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THE CONTEXT CONDITIONS STUDENTS´ REPRESENTATIONS OF THE HUMAN NUTRITION MODEL

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Abstract. *The human nutrition model is relevant in Biology education. Researchers and policymakers propose the introduction of modelling practices in science education, including the representation of the model. Despite being scarce, previous studies have shown that the guideline given to students conditions their performance when representing their models. This study addresses how the context given to 79 preservice teachers (PSTs) in two cohorts at the end of a modelling sequence conditions the representations of the nutrition model constructed by them. The contexts were a child running and a lactose intolerant person. Written explanations and drawings of PSTs were analyzed according to the components-mechanisms-phenomena (CMP) framework. PSTs of both cohorts expressed a more developed nutrition model in a running context than in an intolerance context with respect to CMP aspects, which was shown by statistically significant differences. Therefore, the conclusion is that the context conditions the expression of the model. In this case, it was the context that appealed directly to the circulatory system and implied the use of energy, the one that led to a more complete representation of the human nutrition model.*

Keywords: *evaluation context, preservice teachers, nutrition model, model representation*

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Introduction

To understand human nutrition favors a global understanding of the human body itself. Nutrition is an essential function with the purpose of providing the organism with the nutrients and energy necessary to maintain its integrity. This involves transport and exchange of substances in dynamic connections between different systems, which are difficult to understand (Hmelo-Silver & Azevedo, 2006). Among the attempts to achieve systems thinking in human nutrition, it is worth highlighting the Components-Mechanisms-Phenomena (CMP) framework by Hmelo-Silver et al. (2017), which includes elements of the system (Components), the interrelated processes (Mechanisms) occurring among them, and the resulting outcomes or manifestations (Phenomena) of these processes within the system. The main obstacles to understanding nutrition can be sorted according to the CMP framework. Previous studies have described that it is frequent to restrict human nutrition to the digestive and respiratory organs (Components) (i.e., Reiss & Tunnicliffe, 2001).

Other studies have concluded that although students generally possess knowledge about the organs in the human body, they often struggle to place them within systems, establish connections between these organs, and gain a complete understanding of their respective functions (Mechanisms) (Aydın, 2016; Cuthbert, 2000; Özsevgeç, 2007; Reiss et al., 2002). Finally, Uskola et al. (2022) described that students did not explain the energy transfer of carbohydrates in the cells (Phenomena) when studying lactose intolerance.

This could be explained because the teaching of the human body and its systems have traditionally been worked in a way that many students finish their primary and secondary education without developing an integrated and global notion about the human nutritional processes (García-Barros et al., 2011; Granklint Enochson et al., 2015; Nuñez & Banet, 1997), probably because understanding the inter-relationships between concepts is harder than

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understanding the concepts separately (Lin & Hu, 2003). Thus, it seems to be necessary to overcome reductionist-teaching strategies based on the memorization of organ names when teaching the human body (Landinho et al., 2022). Therefore, progress in constructing the nutrition mental model must be accompanied by the development of skills that allow its application in justifying phenomena and in personal actions and attitudes related to health or the environment (García-Barros, 2016).

This can be achieved by the scientific practice of modelling, which involves constructing, using, evaluating, and revising scientific models (Schwarz et al., 2009). A model can be defined as a representation of reality used to explain and predict scientific phenomena (Gilbert et al., 2000) and one of the phases of the modelling process is such representation of the mental model (Gilbert & Justi, 2016; Schwarz et al., 2009). As it is intentional, it can be communicative, cognitive or operational (Adúriz-Bravo, 2005). Thus, several studies have shown how representations can be used to reflect on the model and learn science (Prain & Tytler, 2012; Tytler et al., 2020).

In previous research on modelling, Uskola et al. (2022) suggested that research on how context facilitates the incorporation of process outcomes (Phenomena) was necessary. According to Gilbert (2006), the word context refers to a situation that provides meaning to words, phrases, and sentences. This is consistent with the idea that one of the goals of the use of context-based learning is to allow students to build mental maps that help them establish coherent connections and relationships of the scientific ideas that are being learned (Gilbert, 2006). Therefore, context-based learning in science education is a teaching strategy that promotes meaningful and socially relevant learning. The idea is that science should be taught based on real and meaningful situations for students, that are used as a focus, incorporating scientific concepts as they are necessary to better understand the situation (King, 2012).

As a proof of this, research has shown that how students activate ideas when they are asked a question depends on the context of that question (Hammer et al., 2005). In fact, students may show higher levels of performance in one context and lower levels in another context (Duncan et al., 2009). For example, Heredia et al. (2016) conducted a study on natural selection and found that students' responses significantly differed depending on whether a plant or animal was used as the context. In particular, students chose the scientifically accepted response more frequently in an animal context than in a plant context, probably because students have been exposed to more animal examples in class or because they might not consider plants as living beings (Heredia et al., 2016). Thus, a lack of response to a particular question may be due to an inability to use existing knowledge in the context of evaluation (Nehm & Reilly, 2007). Concerning human body systems, it is well known that the mode of representing knowledge influences results; for example, the differences between written answers and drawings (Fančovičova & Prokop, 2019; Prokop & Fančovičova, 2006; Reinoso & Delgado-Iglesias, 2020; Uskola et al., 2022). However, the impact of the context has been comparatively less explored. García-Barros et al. (2011) asked 342 children up to the age of 7 to draw the paths of food, drink, and air entering human and other animal bodies (dog, duck, fish). What they found was that they drew practically the same organs and structures in humans and animals, and it was only when they grew up that they began to differentiate, for example, fish organs. Khwaja and Saxton (2001) found that the instruction given to students for drawing conditioned the results: with the specific instruction "*Draw the bones that are inside your body*" students drew systems at higher levels than with the more general expression "*Draw what you think is inside your body*" used in a previous study. Based on these results, Prokop et al. (2009) compared the drawings of the urinary and endocrine systems made by children and university students after asking them to draw the inside of the human body and after asking them to draw a particular system. Although some of their results suggested that the drawings were similar to general and specific instruction, statistical analysis showed that they did not correlate with the endocrine system which they explained by the complexity of the endocrine system. Thus, they concluded that knowledge of the anatomy of the apparatus in question was a determining factor in drawing it well. The question of how a given context or guideline can influence the outcome, therefore, remains a subject of interest for research in science education. Teachers need to know more about how the guideline they give or the contexts they use to assess their students' knowledge can condition such outcomes, so that they can design activities that allow students to express their knowledge in the best way.

Research Aim and Research Questions

This study addresses how the guideline given to students, in this case, the given context, conditions the representation of the nutrition model constructed by the students (in the present study preservice teachers (PSTs)). In that sense, the aim of the research was to study the differences between the representations in different contexts and reflect on the characteristics of those contexts that can account for the differences, so that teachers can

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consider them. Thus, the research question was: To what extent does the context condition the representation of PSTs' human nutrition model at the end of a modelling sequence?

Research Methodology

General Background

This study analyzed how the context given by the teacher conditioned the expression of the student's model of human nutrition after participating in a modeling sequence (with the objective of constructing the model of human nutrition) in two cohorts of PSTs (2021/22 and 2022/23). Two contexts were used, one related to lactose intolerance (Context1-LI) and the other to running (Context2-R). Categorization was made from a systemic view of human nutrition, according to the CMP framework proposed by Hmelo-Silver et al. (2017). Hence, the present study falls within the framework of mixed methods research (Creswell, 2012): the data collected are qualitative (drawings and written expressions) and then treated quantitatively for statistical analysis.

Participants

The participants were all the PSTs studying a Degree in Childhood Education (third year) at the Faculty of Education of Bilbao (Spain) in 2021/22 and 2022/23, that is 79 PSTs (32 in Cohort 1, 47 in Cohort 2). In both cohorts, the teacher was the first author. Purposeful sampling was undertaken. That is, researchers intentionally selected the participants that could help them understand the influence of the context in the expression of the mental models of nutrition (Creswell, 2012). For convenience participants were those willing and available to participate. All participants gave informed consent to participate in the research. It was clearly stated that participation was voluntary and anonymous. PSTs in the data collection process were coded as PST1-1 to PST1-32 in Cohort 1 and PST2-1 to PST2-47 in Cohort 2. The present study is part of the research project (M10_2021_161) in which this work was approved by the Ethics Commission for Research Involving Human Beings (CEISH) of the University of the Basque Country (UPV/EHU) on 20 May 2021).

Teaching Sequence

The sequence was structured in several stages as described before (Uskola et al., 2022). On a silhouette of a human body, participants first wrote and drew the elements and processes involved in lactose intolerance. After conducting research in small groups of three to five students, PSTs reconfigured their initial model under the guidance of the teacher. Once a consensus was reached, PSTs performed, in large groups (20-25 PSTs) and supervised by the teacher, a drama representation of nutrition, in which they drew a body silhouette (5 meters approximately) on the floor and acted as the elements (nutrients and gases) involved and the processes they undergo throughout the body. The drama activity was an experiential and scripted role-play with a structured frame, where participating roles and the script were previously defined by the PSTs. The small groups then created a video in which the physical model was used to illustrate processes, representing their consensus model in a three-dimensional and dynamic physical model. Finally, PSTs were asked to draw and explain the elements and processes involved in two contexts. The representation modes were exactly the same to avoid differences coming from the representation mode (Fančovičova & Prokop, 2019; Prokop & Fančovičova, 2006; Reinoso & Delgado-Iglesias, 2020; Uskola et al., 2022). Context1-LI had the guideline "What happens in your body when you drink milk if you are intolerant? Draw and explain the elements and processes" that had been used in previous sequences over 4 years. As the PSTs did not express a complete model despite the improvements made over the years (Uskola et al., 2022), it was decided to include a new context to test if it was the context that showed the limitations. In Context2-R students were asked to answer the following: "You have run, and your heart rate has increased. Indicate what has happened in your body. Draw and explain the elements, pathways and processes that have occurred."

Data Collection and Analysis

Data were gathered from students' drawings and written texts at the end of the sequence, as recommended by Prokop and Fančovičova (2006). Written explanations and drawings were analyzed according to the CMP framework

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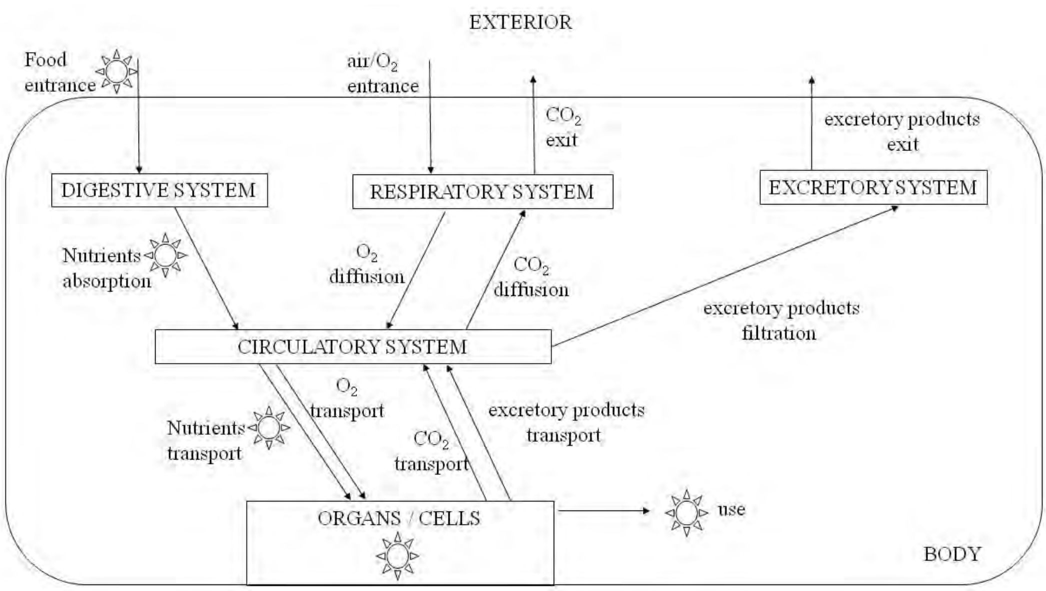
proposed by Hmelo-Silver et al. (2017), which was adapted to the task. The components could be macroscopic or microscopic. For the former components, five levels were established based on the number of boxes (digestive, respiratory, circulatory or excretory system and the organs (cells were also taken into account) where the energy is needed) and the number of connections between boxes mentioned (maximum 4 connections). A system was considered to be present even if the system was not completely represented. In the case of the microscopic components, the presence or absence of oxygen, carbon dioxide, nutrients and excretory products were considered. For the Mechanisms, the entrance and exit and the internal processes of microscopic components were evaluated. The internal processes reached values from 0 to 2 (2: nutrients absorption, gases diffusion or excretory products filtration and their transport; 1: nutrients absorption, gases diffusion or excretory products or their transport; 0: none). Phenomena are the outcome of the operating mechanisms (Snapir et al., 2017). In the present work concepts related to energy were included as phenomena. That is, mentioning energy throughout the explanation, considering that nutrients are a source of energy and oxygen is involved in the production of energy, mentioning cellular respiration, addressing that energy is obtained in this process and mentioning the final use of energy.

Figure 1 shows the aspects considered essential for the comprehension of human nutrition as a set of integrated systems, elements and processes (adapted from Nuñez & Banet, 1997). It could be considered a schematic representation of the target scientific model PSTs should reach.

Figure 1

Schematic Representation of the Human Nutrition Scientific Model



Measures of central tendency (mean and median), dispersion (standard deviation) and frequency distribution were calculated for all the variables in the two cohorts with the objective of comparing the runner context with the lactose-intolerant context. Wilcoxon signed-rank tests were conducted to statistically test the differences between both contexts; Hodges-Lehmann confidence intervals were also calculated. The effect size was measured with Cohen's d values, which were calculated for significant pairwise comparisons ($p < .05$) from z values obtained in Wilcoxon hypothesis tests (Ellis, 2010). Before tests were performed, normality was checked by Q-Q plots. All analyses were performed in SPSS and the Psychometrica calculator was used for the effect size analysis (Lenhard & Lenhard, 2016). Statistical analyses were undertaken and reinforced with qualitative data.

Research Results

Figure 2 shows the absolute frequencies for all the variables in Cohort 1. As shown in this figure, PSTs expressed a more developed model in Context2-R than in Context1-LI in respect to the three evaluated aspects: components, mechanisms and phenomena. In Context2-R, PSTs represented more boxes and connections between boxes than

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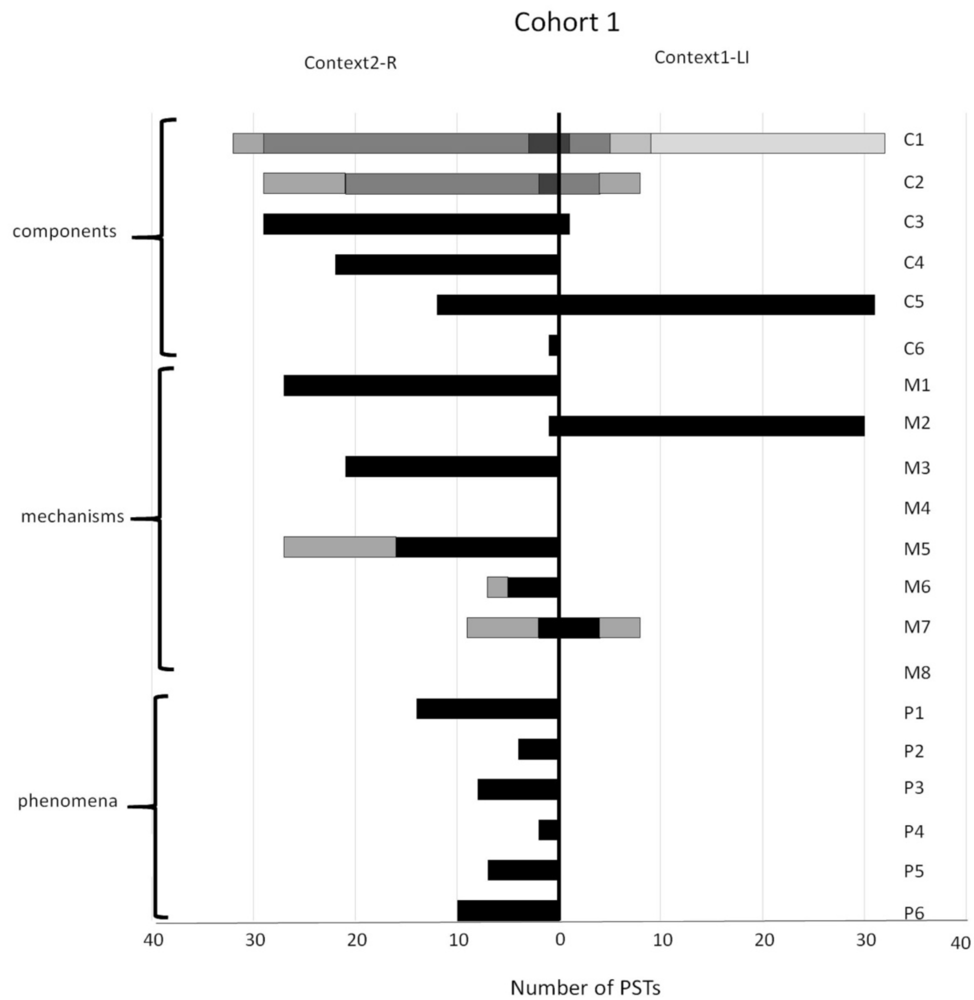
in Context1-LI. That is, in Cohort 1, the basic structure of the nutrition model (digestive, respiratory, circulatory and excretory systems and organs/cells as well as pathways among them) was better expressed in Context2-R than in Context1-LI. In Context1-LI, components and mechanisms related to the nutrients were almost the only ones represented: presence of nutrients, entrance of nutrients to the digestive system and absorption and transport of nutrients. That is, representations of components and mechanisms involved in other systems than the digestive system were almost absent. In contrast, more than half of the PSTs in Context2-R mentioned components and mechanisms related to oxygen and carbon dioxide: oxygen, its entrance into the respiratory system and processes (diffusion and transport); and carbon dioxide and its exit from the respiratory system. Energy (phenomena) was completely absent in Context1-LI.

Figure 2
Side by Side Comparison Bar Graph of Results in Cohort 1



Note: Absolute frequencies for variables in Cohort 1 for Context2-R (left) versus Context1-LI (right). Higher color intensity indicates higher value in the given variable (on the right). Note that only frequencies above 0 are shown; that is, only PSTs with some knowledge are shown. Variables are sorted in 3 categories (components, mechanisms and phenomena). C1: number of boxes; C2: number of connections; C3: oxygen; C4: carbon dioxide; C5: nutrients; C6: excretory products; M1: entrance of oxygen; M2: entrance of nutrients; M3: exit of carbon dioxide; M4: exit of excretory products; M5: diffusion and transport of oxygen; M6: diffusion and transport of carbon dioxide; M7: absorption and transport of nutrients; M8: filtration and transport of excretory products; P1: energy; P2: nutrients as source of energy; P3: oxygen for production of energy; P4: cellular respiration; P5: obtain energy; P6: use energy.

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In order to better define results in Cohort 1, examples of drawings of two PSTs of Cohort 1 are given (Figure 3). Drawings made by PST1-32 show that this PST draws both respiratory and circulatory systems (as well as diffusion and transport) leaving out the digestive system in Context2-R, while in Context1-LI the drawing is focused on the digestive system (Figures 3a and 3b). No phenomena are drawn nor described by PST1-32. Drawings made by PST1-5 show similar results (Figures 3c and 3d).

Figure 3
Examples of Drawings Made by PST1-32 (a, b) and PST1-5 (c, d).

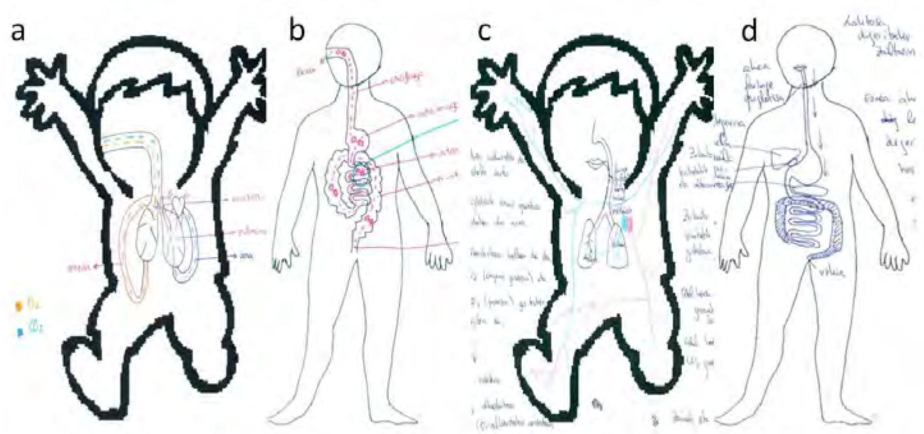

Table 1 includes measurements of the mean, median and standard deviation for both contexts in Cohort 1. The results given in Table 1 indicate that the differences between the means and medians obtained by Cohort 1 in Context1-LI and Context2-R are large in most variables. The scores obtained from Context1-LI and Context2-R of Cohort 1 were compared through the Wilcoxon signed-rank test. Hodges-Lehmann confidence intervals were also calculated. As the table shows, the differences between Context1-LI and Context2-R are significant ($p < .05$) for most of the variables. Exceptions are those variables related to the excretory system (the number of PSTs that represented them is 0 or close to 0 in any of the contexts); nutrient absorption and transport (means are 0.38 for Context1-LI and 0.34 for Context2-R) and cellular respiration (values close to 0). Results are reinforced by high Cohen's d values (> .6 according to Hattie 2008). Thus, based on the confidence interval and Cohen's d values, it is safe to say that PSTs in Cohort 1 performed better in Context2-R than in Context1-LI.

Table 1
The Statistics Results in Cohort 1

Variable	Context	*M*	*Mdn*	*SD*	*p*	*CI %*	*CI limits*	*d Cohen*
N boxes (0,1,2,3,4,5)	1-LI	1.47	1	0.84	< .001	95	-1.5/-0.5	3.17
	2-R	3	3	0.44				
N connections (0,1,2,3,4)	1-LI	0.38	0	0.71	< .001	95	-1.5/-1.0	2.58
	2-R	1.62	2	0.75				
O2 (0,1)	1-LI	0.03	0	0.18	< .001	95	-1.0/-1.0	5.29
	2-R	0.91	1	0.47				
CO2 (0,1)	1-LI	0	0	0	< .001	95	-1.0/-0.5	2.97
	2-R	0.69	1	0.47				

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Variable	Context	*M*	*Mdn*	*SD*	*p*	*CI %*	*CI limits*	*d Cohen*
Nutrients (0,1)	1-LI	0.97	1	0.18	< .001	95	0.5/1.0	2.42
	2-R	0.38	0	0.49				
Excretory products (0,1)	1-LI	0	0	0	-	-	-	-
	2-R	0	0	0				
Entrance of O2 (0,1)	1-LI	0	0	0	< .001	95	1.0/1.0	4.65
	2-R	0.84	1	0.37				
Entrance of nutrients (0,1)	1-LI	0.94	1	0.25	< .001	95	-1.0/-1.0	6.22
	2-R	0.3	0	0.18				
Exit of CO2 (0,1)	1-LI	0	0	0	< .001	95	0.5/1.0	2.76
	2-R	0.66	1	0.48				
Exit of excretory prod-ucts (0,1)	1-LI	0	0	0	0.32	-	-	-
	2-R	0.03	0	0.18				
O2 processes (0,1,2)	1-LI	0	0	0	< .001	95	-1.5/-1.0	2.97
	2-R	1.34	1.5	0.74				
CO2 processes (0,1,2)	1-LI	0	0	0	0.014	-	-	0.97
	2-R	0.37	0	0.75				
Nutrients processes (0,1,2)	1-LI	0.38	0	0.7	0.782	-	-	-
	2-R	0.34	0	0.60				
Excretory products processes (0,1,2)	1-LI	0	0	0	-	-	-	-
	2-R	0	0	0				
Energy (0,1)	1-LI	0	0	0	< .001	90	-0.5/-0.5	1.76
	2-R	0.44	0	0.5				
Nutrient as source of energy (0,1)	1-LI	0	0	0	0.046	-	-	0.76
	2-R	0.12	0	0.34				
O2 for production of energy (0,1)	1-LI	0	0	0	0.005	-	-	1.15
	2-R	0.25	0	0.44				
Obtain energy (0,1)	1-LI	0	0	0	0.008	-	-	1.06
	2-R	0.22	0	0.42				
Cellular respiration (0,1)	1-LI	0	0	0	0.157	-	-	-
	2-R	0.06	0	0.25				
Use energy (0,1)	1-LI	0	0	0	0.002	-	-	1.35
	2-R	0.31	0	0.47				

Note: Descriptive statistics, *p* values for the Wilcoxon signed-rank tests, confidence intervals for the median differences (Hodges and Lehmann) with upper and lower limits and Cohen's *d* values for results in Cohort 1 (n=32).

In respect to Cohort 2, the results are congruent with those in Cohort 1; that is, PSTs in Cohort 2 also performed better in Context2-R than in Context1-LI. Figure 4 shows the absolute frequencies for all the variables in Cohort 2. Again, PSTs represented a more developed structure in Context2-R than in Context1-LI, in terms of boxes and

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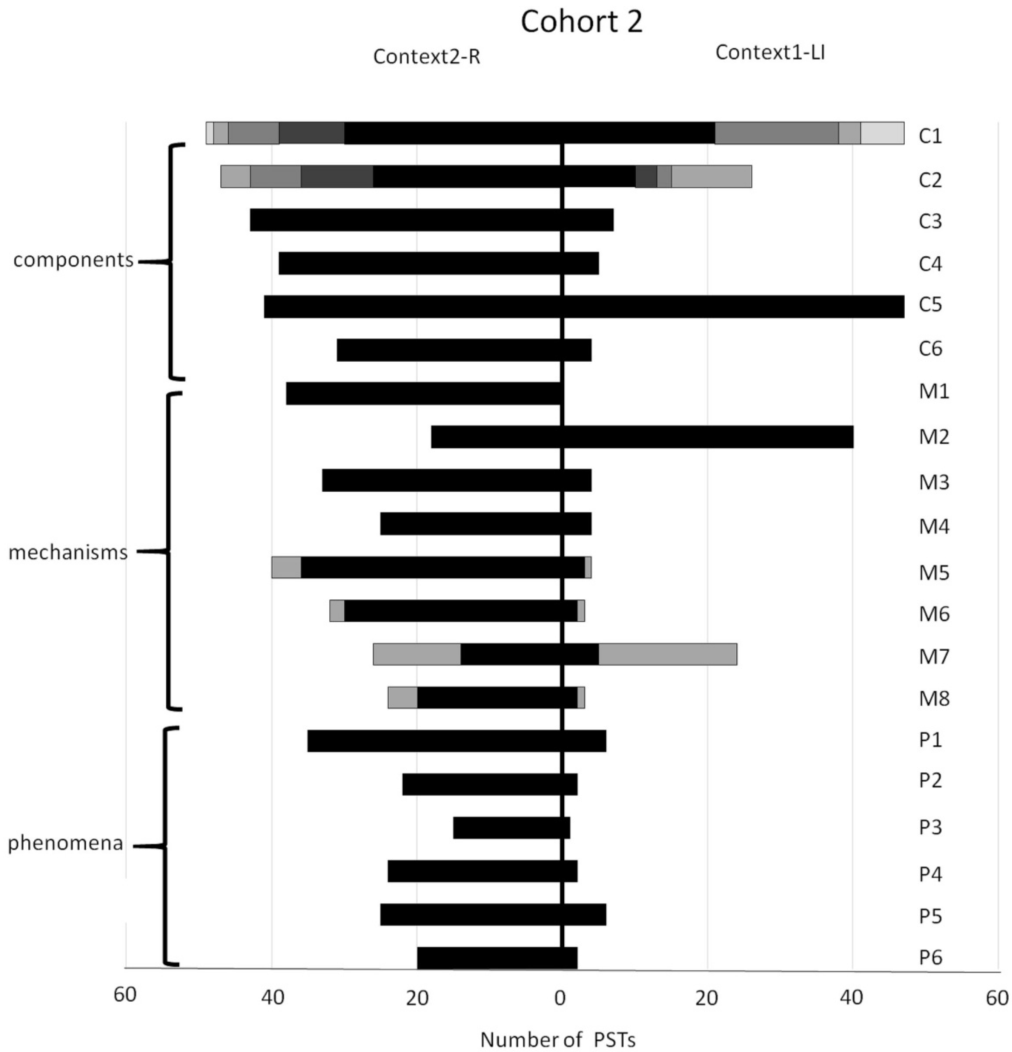
connections among them. In Context1-LI, components and mechanisms related to the nutrients were the most frequently represented: presence of nutrients, entrance of nutrients to the digestive system and absorption and transport of nutrients. In contrast, PSTs in Context2-R mentioned higher frequency components and mechanisms related to all systems integrated in the nutrition model. Variables related to energy (phenomena) were also more frequent in Context2-R than in Context1-LI.

Figure 4
Side by Side Comparison Bar Graph of Results in Cohort 2



Note: Absolute frequencies for variables in Cohort 2 for Context2-R (left) versus Context1-LI (right). Higher color intensity indicates higher value in the given variable (on the right). Note that only frequencies above 0 are shown; that is, only PSTs with some knowledge are shown. Variables are sorted in 3 categories (components, mechanisms and phenomena). C1: number of boxes; C2: number of connections; C3: oxygen; C4: carbon dioxide; C5: nutrients; C6: excretory products; M1: entrance of oxygen; M2: entrance of nutrients; M3: exit of carbon dioxide; M4: exit of excretory products; M5: diffusion and transport of oxygen; M6: diffusion and transport of carbon dioxide; M7: absorption and transport of nutrients; M8: filtration and transport of excretory products; P1: energy; P2: nutrients as source of energy; P3: oxygen for production of energy; P4: cellular respiration; P5: obtain energy; P6: use energy

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Figure 5 shows examples of drawings of two PSTs in Cohort 2. Drawings made by PST2-10 in Context2-R reached the highest level in the target human nutrition model (Figure 1) in terms of components, while in Context1-LI the drawing is mainly focused on the digestive system (Figures 5a and 5b). Drawings made by PST2-16 show similar results but, in this case, the explanations given in Context2-R described the mechanisms and phenomena involved (Figures 5c and 5d).

Figure 5
Examples of Drawings Made by PST2-10 (a, b) and PST2-16 (c. d)

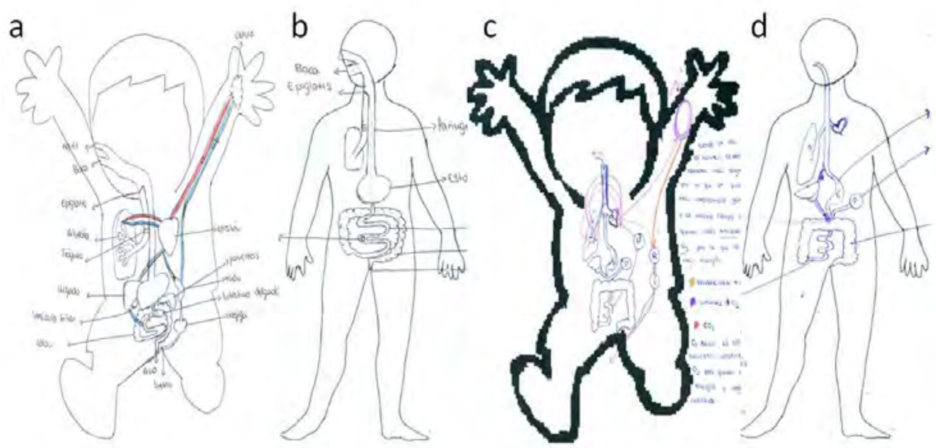

Table 2 includes values for the mean, median and standard deviation for both contexts in Cohort 2. As in Cohort 1, differences between the means and medians between Context1-LI and Context2-R are large in most variables. In respect to *p* values derived from Wilcoxon signed-rank tests, differences between Context1-LI and Context2-R are significant ($p < .05$) for all the variables except for the processes related to nutrients (mean values are 0.62 for Context1-LI and 0.82 for Context2-R). Results are reinforced by high Cohen's d values (> 0.6 according to Hattie (2008)). Thus, as in Cohort 1, based on the confidence interval and Cohen´s d values, it is safe to say that PSTs in Cohort 2 performed better in Context2-R than in Context1-LI. Therefore, based on the results of Cohort 1 and Cohort 2, the Context2-R was a significantly better context for the representation of PSTs' models of human nutrition.

Table 2
The Statistics Results in Cohort 2

Variable	Context	*M*	*Mdn*	*SD*	*p*	*CI %*	*CI limits*	*d Cohen*
N boxes (0,1,2,3,4,5)	1-LI	3.38	3	1.29	< .001	95	-2.0/-1.0	1.22
	2-R	4.33	5	1.01				
N connections (0,1,2,3,4)	1-LI	1.36	1	1.61	< .001	95	-2.5/-1.0	1.83
	2-R	3.10	4	1.18				
O2 (0,1)	1-LI	0.15	0	0.36	< .001	95	-1.0/-0.5	3.23
	2-R	0.88	1	0.33				
CO2 (0,1)	1-LI	0.11	0	0.31	< .001	95	-1.0/-0.5	3.06
	2-R	0.79	1	0.41				

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Variable	Context	*M*	*Mdn*	*SD*	*p*	*CI %*	*CI limits*	*d Cohen*
Nutrients (0,1)	1-LI	1	1	0	0.008	-	-	0.84
	2-R	0.84	1	0.37				
Excretory products (0,1)	1-LI	0.85	0	0.28	< .001	95	-0.5-0.5	2.05
	2-R	0.63	1	0.49				
Entrance of O2 (0,1)	1-LI	0	0	0	< .001	95	1.0/-0.5	3.62
	2-R	0.78	1	0.42				
Entrance of nutrients (0,1)	1-LI	0.85	1	0.36	< .001	95	0.5/0.5	1.45
	2-R	0.37	0	0.49				
Exit of CO2 (0,1)	1-LI	0.08	0	0.28	< .001	95	-1/-0.5	2.24
	2-R	0.67	1	0.47				
Exit of excretory products (0,1)	1-LI	0.08	0	0.28	< .001	90	-0.5/-0.5	-
	2-R	0.49	0	0.26				
O2 processes (0,1,2)	1-LI	0.15	0	0.51	< .001	95	-2/-1	2.98
	2-R	1.55	2	0.79				
CO2 processes (0,1,2)	1-LI	0.11	0	0.43	0.014	95	-1.5/-1	2.34
	2-R	1.27	2	0.95				
Nutrients processes (0,1,2)	1-LI	0.62	1	0.68	0.158	-	-	-
	2-R	0.82	1	0.85				
Excretory products processes (0,1,2)	1-LI	0.11	0	0.43	< .001	95	-1/-0.5	1.44
	2-R	0.89	0	0.96				
Energy (0,1)	1-LI	0.13	0	0.34	< .001	95	-1/-0.5	2.24
	2-R	0.71	1	0.46				
Nutrient as source of energy (0,1)	1-LI	0.04	0	0.20	< .001	95	-0.5/-0.5	1.72
	2-R	0.45	0	0.50				
O2 for production of energy (0,1)	1-LI	0.02	0	0.14	< .001	-	-	1.30
	2-R	0.31	0	0.47				
Obtain energy (0,1)	1-LI	0.13	0	0.38	< .001	90	-0.5/-0.5	1.33
	2-R	0.51	1	0.50				
Cellular respiration (0,1)	1-LI	0.04	0	0.20	< .001	95	-0.5/-0.5	1.79
	2-R	0.49	0	0.50				

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Variable	Context	*M*	*Mdn*	*SD*	*p*	*CI %*	*CI limits*	*d Cohen*
Use energy (0,1)	1-LI	0.04	0	0.20	< .001	80	-0.5/-0.5	1.45
	2-R	0.42	0	0.49				

Note: Descriptive statistics, *p* values for the Wilcoxon signed-rank tests, confidence intervals for the median differences (Hodges and Lehmann) with upper and lower limits and Cohen's *d* values for results in Cohort 1 (*n*=47).

Discussion

This study aimed to address how the context conditioned PSTs´ representation of their human nutrition model after participating in a modeling sequence whose objective was to construct the human nutrition model.

The findings showed two noteworthy aspects that deserve to be discussed. Firstly, in response to the research question, the PSTs showed a more complete model in Context2-R than in Context1-LI. This was evident in terms of representing a greater number of elements, organs and systems involved in human nutrition, more processes and a more thorough consideration of the underlying mechanisms. Secondly, this difference between the contexts persisted across both cohorts, even though the results were better in Cohort 2.

The results in Cohort 2 were better than those in Cohort 1 in both contexts. However, in Cohort 2, non-digestive system aspects still rarely appeared in Context1-LI. The situation present in quite a few PSTs was that, while in Cohort 1 Context1-LI was limited to the digestive system and Context2-R to the circulatory and respiratory systems (Figures 2 and 3), in Cohort 2, Context2-R reflected also the digestive and urinary systems, the various elements, processes, and energy extraction, while Context1-LI included some organs of the other systems but did not expand the elements, processes, and energy extraction to the same extent (Figures 4 and 5). This indicates that the model represented in Context2-R in Cohort 2 was in many cases quite complete and close to the target model represented in Figure 1, but such an improvement was not reflected to the same extent in Context1-LI. In fact, the difference between the contexts was statistically greater in Cohort 2.

This reinforces the idea that Context2-R was more appropriate for representing the model of nutrition and that Context1-LI, on the contrary, has been limiting. In fact, it did not reflect the development in the model that PSTs had made. This finding supports previous research indicating that instructions and contexts have varying limitations and potentials and should be taken into account when designing activities to assess students' knowledge (Heredia et al., 2016; Khwaja & Saxton, 2001; Nehm & Reilly, 2007; Prokop et al., 2009).

The emerging question from this study is what limitations Context1-LI has and/or where the potential of Context2-R lies. For this new question, hypotheses from researchers, which would need to be tested in future research, are that the context facilitates the representation of the nutrition model when it refers to the circulatory system and when it represents an energy use phenomenon.

Regarding the first hypothesis, the circulatory system is characterized by connecting the different systems, as shown in Figure 1. Its function is to transport elements such as nutrients, gases, excretory products and other substances within the organism; these elements come and go from different systems. This could potentially facilitate students' understanding of interrelationships and transport processes. In fact, Tripto et al. (2017) introduced the circulatory system as a mediating system, that links the function of the body's other systems and participates in the activities that enable homeostasis.

Concerning the second hypothesis, in Context1-LI the aim was for PSTs to allude not only to how the intolerance is produced but also to the consequences it has both on the formation of symptoms and on the failure to obtain energy due to the non-absorption of lactose in the small intestine, i.e., to the phenomenon produced (Hmelo-Silver et al., 2017; Uskola et al., 2022). However, the PSTs focused on explaining the phenomenon as a digestive problem. This aligns with Franco and Colinvaux's (2000) idea of synthesis when representing mental models due to the economy of cognitive resources. A representation is never a complete reproduction of the mental model because it implies the selection of what aspects will be represented and what other aspects will be left out of the representation (Prain & Tytler, 2012; Tytler et al., 2020). The idea here is that, depending on the context, PSTs' representations of their models were more or less synthetic. In Context2-R the phenomenon focused on the use of energy for running. In fact, energy was mentioned by 44% in Cohort 1 and 72% in Cohort 2, while only 0% and 13% respectively in the case of Context1-LI. Explaining where this energy comes from requires PSTs to focus on both nutrients and

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oxygen, their pathways and processes, and the disposal of the excretory products produced by obtaining usable energy in the cells. Therefore, teachers should choose a phenomenon that necessarily requires students to make reference to and use their knowledge of the organs, elements, structures, pathways and processes to be assessed.

A potential way to test the weight of these hypotheses could involve using a context in which only one of the two factors is present. For example, a teacher might adjust the intolerance scenario to incorporate an energy-related aspect, such as indicating that the intolerant person experiences fatigue. Conversely, a teacher could use a context only focused on the circulatory system, such as the one where students have to predict outcomes following blood loss from a wound.

Other studies on human systems have used instructions focused on the structure (in its general or specific form (Prokop et al., 2009; Reinoso & Delgado-Iglesias, 2020; Reiss & Tunniclife, 2001), others in the paths several elements follow inside the body (García-Barros et al., 2011; Robles-Moral et al., 2023). The results of the study suggest that, when teaching the nutrition topic, guidelines for students and contexts containing references to the circulatory system and energy use, that is, those that emphasize interrelationships between the components of the model and the phenomenon, should be used to evaluate the human nutrition model.

Limitations

The sample selection was non-random, limiting the capacity to draw statistically significant conclusions between contexts. Nevertheless, the congruence of results across both cohorts was noteworthy for this study's purpose. PSTs demonstrated improved performance within the runner context in both Cohort 1 and Cohort 2.

Conclusions and Implications

The present study showed that the context conditions the expression of the mental model. Given that teachers and their proposed activities constitute one of the main components in the teaching-learning process, this study added some evidence on the importance of selecting an appropriate context for the students to express their mental models. Teachers play a crucial role in offering the most appropriate context to evaluate the knowledge students construct. The findings of the present study showed that the guidelines given to students did condition the representation of the mental model of the students. The results lead to the suggestion that guidelines given to students and contexts that appeal to the interrelationships between the components of the model and the phenomena resulting from them should be used to assess the nutrition model. Contexts like these could be used not only as assessment tools but also for their construction in modelling sequences that involve representing the model to be assessed and revised. Representing the model gives the opportunity not only to communicate what has been learned but also to be able to ask new questions, reflect and construct knowledge. Incorporating contexts that facilitate the model to be represented as fully as possible can stimulate more questions, broader evaluation and, therefore, the construction of models closer to scientific ones.

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Declaration of Interest

The authors declare no competing interest.

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