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Assessment and Evaluation of Student Learning Through a Project-Based Assignment on Note by Note Cooking

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Abstract

Many innovative teaching and learning methods are used in higher level education including project-based learning (PBL). Since 2012 a PBL assignment project has been undertaken by master students of the Advanced Molecular Gastronomy module at Technological University Dublin (TU Dublin). The aim is to stimulate student learning and creativity by using Note by Note cooking in a PBL assignment while at the same time complying with the requirements of the annual International Note by Note contest which is held in Paris, France. Direct and indirect assessment methods were used to assign individual grades and to gather student feedback about the module. The direct methods were both formative and summative. The indirect method used was a student feedback questionnaire. Results to date (2012-2019) showed that 92% of learners successfully passed the module. However, further evaluation of individual assessment results revealed that most students achieved higher scores for finding and using resources, asking further questions and developing their own answers than for analysing, synthesising and evaluating information ($P \leq 0.01$). Overall students were happy with the module content and said that they learnt about Note by Note cooking, chemical compounds, researching, independent-thinking and perseverance. In future students should carry out a more in-depth analysis, synthesis and evaluation of information.

Keywords: Molecular Gastronomy; Project-based learning; Note by Note Cooking

1 Introduction

Food science education has undergone a paradigm shift from a delivery of knowledge in a traditional lecture and laboratory system to a more inquiry-based and discovery process (Iwaoka, Britten & Dong, 1996 cited in Shewfelt (2012)). Traditional style laboratory practicals often leave little room for creativity or contextualisation, and are usually a verification of a known quantity or a testing of a theory that has been presented in lectures (Mc Donnell, O'Connor & Seery, 2007). Innovations such as the use of journals, team-based learning, simulations, problem-based studies, and other techniques engage students more actively in the learning process (Shewfelt, 2012).

Many terms are used for learning through inquiry, including 'inquiry-based learning', 'guided-inquiry', 'problem-based learning' and 'research-based teaching' (Spronken-Smith & Walker, 2010). Project-based learning (PBL) uses instructional strategies that are intended to engage students in authentic, "real world" tasks

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to enhance learning. It can be an individual or group activity that goes on over a period of time, resulting in a product, presentation, or performance (Donnelly & Fitzmaurice, 2005). These authors explain that PBL typically has a timeline and milestones, and other aspects of formative evaluation as the project proceeds. Students engage in deeper learning, high-level reading and increased motivation (Bell, 2010). One study, carried out over the course of three years in Britain, showed that three times as many PBL students achieved the highest possible grade in mathematics in the national exam than the students at a traditional school. Students at the PBL school were equally able to answer procedural questions that used formulas, but they were superior in answering applied and conceptual problems (Boaler, 1999). In the United States of America, Thomas (2000) noted that studies conducted on the effectiveness of using PBL over three years in a school in Iowa showed that reading gains "ranged from 15% in one school to over 90% in two other schools while the district average remained the same", and in Boston, eight graders exhibited the second highest scores in the district on the Stanford 9 open ended reading assessment. Similar findings in Portland, Maine, led to a conclusion that a middle school using a PBL approach showed significant increases in all achievement areas on the Maine educational assessment test for cognitive development after only one year of using the PBL approach. The gains made by this school were three to ten times higher than the state average. Similar improvements were reported for schools in Colorado, Illinois, Georgia, Cincinnati, Ohio, Memphis, Tennessee, and New York City. Doppelt (2003) states that students who took part in PBL were motivated to learn their discipline and willing to work on their projects for a longer time. In another study, attendance was found to be higher in PBL schools (Thomas, 2000).

The process used in PBL can replicate the commonly used systemic approach to resolving problems or meeting challenges that are encountered in life and career. Historically the project-based approach has been widely used in the science classroom (Krajcik & Shin, 2014) and as a result, the findings from evaluations of science orientated PBL has helped to build evidence for the efficacy of the design principles (Condliffe, Visher, Bangser, Drohojowska & Saco, 2016).

Molecular gastronomy, a sub-discipline of food science, has since 2009 been established as a subject discipline at the Technological University Dublin (abbreviated as TU Dublin and formerly known as the Dublin Institute of Technology) in Ireland (Burke & Danaher, 2018; Burke, Danaher & Traynor, 2012). The culinary activity called "Note by Note" cooking is an application of molecular gastronomy (MG) and it makes an important contribution to the fight against spoilage, while sparing water, energy, foodstuffs, and taking care of the environment (This, 2017). In this type of cooking, traditional food ingredients are not used to make dishes but pure compounds or mixtures of pure compounds are used (Burke & Danaher, 2016; This, 2014). They are assembled by the chef to design the shapes, colours, tastes, odours, temperatures, trigeminal stimulation, consistencies, nutritional aspects, and more, of the desired dish (This, 2017). The project-based principles for the Note by Note assignment are shown in Figure 1.

This paper provides results and discussion on the assessment of individual students and an evaluation of the achievement of the module learning outcomes.

2 Methodology

2.1 Student Group

The student group were TU Dublin students from the taught M.Sc. programme in Culinary Innovation and Food Product Development who took the postgraduate module in Advanced Molecular Gastronomy (approximately 13 in each academic year since 2012/2013 until the present time, 2018/2019).

2.2 Curriculum

The module ran for three consecutive hours, each week, over twelve weeks in one semester of the academic year (36 hours class contact). It was delivered by a teaching team of a culinary sci-

Figure 1: Stages in the Note by Note project-based learning assignment

ence lecturer (theory and practicals) and a culinary arts lecturer (practicals).

The main features of the postgraduate module were theoretical lectures, practical kitchen classes, and a PBL assignment that was conducted during the last five classes (5×3 hours = 15 hours). The curriculum included theory lectures about the chemical reactivity of pure compounds such as sodium alginate and calcium chloride. Toxicological and nutritional facts relating to chemical compounds used for Note by Note cooking were presented and discussed. Students were asked to check information from the Food Safety Authority of Ireland and the European Union regarding the maximum permitted daily intake levels of compounds that they were using in their Note by Note dishes. Lectures and practicals were focused on the chemical and physical properties of pure compounds such as gelling agents, liquid nitrogen and dry ice, scientific testing of culinary precisions, demonstration of how a Note by Note dish is made and the creation of an entirely new food using Note by Note cooking. Culinary precisions are all the technical additions that are not part of the operating protocol of a recipe; e.g. the operating protocol for an orange jam (marmalade) recipe involves slices of oranges plus sugar plus heat and the culinary precision is that it is sometimes 'said' that you have to cook until a drop of the liquid forms a gel on a cold plate (Burke, This & Kelly, 2016).

2.3 Assessment and Evaluation of the assignment

Breslow (2007) emphasises that best practice in educational research dictates triangulating data. If several different sources of data are used, it increases the probability that the findings present an accurate picture. The essential elements of the assignment were identified as (1) finding and using resources, asking further questions, developing answers and (2) analysing, synthesising and evaluating information. These essential elements were then matched against the learning outcomes of the module and assessment methods. Direct and indirect assessment methods were used in this study and are outlined in Table 1.

Direct assessment

Summative assessment is product-oriented and assesses the final product, whereas formative assessment focuses on the process toward com-

Table 1: Learning outcomes matched to essential elements of the PBL exercise and corresponding assessment methods

Essential element	Learning Outcome	Assessment	
		Formative	Summative
1. Finding and using resources, asking further questions, developing their own answers (Dahm, 2014)	2. Produce a novel and innovative dish/cocktail using ingredients and techniques associated with applications of Molecular Gastronomy.	Informal observation	Academic report
	3. Develop new skills to a high level through using novel techniques such as Note by Note cooking.	In-class activities	Sections 1,2,7: Literature search relating to Molecular Gastronomy, Note by Note cooking and the specific theme for the assignment. Aim(s) of assignment. 3,8: Materials, Equipment, Methods/Recipes. Recording kitchen trials and improvements to be made. International competition
2. Analysis, synthesis and evaluation of information (Dahm, 2014)	1. Critically evaluate the fundamental scientific theories of Molecular Gastronomy.	In formal observation	Academic report
		In-class activities	Sections 4,5,6,7: Results, discussion and conclusion(s) and related supporting literature.

pleting the product (Northern Illinois University, 2012). Both were used to assess the students.

Formative

- Informal observation
  The teaching team (culinary science lecturer and culinary arts lecturer) were both present during the kitchen classes each week. They were able to informally observe visually, each individual student's approach to planning and development of the Note by Note dishes over the five weeks of kitchen trials.

- In-class activities comprised four experimental kitchen trials which included physical and chemical tests, informal sensory analysis, and photographing of their dish(es) and, in the last class, a presentation of the final dish.

Summative

- The academic report
  An academic report on the work which was carried out during five assignment classes accounted for 100 % of the total mark for the module. The sections in the report were an (1) introduction, (2) the aim of the assignment; (3) final materials and methods; (4) results; (5) discussion; (6) conclusions, (7) references and (8) a log book for each of the 5 weeks of the assignment (Table 2). To pass the module, students must have obtained a final mark of 40 %, as calculated by formula 1, in their Note by Note cooking project report.

Formulae

1) Final % awarded to student
   The academic report was marked out of a maximum total of 100
   Introduction (10 marks) + aim (5 marks) + final materials and methods (20 marks) + results (20 marks) + discussion (30 marks) + conclusion(s) (5 marks) + references (5 marks) + log book (5 marks) = a final % (awarded to the individual student).
   Formulae 2 and 3 below were used by the teaching team to evaluate achievement of the learning outcomes of the module.

2) Calculation of Essential Element 1
   Introduction (10 marks) + aim (5 marks) + final materials and methods (20 marks) + references (5 marks) + log book (5 marks) = Total number/45 X 100.

3) Calculation for Essential Element 2

Results (20 marks) + discussion (30 marks) +conclusion(s) (5 marks) + references (5 marks) = Total number/60 x 100.

- The International Note by Note contest The dish that most closely matched the entry requirements of the Note by Note International Contest was selected by the teaching team and entered. If chosen for the finals it was further evaluated by an international jury of scientific, culinary and industry experts. Each year the theme is different, for example in 2018 Hervé This (co-founder of Molecular Gastronomy) decided on the theme 'But the crackling is superb' in remembrance of Professor Nicholas Kurti, his fellow molecular gastronomy co-founder. The aim was to create a dish to include the consistencies of crispiness, crunchiness and crackling by following the principles of Note by Note cooking and the originality of the use of compounds would be evaluated (This, 2017). Each proposed dish would be described in a Word file by a recipe giving (1) the ingredients, including quantities, (2) the process and photographs were to be included. The candidates would have to accept that their recipes and pictures could be used (with their name) by the organizers and the partners of the contest.

Evaluation criteria included:

- Feasibility, reproducibility
- Making crisp, crunchy, crackling products
- Originality of the work.
- The use of pure compounds rather than fractions.
- The ingredients and completed dishes should not be toxic.

The complexity of flavour: dishes should have a shape, consistency, odour, taste, trigeminal sensation, and the effect of temperature should be considered.

2.4 Indirect assessment

Questionnaire

The 2016/17 student cohort (n = 13) was asked to answer a series of open-ended questions relating to the MG module (theory lectures, practicals and Note by Note cooking assignment) that they undertook. By using an open-ended questionnaire, emerging data was 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. Twelve of the thirteen M.Sc. Students (92 % response rate) answered the questionnaire.

Statistical analysis

In order to determine if there was a significant difference between the results of essential element 1 (formula 2) and essential element 2 (formula 3) a t-test was carried out on the assessment results for students who had an overall standard of fair (40-49%); good (50-59%); very good (60-69%) or excellent (70-100%) using Excel (Microsoft Office 365 ProPlus). The t-test was used to compare means and show whether they were different from each other and how significant those differences were. A correlation coefficient was also calculated using Excel (Microsoft Office 365 ProPlus) to determine the strength of relationships between the individual student grade and the project-based essential elements 1 and 2.

3 Results and Discussion

3.1 The task and project brief

At the beginning of the twelve week module, the task and project brief was outlined and discussed with the students in the introductory class of the Advanced Molecular Gastronomy module. As Grant (2002) outlines, the task, guiding question, or driving question explicates what has to be accomplished and embeds the content to be studied. The tasks should be engaging, challenging, and do-able.
By using PBL, students can explore the driving questions by participating in scientific practices and they learn and apply important ideas in the discipline (Krajcik & Shin, 2014). Through this learning approach the students in TU Dublin were able to critically evaluate questions about food structure, sensory properties, nutrition and toxicity. This approach was underpinned by the fact that Note by Note cooking had a real-world context in that it was contributing to the development of a sustainable food system to feed the expanding world population.

3.2 Research and Planning

Students then started researching their dish or dishes. They accessed information from library resources, developed a theme and created drawings and designs of what their dish would look like. They could use the information from the theory lectures and practical classes which were given in weeks 1-7 of the module. It was important when designing the dish to ensure that all sensory attributes would be acceptable. Appropriate sensory tests needed to be identified. The students followed the PBL approach as described by Larmer and Mergendoller (2015) which involved an active, in-depth process over time, generating questions, finding and using resources, asking further questions, and developing their own answers.

Table 2: Evaluation criteria for the academic report

	Marking Scheme				
Report sections	Excellent (> 70%)	Very good (60-69%)	Good (50-59%)	Fair (40-49%)	Fail (< 40%)
1. Introduction (10 Marks)	Consideration of a wide range of relevant literature sources relating to molecular gastronomy, Note by Note cooking and the specific assignment topic. These sources were considered critically and analysed thoroughly. Accurate referencing	Able to critically appraise the relevant literature and theory gained from a variety of sources. Referencing is mainly accurate.	Clear evidence and application of readings which are relevant to the subject. Referencing is mainly accurate.	Literature is presented uncritically, in a purely descriptive way and indicates limitations of understanding.	Published documents summarised, but not linked in any effective way to the aim(s) of the assignment.
2. Aim of the assignment (5 Marks)	Clear concise and coherent statement of what is to be achieved.	Clear statement that indicates achievability.	Aim(s) stated, but either too many or is not concise enough.	Aim(s) stated but unclear.	The aim(s) does not link to the work carried out.
3. Final Materials and Methods (20 Marks)	Materials and methods clearly described. Details of makes and models of all equipment provided. Accurate and clear recipes for all elements of a dish and/or cocktail. Accurate referencing.	Good description of materials and methods. Recipes included. Referencing mainly accurate.	Adequate description of the materials and methods used. Referencing is mainly accurate	Vague and with some gaps in the materials. Methods are not presented in a logical order but are partially related to the project aim(s). Some attempt at referencing.	Incomplete or no list of materials used. Methods, handled incompletely, with little evidence of link to aim(s). Inaccurate or no recipes included.
4. Results (20 Marks)	Relevant results clearly set out. All figures, charts (sensory and spider plots), tables, photos etc. are correctly and uniformly labelled. Photos (300 dpi).	Results are well presented. All relevant figures, charts, tables, photos etc. are included.	Results are adequately presented. All relevant figures, charts, tables, photos etc. are included.	Results are not presented in a logical order. Inaccuracies in labelling of figures, charts, tables, photos etc.	Incomplete set of results with inaccurate or no labelling of figures, charts, tables, photos etc. No clear link between results and assignment aim(s).
5. Discussion (30 Marks)	The results are compellingly supported by appropriate evidence. In depth discussion and exploration of the driving questions.	The results are clearly supported by appropriate evidence.	The application of analysis and validity of results and evidence are indicated	Results are repeated but very little attempt of a discussion of their relevance is presented.	Findings bear little or no relation to evidence.

Table 2: Evaluation criteria for the academic report (cont.)

	Marking Scheme				
Report sections	Excellent (> 70%)	Very good (60-69%)	Good (50-59%)	Fair (40-49%)	Fail (< 40%)
6. Conclusion(s) (5 Marks)	Conclusions are clearly and succinctly stated and are relevant to the aim(s). They are linked to results and discussion.	Conclusions stated which are relevant to the aim(s) and linked to results and discussion.	Attempts to draw conclusions from results are not entirely convincing.	Conclusions are weak and do not really follow from the results and discussion.	No detectable conclusions
7. References (5 Marks)	Complete and accurate referencing in Harvard format	Referencing is mainly accurate.	Referencing is mainly accurate.	Some attempt at referencing.	Incomplete, unsystematic or no reference list. Referencing errors.
8. Log book (5 Marks)	All 5 weeks work to be included. Written in correct format.	All 5 weeks work is included and it is written in the correct format but more detail is required	All 5 weeks work is included and it is written in the correct format but a lot more detail is required	Not all work is included. Not always in a logical sequence. Lack of detail.	Incomplete and not written in the correct format.

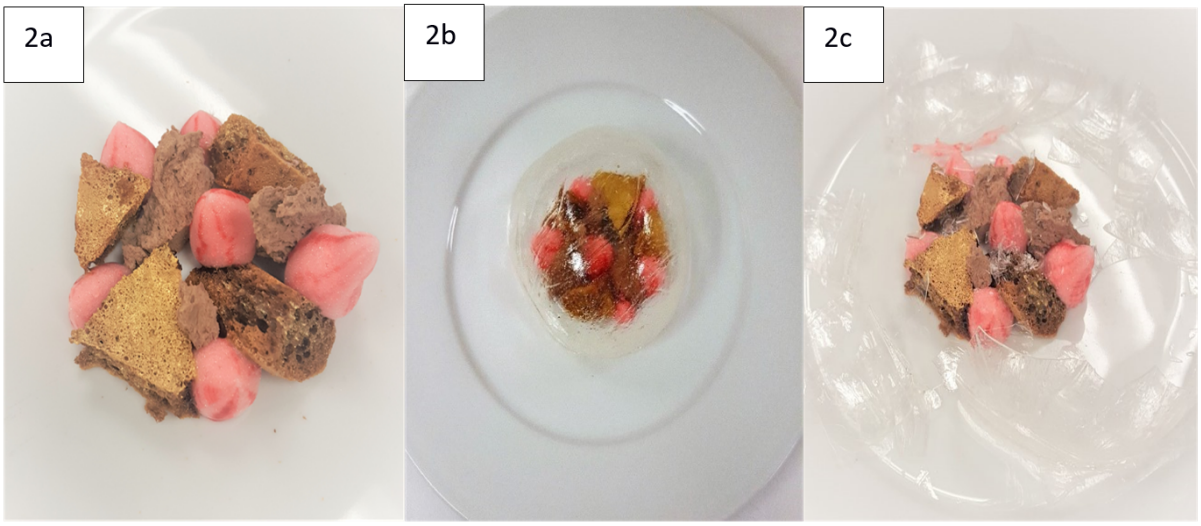

Figure 2: '*A Reminisence of a Black Forest Gateaux*' (2018). Dish by Ruth Kelly. Theme: Crispiness, Crackling, Crunchiness. Figure 2a shows the dish without the isomalt dome. Figure 2b shows the dish covered with the intact isomalt dome. In Figure 2c the diner shatters the dome with a spoon and flavoured smoke is released, which gives the impression of a misty forest atmosphere

Figure 3: Gold colouring being applied to cut honeycomb - Image: Ruth Kelly (2018).

3.3 Kitchen trials and improving recipes

In the last five weeks of the twelve week module, the students carried out three hour kitchen classes once a week. The time planning for these classes was done during the first seven weeks of the module. Ingredients and equipment needed to be ordered a minimum of two weeks in advance of starting the kitchen work. During the kitchen trials, the students kept a log book and recorded information about ingredients and equipment, their progress and recommendations for the next week. Grant (2002) notes that the process and investigation stage of project-based learning includes the steps necessary to complete the task or answer the guiding or driving question. The process should include activities that require higher-level and critical thinking skills, such as analysis, synthesis, and evaluation of information. For example in 2018, it was necessary for the students to explore what was meant by crispiness, crunchiness and crackling and to design a dish with food structures that would give the sensation of these consistencies. This was not an easy task and the student who best met the challenge developed these elements in her dish. An isomalt ((3R,4R,5R)-6-[(2S,3R,4S,5S,6R)-3,4,5-trihydroxy-6-(hydroxymethyl)oxan-2-yl]oxyhexane-1,2,3,4,5-pentol) dome was created following testing of thicknesses, temperatures, concentrations of ingredients and moisture content. The goal was to create a crisp and brittle texture (Figures 2a, 2b and 2c). For the crunchy and crackling element, she developed a honeycomb which was made by producing CO_2 gas from sodium hydrogen carbonate (Figure 3).

The gas bubbles evaporated during heating and formed pockets, of approximately 1 to 1.5 mm diameter on average, which were set in place by sugar. The structure collapsed in the mouth when broken with the teeth. This resulted in crunching and crackling sounds while eating. In this project, scientific practices included physical and chemical testing and sensory analysis testing (informal) each week with fellow classmates. Students discussed their ongoing project with lecturing staff (culinary science and culinary arts) and gained formative feedback to help them improve their recipes both scientifically and artistically.

3.4 Presentation of the dish(es)

In the final class the students presented their dish(es) for sensorial valuation by the lecturing staff. They took photographs to include in their TU Dublin project and also for the Note by Note competition. An example of a recent winning dish (joint first place in the student category) is shown in Figures 2a, 2b and 2c.

3.5 Assessment and evaluation of the project-based learning assignment

The aim of the Advanced Molecular Gastronomy module was to allow the learner to gain an in-depth understanding of the principles and applications of molecular gastronomy at an advanced level. The learning outcomes of the module are outlined in Table 1. According to Nusche (2008), learning outcomes refer to the personal changes or benefits that follow as a result of learning. Such changes or benefits can be measured in terms of abilities or achievements. Since 2012 until the present time, 92 % of all students passed the module. Results ranged from 40 % (pass standard) to 76 % (excellent standard). However, the individual student percentage mark did not provide information on the level of attainment for each of the two essential elements of the project-based assignment. Dahm (2014) crafted detailed rubrics for each of the essential elements in his courses and mapped student outcomes to project elements. He then compiled the data in Excel which allowed a summary of student performance with respect to each of the programme's student outcomes to be automatically generated. A similar rubric with defined evaluation criteria was used (Table 2) to provide a detailed insight into the level of achievement of the essential elements and corresponding learning outcomes.
Figure 4 shows the results for overall totals and for corresponding essential elements from a representative sample of individual marks in the fair, good, very good and excellent categories. It was carried out for recent student cohorts (2016/17, 2017/18 and 2018/19) and revealed that overall students achieved a significantly higher percentage for essential element 1 compared to essential element 2 ($P \leq 0.01$). The exceptions were results in the excellent category (>70%) where essential element 2 scored higher than 1. Correlation coefficients for the project-based essential elements and the individual student grades were 0.92 and 0.97 for essential elements 1 and 2 respectively, showing that there was a good relationship between the individual grade and each of the essential elements.

3.6 International assessment

The student who was selected by the teaching team to represent their class at the international Note by Note contest had not always achieved the highest individual grade in the class but did create a dish that best matched the criteria for the contest. In doing so they demonstrated what they had learnt by creating a product that was presented to people beyond the classroom (Larmer & Mergendoller, 2015; Thomas, 2000). All of the representative dishes which were entered by TU Dublin into each of the six international Note by Note contests (2013-2018) were awarded first place in the student category of the contest.

3.7 Questionnaire

The students were asked if they had studied science subjects before and if so at what level. There is no entry requirement for applicants to have previously studied science. However, the

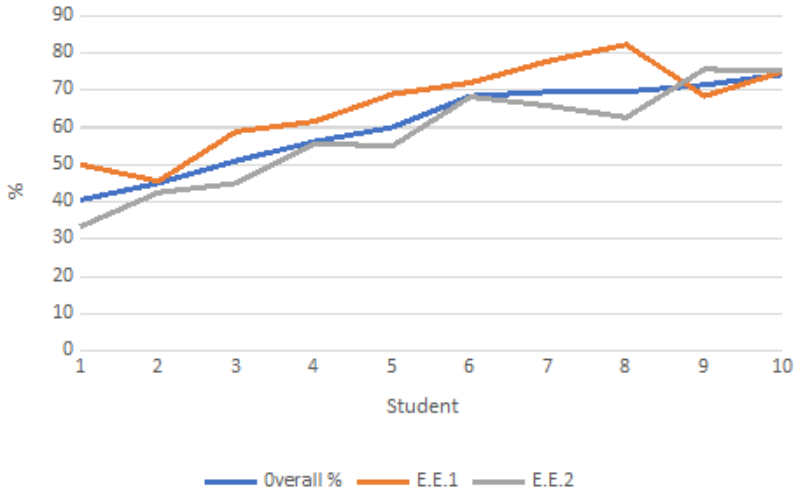

Figure 4: Individual overall marks and individual essential element (E.E.) 1 and 2 marks.

Table 3: Student Evaluation of the Module

Question to students	**Collation of responses**
Highlights of the MG module	The main highlights of the postgraduate module were the kitchen practicals including the demonstration of Note by Note cooking and the use of liquid nitrogen. They liked that they had the freedom to experiment. The students also enjoyed learning about Note by Note cooking and Note by Note cuisine as well as new culinary concepts
Improvements that can be made to the modules	Many of the postgraduate students would have liked more time in the kitchen and more time allocated to experimenting with Note by Note cooking in the kitchen as well as more time allocated to the Note by Note project.
Theory lectures before the practical kitchen classes	The most effective teaching strategy was to have theory lectures followed by the application of knowledge in practical kitchen classes. The M.Sc. students found the theory classes very beneficial and important in helping them to understand the properties and chemical reactions of the compounds that they would use in Note by Note cooking. A couple of students suggested condensing the lectures and giving more time in the kitchen.
Team teaching	All the postgraduate respondents were unanimous in their comments that the team teaching was very important and helpful. Half of the postgraduate students, those who had not previously worked in industrial kitchens, commented that they learnt from the other students about working in a kitchen environment and food presentation skills.
Project-based learning assignment	The postgraduate students got a better understanding of the compounds and e-numbers and their functions and culinary uses. They also learnt about Note by Note cooking, as well as researching, independent thinking and perseverance.

responses from the participants of the MG module showed that some had studied science subjects albeit at various levels. These included final year school biology, and culinary science, microbiology, biochemistry, food safety, biology, chemistry, physics and nutrition at higher education level (see Table 3).

4 Conclusion

By using a project-based Note by Note cooking exercise, 92% of students achieved the learning outcomes of the module. A detailed evaluation of the individual assessment grades however revealed that most of the students were better at finding and using resources, asking further questions and developing their own answers than analysing, synthesising and evaluating information. In future students should carry out a more in-depth analysis, synthesis and evaluation of information.

Students who were chosen to represent their class at the international contest in Paris did not always have the highest grade in their class but were deemed to have produced the dish which matched the requirements of the competition the closest. This was endorsed by their success, winning first place in the student category each year since the contest started six years earlier.

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