Almost all the FS students commented that they enjoyed the practical application of MG. Each student said that having an interdisciplinary teaching team added depth and made the module more complete. Results showed that when writing the discussion sections of the assignment report, it would be more beneficial for a CA student to write the discussion section together with a FS student. In conclusion interdisciplinary teaching and learning within Molecular Gastronomy education is beneficial for Culinary Arts and Food Science student participants.

Key words :
Molecular Gastronomy, Interdisciplinary, Project-Based Learning, Team Teaching.

Introduction

The term "STEM education" refers to teaching and learning in the fields of science, technology, engineering, and mathematics (Gonzalez and Kuenzi, 2012). According to the Independent (2016), a newspaper in the UK, one aspect which has been incorporated into the field of STEM is the Arts (STEAM). In many European Union (EU) member states there is unmet demand for graduates in science, technology, engineering, (arts) and maths (STE(A)M) fields (European Commission, 2017a). The European Commission (2017b) will soon launch an up-scaled EU STE(A)M coalition bringing together different education sectors, business and public sector employers to promote the uptake of relevant STE(A)M subjects and modernise STE(A)M and other curricula, including through multi-disciplinary programmes and cooperation between relevant faculties and Higher Education Authorities (HEIs). This will involve building on EU projects to date, including the EU STEM coalition. They state that the evolution from STEM to STEAM reflects recognition within higher education of the increased importance of interdisciplinary approaches. The European University Association (EUA) is the representative organisation of universities and national rectors' conferences in 47 European countries and plays a crucial role in influencing EU policies on higher education, research and innovation (EUA, 2017a). The EUA are convinced that STEAM is not an adequate concept to include the unique contributions of arts, humanities, and social sciences. They would prefer to see greater recognition of the value of a diverse disciplinary and interdisciplinary landscape, including small and rare disciplines (EUA, 2017b). Higher education has a duty to ensure that educational content is up to date, provide relevant study programmes in fields where skills shortages exist and develop methods of learning and teaching that allow students to acquire the breadth and depth of skills they need (European Commission, 2017b).

A relatively new sub-discipline of Food Science, namely Molecular Gastronomy, was created in 1988 (This, 2002). In the world of food science, Molecular Gastronomy is a term which describes the convergence of the two long-established core food disciplines, i.e., food science and the art of the chef (Burke, This and Kelly, 2016). There are many examples of such a convergence e.g. Hervé This the co-founder of Molecular Gastronomy collaborates regularly with his great friend, Pierre Gagnaire, one of the most influential chefs in the world (Iqemusu, 2017). They publish their inventions online (Gagnaire, 2017). Another example of such a collaboration has been between molecular gastronomist, Professor Peter Barham, and chef Heston Blumenthal. Burke (2003) notes that collaborations with chefs are vital but the scientist has much to gain as well.

According to This (This, 2009) there are educational applications of molecular gastronomy: new insights into the culinary processes have led to new culinary curricula for chefs in many countries such as France, Canada, Italy, and Finland, as well as educational programs in schools. Many countries around the world have established Molecular Gastronomy educational modules or full programmes (This, 2017). A variety of teaching and learning approaches are used e.g. projects, online courses, use of a diary/journal and theoretical development and oral and problem based learning (This, 2011; Risbo, Mouritsen, Bom Frøst, Evans and Reade, 2013).

This paper will provide results and discussion of an interdisciplinary approach, between food science and the culinary arts, which is used at the Dublin Institute of Technology for the teaching and learning of Molecular Gastronomy at final year undergraduate level.

Methodology

Student groups: During the academic year 2016/2017 there were two student groups who participated in an MG optional module: (1) fifteen students were fourth years from a Culinary Arts honours degree programme who took an undergraduate module in Molecular Gastronomy and (2) thirteen fourth years from a Food

Science honours degree programme who also took the same undergraduate module in Molecular Gastronomy.

Curriculum: The MG module ran for three consecutive hours, each week, over twelve weeks in one semester of the academic year (36 hours class contact). The module was delivered by a teaching team of a Culinary Science lecturer (theory and practicals) and a Culinary Arts lecturer (practicals).
The main features of the undergraduate module were theoretical lectures and practical kitchen classes that took place during the first eight weeks and a project-based learning assignment that ran over the last four weeks (12 hours). The curriculum included the chemistry and physics of hydrocolloids, foams, and gels; scientific aspects of culinary precisions (old wives tales); formalisms of disperse systems; molecular cuisine (an application of Molecular Gastronomy): ingredients, equipment (e.g. siphons, dehydrators, water baths, Thermomix®, Pacojet®) and methods (e.g. Sous Vide); application of science (chemistry, physics and sensory) and gastronomy to create a novel food and/or drink.

Assessment of the students: (a) A two hour written Exam, weighting 60 %; (b) PBL* assignment; weighting 40 % (Project-based learning and Problem-based learning can both be abbreviated to PBL. However, for the purposes of this paper PBL will be used to abbreviate Project-based learning only.).
In the academic year 2016/2017 students were asked, for the first time, to work on the PBL assignment in teams of two (or three max), at least one student to be from a Culinary Arts programme and one from a Food Science programme. Prior to this each student wrote an individual assignment report.
The four assignment classes accounted for 40 % of the total mark for the module. Each team decided among themselves how they would achieve the aims of the assignment. They decided if and when to hold meetings, who would develop the recipes and who would create which parts of the recipes. The students also decided what results needed to be recorded and how this would be done and by whom. For example, informal sensory analysis was carried out each week if appropriate. Score sheets were designed, and results recorded. They also decided who would write which parts of the report. It was to be written by all team members and the 'Table of Contents' should be structured to identify which student wrote which part. In the last class the dish(es) were prepared, assembled and showcased for final sensory analysis and photographing.
In this academic year the assignment brief was to create a drink and a dish using one or more seaweeds and/or seaweed extracts. The functional properties of the seaweed(s) and/or extracts was be exploited to enhance the sensory properties of the drink and dish. Students were asked to submit a detailed report including Aim, Materials and Methods, Results, Discussion, Conclusions and References as well as a log book for the work carried out each week.

Evaluation of Exam and Project : The results of the written exam (weighted 60 %) were combined with the results of the project (40 %) and a final percentage calculated (60 %+40 %=100 %). In order to pass the module students must have obtained an overall mark of 40 %

Questionnaire: Each student (n = 28) was asked to answer a series of open-ended questions relating to the MG module that they undertook. By using an open-ended questionnaire, emerging data can be collected with the primary intent of developing themes from the data (Creswell, 2003). The initial questions were general relating to prior qualifications and any work experience. The following qualitative questions were more detailed so that participants opinions and observations could be uncovered. 87 % of Culinary Arts students and 92 % of the Food Science students responded to the questionnaire.

Statistical analysis : The final results of the Culinary Arts students (pre-interdisciplinary vs.

interdisciplinary) were compared, using a *t*-test at the 0.05 significance level. Also in the academic year 2016/2017 the undergraduate final results (exam + assignment) for the Culinary Arts and for the Food Science students were compared and again a *t*-test was carried out at the 0.05 level of significance to determine if there was a significant difference in the results obtained between the two different groups of students (*Excel, Microsoft Office 365 ProPlus*).The *t*-test compares two means and tells you if they are different from each other. The *t*-test also tells you how significant the differences are.

Content analysis : The discussion sections of the assignment report for the undergraduates and postgraduate students were analysed for word frequencies using a word cloud. These (also known as text clouds or tag clouds) work in a simple way: the more a specific word appears in a source of textual data (such as a speech, blog post, or database), the bigger and bolder it appears in the word cloud. You can easily see the similarities and differences between two reports at a glance. Frequency of word use was analysed using Wordcloud (Wordcloud, 2018).

Results and Discussion

Evolution of the MG module (since 2009 to the present time)

The MG module was run for the first time in the academic year 2009/ 2010. Then the module was taught only to Culinary Arts students by a Culinary Science lecturer. In the academic years 2010/2011 and 2011/2012 the module was co-taught by both a Culinary Science lecturer and a Culinary Arts lecturer to Culinary Arts students only. Final year students from a Food Science degree programme joined the Culinary Arts students in the academic year 2012/2013 until the present time. The module continues to be taught by the teaching team.
When only Culinary Arts students took the module and were taught by the teaching team, the mean result (exam + assignment) for the module in

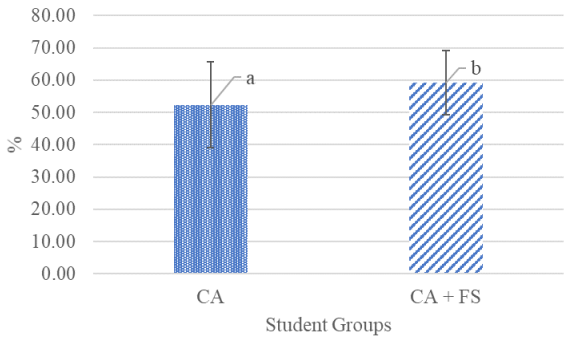

Figure 1.Mean results for CA students without FS students and CA students with FS students. Bars bearing different letters are significantly different, $p \leq 0.05$.

2010/2011 and 2011/2012 (n = 30) was 52.3 % +/- 13.3. When the Food Science students joined the module in the academic years 2012/2013; 2014/2015 and 2016/2017 the mean result for the Culinary Arts students increased significantly ($P \leq 0.05$) to 59.3 +/- 9.9 (*n* = 30). In the academic year 2013/2014 only one Culinary Arts student took the module. The mean result for the Food Science students (*n* = 12) that year was 65.3 +/- 8.4. There was no significant difference between the results of the Food Science students when there was only one Culinary Arts students in the class vs. the results of the Food Science students (2014/2015 (*n* = 8); 2015/2016, (*n* = 22)) with Culinary Arts students in the class (*n* = 10, 5 in each academic year). In the academic year 2016/2017 the ratio of Culinary Arts students to Food Science students was close to 50:50 (Figure 2) and it was the first time that a member from each of the student groups worked together on the assignment for the module. Prior to this each student submitted an individual assignment. A detailed analysis of the MG module which took place in 2016/2017 is presented below.

Academic Year 2016/2017
Student groups taking the optional MG module

The number of students taking the MG module is given in Figure 2.

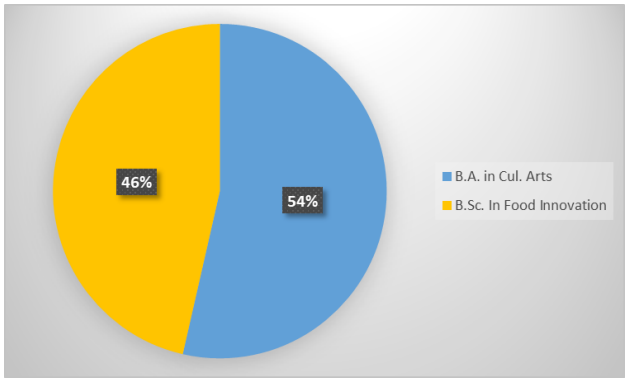

Figure 2.Student groups taking modules in Molecular Gastronomy. The % represents the number of students in each group in relation to the total number of students.

Prior educational qualifications and work experience

There has been a universal trend to increase access to higher education (Jeffrey, 2009) and students accessing higher education have diverse social and academic backgrounds (Beylefeld, Hugo and Geyer, 2008). The term 'Advanced Entry' is given to the route which is open to an applicant with previous work experience and/or educational achievements that are considered directly relevant to the programme they wish to apply for. In such a case, it is possible to gain entry to the second or subsequent year of an undergraduate programme. There were three examples of students with prior qualifications on the undergraduate MG module. Two of the Culinary Arts students had a 'Higher Certificate in Culinary Arts' whereas one of the Food Science students had a 'Higher Certificate in Food Science and Management'. All other students had no prior third level qualifications.
As part of their undergraduate programme, students normally complete a number of months in a work environment. This is in accordance with the policy of many governments where undergraduate students should be encouraged to spend some time in a work or service situation, and formally acknowledge such work through accreditation or inclusion in the student's Diploma Supplement. The Culinary Arts students had completed three-month internships in year 3 of their 4 year programme and in some cases were currently working part-time in Michelin star restaurants, as pastry chefs, chef de partie, wine retail, food styling, and in the Culinary and Hospitality sector. Similarly, the Food Science students had completed work placements in year three of the four year programme in New Food Product Development, Food Processing, Health and Safety and Food Safety.

Scientific learning prior to taking the UG module in Molecular Gastronomy
Culinary Arts Students

Students of the four year B.A. in Culinary Arts had previously studied modules in Food and Life Sciences. In years 1 and 2 they undertook core modules in Culinary Science and Technology, in Nutrition and in Food Safety. In year 3 they studied Food Product Development (theory) and in year 4 they apply that theory in the kitchen to develop their own food product. In year 4 they also studied Occupational Health and Safety and many had taken an optional module in Nutrition.

Food Science Students

The scientific modules undertaken during the four year programme were Biology, Chemistry, IT, Food Processing, Microbiology, Nutrition, Mathematics, Physics, Regulatory Affairs, Food Product R&D, Sensory Evaluation, Food Ingredients & Consumer Foods and Food Engineering.

Assessment and evaluation of student's knowledge and skills

Summative assessments enable tutors to evaluate, and assign a mark to their students' learning at a particular point in time (The

University of Manchester, 2017). Students of the undergraduate module in Molecular Gastronomy were given two forms of summative assessment i.e. a two-hour written end of semester exam paper and a project-based learning assignment. The written exam was given to test the knowledge of the interdisciplinary student population to determine if they had achieved the learning outcomes of the module. These were to (1) demonstrate the application of scientific and gastronomic knowledge and skills and (2) apply concepts, theories and analysis in the development of novel recipes, dishes and food and beverage products.

Lucas, Dippenaar and Du Toit (2014) stress the importance of establishing methods of facilitating learning that will require students to move towards a deeper level of learning and thus to acquire the knowledge, skills, competencies and attitudes that will enable them to perform better at all levels assessed. Favouring the more traditional essay-type exam is associated with greater general knowledge, a deep learning style, and openness (Furnham, Christopher, Garwood and Martin, 2008). They explain that there is a clear negative correlation between surface learning style and preference for the essay-type exam method.

However, it was noted by Eilks and Kapanadze (2012) that learning science, beyond cold memorization of facts and theories, is never a passive diffusion of knowledge. They further highlighted that if new information is presented, challenging the prior understanding of the learner, cognition will be accommodated which will result in new knowledge. PBL was used to challenge the facts and theories which were discussed during the theoretical lectures of the undergraduate MG module as well as scientific knowledge acquired from previous studies. According to Klein (2005) truly interdisciplinary models restructure the curriculum with explicitly integrative activities that are typically theme-based, problem-based, or question-based, and organised within a curriculum that has a spine of required core courses ensuring attention is paid to interdisciplinary theory, concepts and methods.

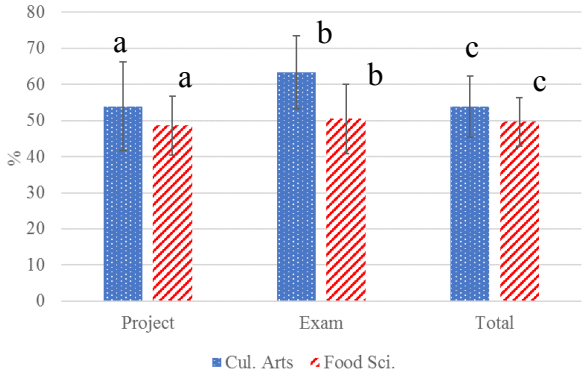

Figure 3.Mean results for the two student groups who took the undergraduate MG module in 2016/2017. Within project, exam and total, bars bearing different letters are significantly different, $p \leq 0.05$.

As Figure 3 shows, in the academic year 2016/2017 the mean final total percentages for the undergraduate Culinary Arts students and the Food Science students were 53.9 % +/- 8.5 and 49.7 % +/-6.7 respectively. Overall there was no significant differences between the results for the exam, project or final totals of the two groups ($p \geq 0.05$). The difference between coursework marks and examination marks tends to be greater in some disciplines than others (Richardson, 2015)

Undergraduate exam paper in January 2017

The exam questions are shown in Table 1. The instructions are to answer three (3) of five (5) questions. Duration 2 hours. All questions carry equal marks.

As can be seen in Table 1 the students from the two programmes had different preferences when answering some of the exam questions. This is understandable considering that they have different educational backgrounds. It was important to design the exam paper to allow for a balanced choice of questions.

Table 1.Exam questions and % answered by Culinary Arts (CA) students and by Food Science (FS) students.

Question	%CA	%FS
Discuss the chemical and physical properties of the following gelling agents: Agar; Gelatine; Low Acyl Gellan and High Acyl Gellan	86	39
Discuss the scientific approach you would take to reduce the effect of variability when testing an old wives tale.	50	85
Write detailed notes on each of the following: Sous vide; Hydrocolloids; Siphons; Centrifuges.	100	100
Describe: The chemical reaction which causes spherification to occur. The chemical reaction which causes reverse spherification to occur.	43	31
Discuss Xanthan gum in detail under the following headings: Source; Physical and Chemical properties; Uses and applications in the kitchen; a recipe using Xanthan gum.	71	54

Undergraduate PBL assignment

The students were asked to create a drink and a dish using one or more seaweeds and/or seaweed extracts. Larmer (2014) describes the main elements of project-based learning as multi-subject, lengthy (weeks or months), following general variously named steps, creating a product and possibly using scenarios but often involving real-world, fully authentic tasks and settings. To comply with the assignment brief, the students had to apply their knowledge of chemistry, physics, nutrition, sensory science, culinary science, culinary arts and gastronomy. The project ran over four weeks, following defined steps, in an industrial kitchen setting and resulted in a finished drink and dish. The students worked in pairs or threes, with at least one student from Culinary Arts and one from Food Science. This meant that they had to learn to work together and communicate with each other. Eilks and Kapanadze (2012) observed that communication and negotiation between learners provokes meaning and making and shaping of concepts in their minds. They emphasize that student-active learning in science should provoke various forms of communication

Student evaluation of the modules
Highlights of the MG modules

Each of the two student groups outlined, what for them were, the highlights of the modules. Both undergraduate groups enjoyed the kitchen practical classes. The Culinary Arts students also enjoyed developing their own recipes, and the classes on Sous-vide and the precisions/old wives tales. Some of the Food Science students found that through the module they were able to experience the links between science and food.

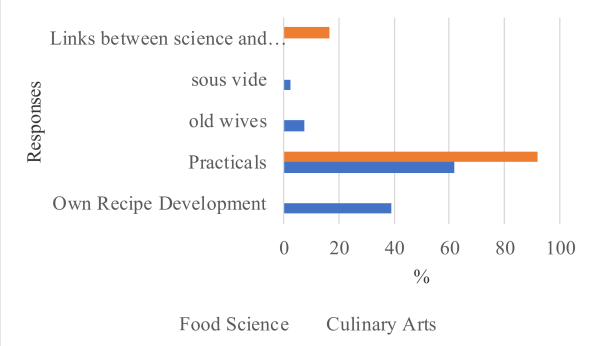

Figure 4.The main highlights of the undergraduate MG module

Improvements that can be made to the modules

According to O'Connor (2006) module design and development is a dynamic process and to obtain meaningful information and to improve

the module, evaluation mechanisms such as questionnaires must be put in place. The students of the modules were asked what improvements could be made. A few of the Culinary Arts students would have liked more time to develop the product and to get more feedback and another would have liked if more time constraints could have been set. A few of the Food Science students suggested that in the first class a basic introduction to the kitchen would be 'really helpful'.

Theoretical lectures before the practical kitchen classes. Examples where the theoretical knowledge helped in the understanding of the practical application.

The reality is that there is no shortage of teaching strategies. However, the key issue for module designers is selecting the strategies that are most likely to support the achievement of learning outcomes and are suitable for use in the teaching context while considering the resources available (Donnelly and Fitzmaurice, 2005). The most effective strategy was to have theoretical lectures followed by the application of knowledge in practical kitchen classes. Then in the last four weeks of the twelve-week module the students could apply their knowledge and skills in their project assignment. Both the Culinary Arts and Food Science students all agreed that learning about the physical and chemical properties of compounds/ingredients such as maltodextrin, gels, xanthan gum 'helped us to understand more clearly how things work before applying the knowledge practically'. Another student said that they like to know beforehand why 'it happens'. It was suggested that a theory class on sensory analysis would be beneficial for Culinary Arts students while a basic cooking class would be beneficial for Food Science students.

Team teaching

Team teaching can be applied in different course contexts. It offers benefits such as different explanations of the same concept by multiple teachers or teacher development through mutual reflection on action (Liebel, Burden and Heldal, 2017). The responses from the undergraduate students showed that they found team teaching allowed for classes that had more depth and were more complete. They said that the scientific approach and practical applications were reinforced as a result. However, because of logistics the students were divided between two kitchens for practicals and the PBL exercise, with the same lecturer assigned to the same kitchen each week. It would have been more beneficial if the lecturers had alternated between the kitchens.

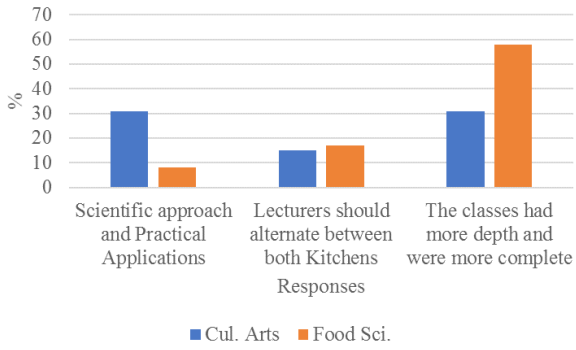

Figure 5.Undergraduate student comments about team teaching

Clark and Button (2011) found that through team teaching, students were learning from instructors, instructors were learning from students, students were learning from students, instructors were learning from instructors, and all were learning and sharing knowledge with the greater community. The Culinary Arts students commented that they learnt from the Food Science students the importance of accurate measurements and recording all parts of the investigation (including time, temperature etc.). They also learnt how to report and formulate a theory and how to recreate the recipe again. Additionally, they learnt how to design sensory analysis score sheets and how to use arbitrary numbers to label sensory samples. All of the

Food Science students commented that they learnt about kitchen practices from the Culinary Arts students. This included food preparation, the use of equipment such as siphons and techniques such as chopping and forming quenelles. They also learnt about temperature control, time management and team work.

Project-based learning assignment

When asked what they had learnt from doing the PBL assignment, the majority of undergraduate students wrote that they had learnt about flavours, versatility of seaweeds (including its use for vegetarian recipes) and recipe development. They also mentioned that they had learnt about the application of Molecular Gastronomy. The Food Science students learnt culinary skills and techniques.

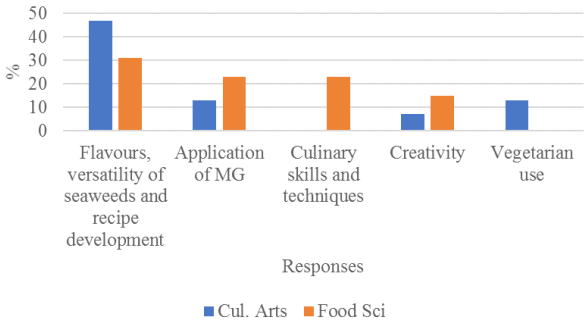

Figure 6.What the students said they learnt from the module assignment on Molecular Cooking using seaweed and/or its derivatives

An analysis of the structure of the written PBL assignment reports of the undergraduate students revealed that all students followed the brief and used the headings Aim; Materials and Methods; Results; Discussion; Conclusions and References. This written structure is typically used when writing a scientific laboratory report (Helmenstine, 2017). A further analysis of the report contents focused on the discussion section of all of the reports. As Borja (2014) noted, it is probably the easiest section to write but the hardest section to get right because it is the most important section. There were thirteen undergraduate reports submitted and the discussion section was either written by all two or three of the students in the group (31 %); a Food Science student (39 %); a Culinary Arts student (15 %); or undetermined (15 %).

Figure 7. (top left) An example of the word frequency of four undergraduate student who were studying Food Science; (top right) An example of the word frequency of two undergraduate students who were studying Culinary Arts; (bottom) An example of a word frequency from three groups of students (CA + FS).

Figure 7 top left emphasises that, in the discussion section, the Food Science students used words mostly relating to sensory analysis such as sample(s), judges, texture, sensory and colour. The Culinary Arts students had previous experience of writing lab reports for scientific practical classes in years one and two of their current degree programme. In the MG module they were able to use this knowledge to help in their academic report writing. However, very few of the Culinary Arts students (15 %) wrote the discussion section of the assignment and those that did used

mainly processing and ingredient terms but included some scientific terms such as texture, analysis and mixture (Figure 7 top right). An examination of three of the reports written conjointly by Food Science and Culinary Arts students shows they mostly used both scientific and culinary related words such as sensory, analysis, recipe, aperitif, mixture, texture, gastronomy and flavour. The results of the word cloud in Figure 7(bottom) indicate that in order to strengthen the scientific content of the discussion section, it was more beneficial for a Culinary Arts student to work together with a Food Science student rather than alone.

Holley (2017) states that given the multiple challenges facing 21st-century society, the question of interdisciplinarity is urgent. How knowledge is defined and disseminated; how and what students learn; and how higher education can be responsive to its external environment are crucial issues facing educators.

Overall the results of this study show that the interdisciplinary teaching and learning approach used in the MG module was beneficial for the student participants but in different ways. The module grades for the Culinary Arts students improved by having Food Science students in the class. As MG is a scientific sub-discipline of Food Science it is logical that the knowledge gained in the module would be scientific rather than socially-scientific.

Appleby (2015), explains that critical thinking skills are used and developed as students look across disciplinary boundaries to consider other viewpoints and also begin to compare and contrast ideas and concepts across subject areas. Such interaction is in support of the constructivist paradigm which allows for new knowledge construction and a deeper understanding of ideas than in disciplinary study. Almost all the Food Science students found the practical kitchen classes to be the main highlight of the module. These classes together with the assignment kitchen classes allowed them to develop their culinary skills and techniques which helped them to be more creative. Interdisciplinary knowledge and application of different disciplines can lead to greater creativity (Appleby, 2015). It was important that creativity would be nurtured during the MG module so that, through scientific knowledge and culinary skills, students could develop innovative drinks and dishes.

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