

## **UNIVERSITY–SCHOOL INTEGRATION AS A STRATEGY FOR SCIENTIFIC LITERACY: EXPERIMENTAL ASSESSMENT OF PROTEIN CONTENT IN SCHOOL MILK USING A LOW-COST METHOD**

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### **ABSTRACT**

This study reports an interdisciplinary educational intervention designed to promote scientific literacy through the integration of public school students into a university laboratory environment. Eighth-grade students from a municipal public school in Fortaleza, Brazil, participated in an immersive scientific experience at the Experimental Biology Center of the University of Fortaleza, where they conducted an experimental activity to assess the protein content of milk provided in the school feeding program. The methodology was based on acid-induced protein precipitation using acetic acid (commercial vinegar), enabling visualization and comparative evaluation of protein presence through casein coagulation. The approach combined biochemical principles with an accessible and low-cost experimental design suitable for educational contexts. The activity allowed students to

engage directly with the scientific method, including hypothesis formulation, experimentation, and interpretation of results, while also critically reflecting on the nutritional quality of their daily food intake. The findings demonstrated that the proposed strategy effectively fostered student engagement, contextual understanding of scientific concepts, and awareness of the relationship between nutrition and health. This study highlights the relevance of integrating basic education with academic scientific environments as a means of strengthening scientific literacy, promoting social awareness, and expanding access to meaningful science education experiences.

**Keywords:** Scientific literacy; Experiential learning; Protein quantification; Milk analysis; Nutritional assessment

## 1. INTRODUCTION

The integration of basic education students into scientific environments has emerged as a powerful strategy to enhance scientific literacy and promote active engagement in the learning process. Traditional teaching approaches, often centered on passive content transmission, may limit students' ability to connect scientific concepts with real-world applications. In contrast, experiential and inquiry-based learning models encourage students to actively participate in knowledge construction, fostering deeper understanding and critical thinking skills (Freeman *et al.*, 2019).

Scientific literacy plays a crucial role in contemporary society, enabling individuals to interpret information, make informed decisions, and understand issues related to health, nutrition, and the environment. In the context of public education, particularly in underserved regions, providing students with access to authentic scientific experiences is essential to reduce educational inequalities and stimulate interest in science-related careers (Ribeiro *et*

*al.*, 2023).

School feeding programs represent a key component of public health and educational policies, especially in developing countries such as Brazil. These programs aim not only to reduce food insecurity but also to support cognitive development and academic performance through adequate nutrition. Among macronutrients, proteins are essential for growth, tissue repair, and metabolic regulation, making their presence in school meals a critical factor in ensuring nutritional quality (Silva *et al.* 2019).

Despite the recognized importance of both scientific literacy and nutritional education, these domains are frequently addressed separately within the school curriculum. Integrating experimental scientific activities with real-life issues, such as evaluating the nutritional content of school-provided food, offers a valuable opportunity to bridge this gap. Such approaches allow students to contextualize scientific knowledge while developing awareness of their own health and well-being (UNESCO, 2020).

In this context, the present study aimed to develop and implement an educational intervention in which public school students participated in a laboratory-based experimental activity to assess the protein content of milk provided in their school meals. By utilizing a low-cost biochemical method based on acid-induced protein precipitation, the study sought to promote scientific immersion, enhance student engagement, and encourage critical reflection on nutritional quality, thereby connecting scientific learning with everyday life.

## **2. MATERIALS AND METHODS**

### **2.1 Study Design and Educational Framework**

This study was designed as an interdisciplinary, exploratory educational intervention integrating experimental science with nutritional assessment. The activity was conducted through a partnership between a public municipal school in Fortaleza, Ceará, Brazil, and the

Experimental Biology Center at the University of Fortaleza.

The intervention involved eighth-grade students who participated in a structured laboratory immersion experience aimed at promoting scientific literacy through hands-on experimentation. The pedagogical approach was based on experiential and inquiry-based learning, in which students actively engaged in hypothesis formulation, experimental procedures, and interpretation of results (Figure 1).

**Figure 1.** Eighth-grade students from a public municipal school participating in a laboratory immersion activity at the Experimental Biology Center, University of Fortaleza, under the supervision of Prof. Dr. Antonio Eufrásio Vieira-Neto, PhD.



All students had their image authorization granted by their guardians through a consent form. **Source:** author.

Such approaches have been widely recognized as effective in enhancing student engagement, conceptual understanding, and retention of scientific knowledge, particularly

in science education contexts that emphasize active learning methodologies (Freeman *et al.*, 2019).

## **2.2 Participants and Educational Context**

The participants consisted of students enrolled in the 8th grade of a public municipal school. The activity was conducted as part of a science education initiative aimed at bridging the gap between basic education and academic scientific environments.

Prior to the laboratory activity, students received a theoretical introduction covering fundamental concepts of proteins, nutrition, and the importance of macronutrients in human health. During the laboratory session, students were organized into small groups and supervised by researchers and educators, ensuring both safety and effective learning.

The inclusion of students in authentic scientific environments has been shown to positively influence their perception of science, increase motivation, and foster interest in scientific careers, particularly among students from public education systems (Ribeiro *et al.*, 2023).

## **2.3 Sample Collection and Handling**

Milk samples were obtained directly from the school feeding program and collected on the same day as the experimental activity. Samples were transferred to the laboratory in sterile, sealed containers to prevent contamination. Upon arrival at the laboratory, samples were stored under refrigeration at approximately 4°C and analyzed within a short time frame to preserve physicochemical stability and protein integrity. Milk was selected as the study matrix due to its recognized nutritional relevance as a source of high-quality proteins and its well-characterized biochemical composition, which makes it particularly suitable for

experimental and educational analysis (Haug *et al.*, 2007).

## **2.4 Experimental Procedure: Protein Precipitation Using Acetic Acid**

Protein content in the milk samples was evaluated using an acid-induced precipitation method based on the physicochemical properties of casein. This approach relies on the reduction of pH to the isoelectric point of casein (approximately pH 4.6), resulting in destabilization of casein micelles and subsequent coagulation (Haug *et al.*, 2007). Briefly, approximately 10 mL of milk sample was transferred into a transparent container. Commercial vinegar (acetic acid solution, ~4–6%) was gradually added under gentle agitation until visible coagulation occurred. The formation of curds (precipitated protein) and separation of the liquid phase (whey) were observed as indicators of protein presence.

The precipitated material was qualitatively assessed based on volume, density, and visual characteristics. In some cases, simple filtration was performed to separate the solid fraction, allowing comparative observation among samples (Figure 2).

**Figure 2.** Acid-induced protein precipitation in milk samples following the addition of acetic acid (vinegar), demonstrating casein coagulation and phase separation between curd and whey.



**Source:** author.

Acid-induced casein precipitation is a well-established biochemical process widely used in both laboratory and industrial dairy applications, providing a reliable and accessible method for demonstrating protein structure and behavior (Dalglish, 2011).

Although the method employed is qualitative in nature, it is grounded in well-established physicochemical principles governing protein stability and solubility. Casein micelles remain stable at neutral pH but undergo aggregation when the pH approaches their isoelectric point, resulting in precipitation. This property has been extensively described in dairy science and is widely used in both laboratory and industrial applications. While this approach does not provide quantitative protein determination, it offers a reliable visual indicator of protein presence and structural behavior, making it particularly suitable for educational and exploratory purposes.

## **2.5 Data Collection and Analysis**

Given the educational and exploratory nature of the study, data collection was primarily qualitative. Observations focused on the presence and extent of protein precipitation, visual characteristics of the coagulated material, and differences among samples. Students were encouraged to record their observations and discuss potential explanations for the results, promoting critical thinking and scientific reasoning.

The qualitative analysis was conducted through systematic observation of predefined parameters, including onset of coagulation, relative volume of precipitate, and visual density of the curd formed. These criteria were used to ensure consistency in observations across groups. Although numerical measurements were not obtained, this structured observational approach allowed for comparative assessment among samples. Such qualitative frameworks are widely accepted in educational research contexts, particularly when the primary objective is to evaluate conceptual understanding and engagement rather than analytical precision. (Hernández-de-Menéndez et al., 2019).

## **2.6 Ethical Considerations**

The study was conducted in accordance with ethical principles for educational research. Participation of students was voluntary and supervised by teachers and researchers, ensuring a safe and controlled learning environment. No personal or sensitive data were collected, and the activity posed minimal risk, as it involved common food materials and low-risk substances such as diluted acetic acid. The intervention was designed exclusively for educational purposes, with additional benefits related to scientific literacy and nutritional awareness.

### 3. RESULTS AND DISCUSSION

The experimental activity successfully enabled the visualization of protein presence in the milk samples through acid-induced precipitation, evidenced by the formation of visible curds following the addition of acetic acid. This phenomenon is consistent with the well-established behavior of casein, the predominant protein in bovine milk, which precipitates near its isoelectric point ( $\text{pH} \approx 4.6$ ), resulting in phase separation between solid (curd) and liquid (whey) fractions. The clear visual outcome of this reaction provided an effective means for students to directly observe a fundamental biochemical process, reinforcing the connection between theoretical concepts and practical application (Walstra et al., 2005).

From a compositional perspective, bovine milk typically contains approximately 3–3.5% protein, corresponding to 30–35 g per liter, with casein representing about 80% of the total protein fraction and whey proteins accounting for the remaining 20%. The coagulation observed during the experiment is therefore primarily attributed to casein aggregation, while whey proteins remain soluble in the aqueous phase. This biochemical distinction was critical in helping students understand not only the presence of protein in the sample but also the structural and functional diversity of milk proteins (McSweeney & Fox, 2013).

Although the methodology employed in this study does not provide precise quantitative measurements, the relative volume and density of the precipitated material allowed for a qualitative assessment of protein presence. The consistency of coagulation across samples suggested that the milk provided in the school feeding program contained detectable and nutritionally consistent levels of protein. This observation is particularly relevant in the context of school nutrition, where adequate protein intake plays a fundamental role in supporting growth, metabolic function, and overall health in children and

adolescents (Park et al., 2022).

Although qualitative, the consistency observed among samples suggests a relatively homogeneous protein composition in the milk provided, which is consistent with standardized nutritional regulations for school feeding programs. This observation reinforces the reliability of the experimental approach as a comparative tool, even in the absence of precise quantification.

Beyond the biochemical outcomes, the educational impact of the activity was evident through student engagement and participation. The opportunity to conduct an experiment within a university laboratory environment fostered curiosity, collaboration, and critical thinking. Students were able to formulate hypotheses, observe experimental outcomes, and discuss their interpretations, demonstrating an active learning process that contrasts with traditional passive instructional models (Figure 3). Active learning strategies have been consistently associated with improved academic performance and deeper conceptual understanding in science education (Freeman et al., 2019).

**Figure 3.** Students actively engaged in experimental procedures, including sample handling, acid addition, and observation of protein coagulation during the laboratory activity.



All students had their image authorization granted by their guardians through a consent form. **Source:** author.

The integration of a real-world problem (evaluating the nutritional quality of school-provided milk) further enhanced the relevance of the activity. By connecting scientific experimentation with their daily food consumption, students developed a more meaningful understanding of the role of science in everyday life. This contextualization is a key component of scientific literacy, as it enables individuals to apply scientific knowledge to practical situations and make informed decisions related to health and nutrition (Nobre et al., 2024).

In addition, the use of a low-cost and accessible experimental method, such as protein precipitation using vinegar, demonstrates the feasibility of implementing similar activities in resource-limited educational settings. This is particularly important in public education systems, where access to laboratory infrastructure may be restricted. The adaptability of the method supports its potential as a scalable educational tool capable of promoting scientific literacy in diverse contexts (Araújo et al., 2020).

Despite the positive outcomes, some limitations should be considered. The qualitative nature of the analysis does not allow for precise quantification of protein content, which would require more advanced analytical techniques such as spectrophotometric assays (e.g., Bradford or Lowry methods) or nitrogen-based quantification methods such as the Kjeldahl method. However, the implementation of such techniques would not be compatible with the educational context of this study, which involved middle school students with limited prior exposure to laboratory practices. The use of simpler, low-cost methodologies was intentionally prioritized to ensure accessibility, engagement, and inclusivity, thereby preserving the pedagogical objective of introducing young students to scientific

experimentation in a meaningful and approachable way.

Overall, the results of this study demonstrate that the integration of experimental science, nutritional evaluation, and educational practice can generate meaningful learning experiences while addressing relevant social issues. The activity not only confirmed the presence of protein in school-provided milk but also served as a powerful tool for promoting scientific literacy, critical thinking, and awareness of the relationship between nutrition and health. These findings reinforce the importance of strengthening connections between basic education and scientific institutions as a strategy for educational innovation and social development.

#### **4. CONCLUSION**

This study demonstrated that the integration of public school students into a university laboratory environment, combined with a low-cost experimental approach, represents an effective strategy for promoting scientific literacy and contextualized learning. The use of acid-induced protein precipitation enabled students to directly observe fundamental biochemical processes, facilitating the understanding of protein structure and function through practical experience.

In addition to its scientific component, the activity demonstrated strong educational value. Students actively participated in all stages of the experiment, from sample handling to observation and interpretation of results. The hands-on nature of the activity, combined with its direct relevance to their daily lives, contributed to increased engagement and curiosity. The opportunity to conduct the experiment in a university laboratory environment further enhanced students' perception of science as accessible and meaningful. Although formal assessment tools such as pre- and post-intervention questionnaires were not employed, consistent observational evidence indicated high levels of student engagement,

participation, and conceptual discussion during the activity. These qualitative indicators are commonly used in exploratory educational interventions to assess immediate learning outcomes and student involvement.

The findings highlight the potential of school–university partnerships as a transformative approach in science education, particularly in public education systems where access to scientific infrastructure is limited. By utilizing accessible materials and replicable methodologies, this model can be adapted to diverse educational contexts, expanding opportunities for meaningful scientific experiences.

Although the study was based on qualitative analysis, its outcomes underscore the importance of integrating experimental practices into basic education as a means of fostering curiosity, autonomy, and informed decision-making. Future research should explore the incorporation of quantitative analytical techniques and long-term evaluations of educational impact.

Overall, this work reinforces the role of science as a tool for social transformation, emphasizing that early exposure to scientific environments can contribute not only to academic development but also to the formation of more critical, informed, and engaged citizens.

Despite its qualitative nature, the study provides meaningful insights into the use of accessible experimental approaches in science education and highlights the importance of aligning pedagogical strategies with real-world contexts.

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