ISBN: 978-628-95207-8-1. ISSN: 2414-6390. Digital Object Identifier: 10.18687/LACCEI2024.1.1.2026

Impact of Teaching Multivariate Modeling with Digital Tools on the Development Level of Experimental Data Analysis and Interpretation Skills

Carmen Hernández-Brenes, PhD[1], Dariana Graciela Rodríguez-Sánchez, PhD[1], Raúl Villarreal-Lara, PhD[1], Claudia Gonzalez Viejo, PhD[2], and Jorge A. Clorio-Carrillo, MSc[1]
[1]Tecnologico de Monterrey, Mexico, chbrenes@tec.mx, dariana@tec.mx, raulvl@tec.mx, jclorio@tec.mx
[2]The University of Melbourne, Australia, claudia.gonzalez@unimelb.edu.au

Abstract*– Higher education of food engineering professionals requires the skills of scientific data analysis and interpretation to aid in decision-making and problem-solving tasks of the professional exercise. This study focused on teaching multivariate modeling using digital tools to increase the development level of a program learning outcome related to the skills to analyze and interpret practical experimentation results. Data was collected from two semesters of higher education courses on sensory evaluation of foods, including a control group (Control Class, n=15) and a teaching innovation group (Experimental Class, n=20). A written report from a practical project (scientific poster format) served as the assessment instrument. The impact of the teaching innovation was assessed using a rubric to establish the learning outcome development level and the final course grades as response variables. Results indicated that in the control class, almost all the students (12/15) developed over 87.5% of the desired data analysis and interpretation skills (solid and outstanding levels); however, 3/15 students achieved only 63.5-75.0% of the desirable skills (incipient and basic levels). In the experimental group, the introduction of multivariate modeling with digital tools significantly increased (p<0.05) the overall fulfillment of the desired outcome to 96.9%, placing all students in solid and outstanding development levels. Moreover, the teaching innovation also increased the level of the domain of the students beyond the data "analysis" domain of Bloom's Taxonomy. It allowed them to go up into "evaluation" and "creation".

***Keywords*-- higher education, educational innovation, learning outcome development level, bloom taxonomy, data analysis skills, data interpretation skills.**

I. Introduction

Higher education training for food engineers requires practical experimentation in multidisciplinary sciences, including chemistry, microbiology, and engineering. Food product development, quality control, and shelf-life evaluations require the skills of scientific data analyses and interpretation to aid in decision-making and problem-solving tasks of the professional exercise.

The undergraduate degree in Food Engineering at Tecnologico de Monterrey, Campus Monterrey in Mexico, is a program approved by the international professional association Institute of Food Technologists (IFT), Chicago, Illinois, USA. The approval of food science and technology programs by IFT started in 1966 and continues to the present. IFT is not a licensed accreditation body like the Accreditation Board for Engineering and Technology (ABET); its mission is to ensure that the higher education programs that prepare future food science professionals are aligned with IFT's mission to promote the advancement of careers in food science [1].

Digital Object Identifier: (only for full papers, inserted by LACCEI).
ISSN, ISBN: (to be inserted by LACCEI).
DO NOT REMOVE

The IFT has a task force named the Higher Education Review Board (HERB) that, in a joint effort with the Board of Directors, published new approval guidelines and application processes for higher education food science and technology education programs [1]. The approval process of a higher education food science or food engineering program by IFT requires compliance with various essential student learning outcomes defined as "the attainment levels reached by students on completion of an academic program" [2].

The essential learning outcomes, in the IFT approved programs, require documentation through specific assessment instruments (course activities and rubrics) that generate the educational evidence of the student's development level for each program outcome. The new guidelines considered and adaptation of the Bloom's Taxonomy [3] for defining the targeted level of domains of the learning outcomes envisioned for higher education food science programs. For instance, the present work focuses on an IFT essential learning outcome that involves the student's skill to apply experimental designs and statistical methods to sensory studies and its interpretation to solve specific problems in food science. In the new guidelines, this learning outcome was defined in Bloom's Taxonomy domain of "application" of knowledge.

The present work aimed to evaluate the effect of teaching multivariate modeling, using digital tools, on the outcome development level of the student's skills to apply statistical methods and interpret practical experimentation data in a higher education course on sensory evaluation of foods. The impact of the teaching innovation was assessed using the final course grade and the outcome development levels as response variables.

II. Methodology

A. *Subjects*

The population of this study included higher education 3rd-year food engineering students enrolled in the "Sensory Evaluation" course at Tecnologico de Monterrey, Campus Monterrey, México. Data was collected for two semesters, including Fall Semester 2016 (Control Class) and Spring Semester 2021 as a treatment group (Experimental Class). The course is mandatory for students pursuing a major in Food Engineering. A prerequisite for the course is a basic understanding of statistics. Participation in the research was voluntary, confidential, and had no negative impact on students' grades. The participants of this study included 15 students for Control Class and the Experimental Class included 20 students. Both courses were taught by two lecturers (with 5-21 years of teaching experience).

B. *Data Collection*

Techniques in collecting experimental data included documentation of the numeric grades in all class assignments, which included practical cases, exams, and class activities, as well as a written experimental report in the form of a scientific poster. The scientific poster was selected as the assessment instrument to measure the development level of the learning outcome of the students' statistical data analyses and interpretation skills.

C. *Assessment Instrument*

The assessment instrument class activity (practical project) included the components of experimental design, field application of sensory evaluation experiments for data collection from consumers, data analysis, and a written report (scientific poster format). The assessment evidence was the written report in a scientific poster format that contained the elements of a journal article (abstract, introduction, objective, materials and methods, results discussion, and conclusions). The assessment tool used was a rubric as shown in Table 1.

TABLE I

LEARNING OUTCOME DEVELOPMENT LEVEL

Data Analysis and Interpretation Skills	**Incipient (< 69%)**	**Basic (70-80%)**	**Solid (81-94%)**	**Outstanding (95-100%)**
A. Makes use of analytical techniques	Does not understand the fundamentals of the experiment and applies them ineffectively	Does not understand the fundamentals of the experiment but manages to apply them in an efficient way	Understands the fundamentals of the experiment and/or applies them efficiently	Understands the fundamentals of the experiment, conveys it to the audience and can apply them efficiently
B. Analysis of results and decision making based on both traditional and novel techniques	Does not interpret, discuss, or support the results obtained.	Interprets, but does not discuss or support the results obtained based on traditional and/or novel techniques.	Interprets, discusses and/or supports the results obtained based on traditional and/or novel techniques	Interprets and discusses, supporting the results obtained based on traditional and novel techniques.

D. *Teaching Innovation: Multivariate Modeling with Digital Tools*

The core of the innovation was teaching the students how to use digital tools to model sensory data using multivariate analysis and how to interpret the statistical outputs. The Control Class received training on basic sensory methods of statistical analysis (parametric one-way analysis of variance (ANOVA) and mean separation). The assessment instrument for the control group was therefore designed with the expectation of a lower domain level (maximum Bloom Taxonomy outcomes were "application" or "analysis"). The Experimental Class received training on basic sensory data statistical analysis (parametric one-way ANOVA and mean separation) and advanced sensory data statistical analysis (multivariate techniques: correspondence and principal component analyses). Teaching innovation introduced digital tools for multivariate modeling (XLSTAT Software, Version 2023.1, Lumivero, New York, NY, USA). The assessment instrument for the experimental group was the same (written report in a scientific poster format). However, the students in the Experimental Class were equipped with data visualization tools introduced by the multivariate analysis methods. Multivariate data analysis including correspondence and principal component analysis (PCA) used by the Experimental Class students in their assessment instruments (scientific posters) were conducted as in [4].

E. *Statistical Analysis*

The effect of the teaching innovation was evaluated using the final course grade and the outcome development levels as response variables. Treatment effects were evaluated by one-way ANOVA and the mean separations were conducted with the Fisher LSD post-hoc test for parametric variables. Significant differences were assessed at $p < 0.05$. Statistical analyses were performed using XLSTAT 2023.1 (Lumivero, New York, NY, USA).

III. RESULTS & DISCUSSION

Fig. 1A shows that, surprisingly, the introduction of advanced statistical modeling techniques resulted in a significantly higher ($p < 0.05$) final grades for the experimental group when compared to the control group (92.9 and 83.4, respectively).

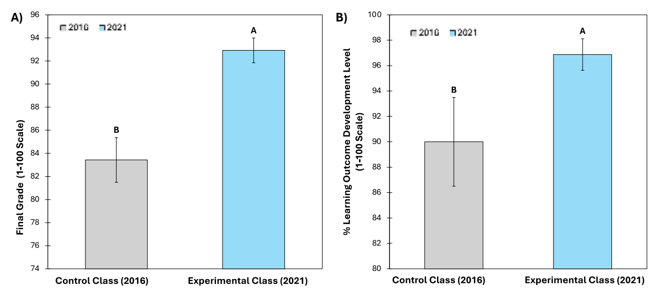

Fig 1. Impact teaching multivariate modeling using digital tools on a program learning outcome focused on the skill to analyze and interpret experimental data in a higher education course of sensory evaluation of foods. A) Effect on the course final grade. B) Effect on the learning outcome development level.

The control class received basic statistical training, which allowed the students to analyze parametric data by ANOVA and conduct mean comparisons of experimental treatments. The project's written reports (scientific posters) contained graphs and figures that the students used to interpret the data and issue recommendations related to results from the sensory evaluation experiments. The assessment tool (rubric) was used to establish the students' development level for data analysis and interpretation skills. As shown in Fig. 1B, the overall mean numeric outcome development level for the control class was 90.0% and significantly ($p < 0.05$) increased to 96.9% by introducing the advanced multivariate modeling tools in the experimental class.

The introduction of digital tools for multivariate analysis resulted in better visualization of the data and integration of knowledge the sensory characteristics of the food products and the affective sensory responses that consumers provided.

Fig. 2 is an example of a multivariate correspondence analysis biplots constructed with consumer affective data collected by the students from the Experimental Class. Sensory evaluations by consumers included affective responses (emojis) elicited by the observation of pictures from a database (Fig. 2A) and categorical selection of emotions elicited by videos of samples from different beer styles (Fig. 2B).

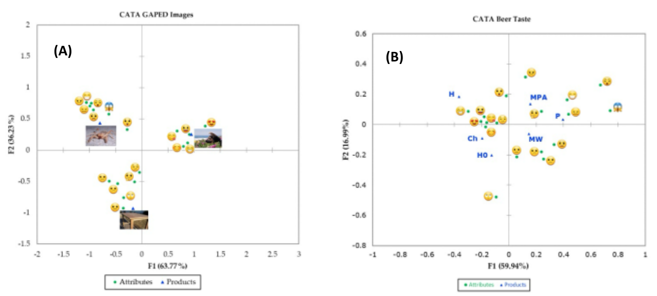

Fig 2. Correspondence analysis using the check-all-that-apply (CATA) with emojis from (A) Self-reported emotional responses to the Geneva Affective Picture Database (GAPED) images and (B) Self-reported emotional responses to beer visual attributes. Samples included top-fermented beers of the styles Pale Ale (MPA), American Pale Ale (P) and American Wheat Ale (MW) and bottom-fermented beers of the styles Pale Lager (H), zero-alcohol Pale Lager (H0), and Pilsner (Ch).

In the present study, the final project served as the assessment instrument for the learning outcome of the ability to analyze and interpret experimental results. Results indicated that for the Control Class, all students performed acceptable analyses of their experimental data and presented data in an oral presentation using the format of a scientific poster (overall fulfillment of the desired outcome averaged 90% of 100% (Fig. 1B). However, when students were evaluated individually, it was evident that 3/15 students still needed to improve their abilities to structure their experimental reports' elements (objective, hypothesis, graphs, interpretation of results, and discussion). Fig. 3A includes the frequency distribution of each student's learning outcome assessment results. Almost all the class (12/15 students) developed over 87.5% of the desired data analysis and interpretation skills (solid and outstanding levels); however, three students achieved only 63.5-75.0% of the desirable skills (incipient and basic levels).

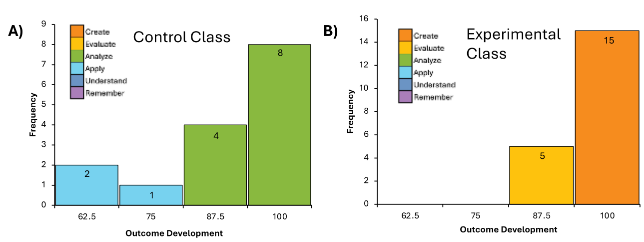

Fig 3. Impact teaching multivariate modeling using digital tools on a program learning outcome focused on the skill to analyze and interpret experimental data in a higher education course of sensory evaluation of foods. A) Control Group (2016) - Learning outcome development level. B) Experimental Group (2021) - Learning outcome development level.

The purpose of introducing digital tools for teaching multivariate analyses in the Experimental Class was to aid in the visualization of scientific data. As previously mentioned, results indicated that the teaching innovation increased the overall fulfillment of the desired outcome in the experimental group, averaging 96.9%, indicating outstanding development levels (Fig. 1B). Furthermore, when students were evaluated individually (Fig. 3B), results showed that 15/20 students developed an outstanding level (>87.5-100%) of the desired skills, and 5/20 students achieved a solid level (87.5%) of the data analysis and interpretation skills. A significant improvement in the development level of the outcome from a teaching perspective indicated a positive achievement in the training of future food engineers.

The strategy also resulted in additional benefits for the students since multivariate modeling using digital tools increased the level of the assessment instrument's domain (higher Bloom Taxonomy goal) because it facilitated data visualization. Therefore, the elements of the scientific posters for the Experimental Class evidenced skills of a higher domain. The data interpretation, discussions, and conclusions contained elements of evaluation and synthesis (creation) of new knowledge derived from their multivariate modeling analyses.

IV. CONCLUSIONS

The introduction of digital tools for advanced statistical modeling and data visualization significantly increased food engineering students' data analysis and interpretation skills in a sensory evaluation course. In the Experimental Class, the desired outcome was fulfilled in the solid and outstanding levels (87.5-100%) for all students 20/20. In the Control Class, most students (12/15) developed solid and outstanding levels (87.5-100%), but 3/15 students achieved only 63.5-75.0% of the desirable skills (incipient and basic levels). A significant improvement in the development level of the outcome from a teaching perspective indicated a positive achievement in the training of the future food engineers.

Moreover, the teaching innovation also increased the level of the domain of the students beyond the “analysis” domain of Bloom's Taxonomy. It allowed them to go up into “evaluation” and “creation”.

ACKNOWLEDGMENT

The authors would like to acknowledge the financial and the technical support of Writing Lab, Institute for the Future of Education, Tecnologico de Monterrey, Mexico, in the production of this work.

REFERENCES

[1] Santau, A. O., MacDonald, R. S., & Roberts, R. R. (2020). The 2018 Guidelines for Initial IFT Approval of undergraduate food science and food technology programs. Journal of Food Science Education, 19(3), 225–231. https://doi.org/10.1111/1541-4329.12191

[2] Ewell, P. (2001). Accreditation and student learning outcomes: A proposed point of departure (CHEA Occasional Paper). Washington, DC: Council for Higher Education Accreditation.

[3] Anderson, L. W., & Krathwohl, D. R. (2001). A taxonomy for learning, teaching, and assessing: A revision of bloom's taxonomy of educational objectives. London, UK: Longman.

[4] Gonzalez Viejo, C., Fuentes, S., de Anda-Lobo, I. C., & Hernandez-Brenes, C. (2022). Remote sensory assessment of beer quality based on visual perception of foamability and biometrics compared to standard emotional responses from affective images. Food Research International, 156. https://doi.org/10.1016/j.foodres.2022.111341