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Attitudes toward Science and Scientific Literacy Among Romanian Young Adults

Barz Daniela-Luminița[a]*

* Corresponding author: Barz Daniela-Luminița, luminita.barz@umfcluj.ro

[a]*PhD Candidate,"Iuliu Hațieganu" University of Medicine and Pharmacy Cluj-Napoca, 8 Babeş Street, Cluj-Napoca, Romania*

Abstract

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The paper explores attitudes toward science and scientific literacy among Romanian young adults, through an online survey following key dimensions - attitudes toward science, integration of science in everyday life, beliefs in pseudoscientific phenomena and knowledge of the scientific method. Moreover, the study focuses especially on healthcare students and professionals' scientific literacy, exploring the level of scientific reasoning within the medical field. Analysis includes multiple comparisons across different fields of study, professional areas and age groups. The novelty of the study consists in shifting the assessment of scientific literacy from general scientific knowledge toward the understanding of the scientific method. Results of the present study confirmed a deficit in scientific knowledge, but more importantly, demonstrated that the relationship between scientific literacy and attitudes toward science was a non-linear one. In fact, the study found a gap between what people accept to be scientific fact and what they choose to integrate into everyday life. Given these results, we argue that science education's focus should be on developing scientific reasoning rather than providing scientific knowledge.

Keywords: Attitudes toward science; scientific literacy; higher education; medical education.

1. Introduction

Scientific literacy refers to an understanding of science and technology, of the scientific process and scientific facts. Even more so, scientific literacy requires "scientific knowledge and use of that knowledge to identify questions, acquire new knowledge, to explain scientific phenomena and to draw evidence-based conclusions about science related issues", as PISA defined it. Scientific literacy is pivotal in today's society, especially given the complexity of modern medicine, one has to be science and health literate to be able to make informed decisions "about themselves and their family as consumers and patients" (Miller, 2011). Integration of science into everyday life proves to be the most challenging task for science education, which impacts the individual throughout his lifespan. Studies have demonstrated that most people understand scientific research and value its benefits for society, but at the same time, hold beliefs in pseudoscientific phenomena, which do not seem to be swayed over time by engaging in formal scientific training. Pseudoscientific beliefs influence the decision-making process and become increasingly important in the context of public policy, views on climate change, vaccines, stem cell research and all technological innovations.

The present study focused on the current level of scientific literacy among Romanian students, but also young adults, with special attention given to the medical field. In line with research on scientific literacy until the present time, we developed a survey which focused on attitudes toward science, integration of science in everyday life, beliefs in pseudoscientific phenomena and knowledge of the scientific method.

2. Paper theoretical foundation and related literature

2.1. Overview on defining and measuring scientific literacy

Scientific literacy has been defined as a collection of skills and knowledge which allow the individual to understand how scientific knowledge is gained and be able to distinguish between scientific facts and other type of information (Impey et al., 2011). Scientific literacy emerged as an interdisciplinary field, which centered on science education, but also drew knowledge from philosophy of science, history of science, pedagogy, sociology and linguistics (Duit, 2007). If we looked at the history of science education, we would find at least nine separate goals of science education which were set to develop scientific literacy (DeBoer, 2000).

Defining scientific literacy has been a challenging endeavor ever since the first comprehensive attempt to quantify the public level of scientific understanding in the 1957 pioneering survey study commissioned by the National Association of Science Writers in the United States (Miller, 2010, Ed. Meinwald & Hildebrand). The 1957 research by Davis provided an initial conceptual framework for the study of scientific literacy and involved the measurement of public understanding regarding issues such as interest in science, sources of scientific information, understanding of scientific concepts and attitudes toward the benefits and limitations of science (Pardo & Calvo, 2002). This framework has been adopted by several empirical studies of public understanding of science worldwide, including the Eurobarometer. The Eurobarometer has been a source of data and insight for educational reforms and analyses for the past several decades. Apart from the Eurobarometer, PISA (The Programme for International Student Assessment) has been the most renowned large-scale survey study to focus on reading, mathematical and scientific literacy. Romania's mean score in PISA 2012 for the science section placed us as low achievers below the OECD average. The low performance with respect to scientific literacy was also confirmed in the 2009 study "STISOC – Science and Society. Interests and perceptions of the public regarding scientific research and research results.", funded by the National Authority for Scientific Research. However, results on this type of large scale-monitoring studies have fueled debate with regard to educational and methodological aspects of assessment. In addition, Pardo & Calvo (2002) accused the lack of theory in studies of the public understanding of science and claimed they are based on "conceptually fuzzy scales and indicators that fall short of the standards generally applied in other areas of social-scientific research".

2.2. Scientific literacy in higher education

Although much of the attention in research on scientific literacy has been given to pre-highschool and highschool students, studies on attitudes toward science and scientific literacy in higher education have yielded meaningful insights. Results from a 20-year survey of basic scientific knowledge and attitudes toward science among nearly 10,000 undergraduate students have shown that there is little difference between first year students and general public with regard to scientific knowledge. Gains over time, up to graduation, have been estimated at 10%-15%, even though curriculum included two or three science courses. The study also found high belief in pseudoscience and were not able to identify predictors of scientific literacy (Impey et al., 2011). Prediction of scientific literacy has proven to be strenuous, most research showed no significant difference in terms of gender, academic level or field of study (Holden, 2012). According to Miller (2010), the most reliable predictors of scientific literacy were attending at least three courses of science during the undergraduate programme, followed by obtaining a college degree and staying in touch with scientific news through media sources. In line with these findings, research showed that medical students demonstrate the same low level of scientific literacy, albeit the importance of scientific reasoning in healthcare (Peña, 2004). These systematic findings of low levels of scientific literacy have led to what has come to be termed as "the deficit model" (Sturgis & Allum, 2004). According to this model, the "deficient" level of scientific literacy has been directly linked to skepticism toward science. Currently, critique against the simplistic deficit model has highlighted the more complex nature of the relationship between scientific knowledge and attitudes toward science.

Health literacy in the general public and scientific literacy in medical education are crucial components for the welfare of a society. In light of the continuous technological developments and the massive amounts of data emerging every day, research in medical education has brought forth a need for change in terms of science learning and education. Aysan (2015) proposed three stages of the change process: the first stage referred to "persuading scientists of the necessity to change science education"; the second stage involved changing scientists' perspective, "they should not place an exaggerated importance on their own academic field and that they should see their field as being on an equal basis with other fields"; the third stage introduced the need for scientists to "condense the bulk of information on their hands to a manageable size".

Based on the conceptualization of scientific literacy provided across sociological and educational research, but also following the body of methodological studies on developing scientific literacy scales (Drummond & Fischhoff, 2015), the present study aimed to answer the following main questions:

Question 1: What are Romanian young adults' attitudes toward science and level of scientific literacy?

Question 2: Are there differences according to field of study in terms of attitudes toward science and scientific literacy?

Question 3: How do healthcare students compare in terms of attitudes toward science and scientific literacy to students in other fields of study?

3. Methodology

The study was conducted from 1st of March through the 31st of March on an online survey platform with access to more than 100.000 respondents across 22 counties in Romania (32.79% Bucharest, 6,46% Cluj, 4.44% Iași and so on), 41.28% male and 51.79% female, with potential respondents between the ages of 18 and 25 years old (16.73%) and the ages of 25-35 years old (47.85%). 90% of the panel came from the urban area, while 10% came from the rural area. The study was conducted on 4029 respondents, out of which 2310 met the criteria for the present study (18-35 years old, level of education – minimum highschool/vocational school graduates).

3.1. Participants

A sample of 2310 young adults was surveyed, between the ages of 18-25 years (42.4%) and 26-35 years (57.6%), out of which 781 were students, 65.6% were female and 34.4% male. 1989 out of the total respondents declared a field of study. Other personal data included: professional status (employment), personal income and last graduated form of education.

3.2. Instrument

3.2.1. Description and structure

We developed a questionnaire with the purpose of assessing the following main dimensions: general attitudes toward science (10 items), pseudoscientific phenomena (10 items), integration of science/ pseudoscience into everyday life (11 items), specific attitudes in health and medicine (15 items), understanding of the scientific method (5 items). The questionnaire also included two preliminary questions regarding the extent to which respondents stay up to date with new articles in their field of study and with new technological advances. 35 of the total number of items referring to general attitudes toward science, integration of science into everyday life and specific attitudes in health and medicine were formulated as statements using 4-point Likert-type response options, ranging from 1 (total disagreement) to 4 (total agreement), while the other items were multiple-choice.

Item generation was based on contemporary topics, scientific consensus, controversial issues which have received attention in the media and previously measured dimensions in large-scale scientific literacy studies. Items were formulated for the general public, so content was accessible to multiple disciplines.

General attitudes with regard to science as conceptualized in previous research (Klopfer, 1971, apud Osborne, Simon & Collins, 2010), encompassed “favorable attitudes towards science and scientists; the acceptance of scientific enquiry as a way of thought; the development of interests in science and science-related activities". Positive items included: "Science can improve human health", "People should know how the scientific process works", while negative items included: "Science moves us away from God", "We should be more skeptical of discoveries and inventions" or "Scientific research has no meaning unless it benefits society".

The *pseudoscientific phenomena* were defined as "claims presented so that they appear scientific, even though they lack supporting evidence and plausibility" (Shermer, 1997, apud Peña, 2004). The measurement of knowledge concerning pseudoscientific phenomena involved indicating the scientific nature of topics/domains such as homeopathy or astrology.

Integration of science or pseudoscience into everyday life focused on topics such as: beliefs in the influence of the position of planets on everyday events, in life after death, in negative/positive energy, in luck, signs or extrasensory powers; sample items included: "I think the month in which I was born has an influence on my personality", "I think there are signs which are sent to warn us about possible future events", "I think there are people who have extrasensory powers".

Attitudes toward specific *health-related issues* included items meant to evaluate people's stand on controversial issues such as doctor-assisted suicide, vaccines, the use of antibiotics, and advances in medicine with moral implications. Content included a combination of negatively and positively formulated items such as: "There are situations where medicine should not be used to extend a person's life", "Scientific researchers should be allowed to experiment on animals", "I believe that research should not be allowed to "rewrite" the genetic code of living organisms".

Understanding of the scientific method was assessed with multiple choice questions in relation to methodological aspects (with one best-choice answer): the specific characteristics of a scientific article, constructing hypotheses, the use of statistics in research, control of variables. Sample items were formulated as follows: "What do you think are the specific characteristics of a scientific article?", "How do you think scientists form hypotheses?" "How do you think scientists reach research results?".

3.2.2. Reliability and validity of the questionnaire

In order to assess the suitability of the questionnaire, we based our validity analysis on Lovelace & Brickman's (2013) best practices for measuring students' attitudes toward science education. We conducted a reliability analysis and factor analysis through PCA (Principal Component Analysis). Firstly, we computed a Cronbach's α for the 46 items which were measured on a Likert-type scale and found an α of .845. Secondly, we conducted a reliability analysis on the remaining 5 multiple-choice items regarding the understanding of the scientific method and found a Cronbach's α of .604. The high reliability found with the main part of the questionnaire could be explained by the large number of items and also, the considerable number of respondents. Multiple-choice items intended to measure understanding of the scientific method must be revised for future studies and were eliminated from the inferential analysis. Based on the reliability results we felt confident about being able to perform further analyses regarding differences in scientific literacy.

Table 1. Factor analysis of the scientific literacy questionnaire

Item content	Item-Total r	Factor 1 loading
I think there are signs which are sent to us to warn us about possible future events	.630	.708
There are no coincidences, just messages sent with a specific purpose	.589	.680
There are people who can heal by touch and channeling energy	.558	.662
I think that miracles are more common than people expect	.584	.659
Faith healing is a valid alternative to conventional medicine	.580	.644
I believe that the testimonies of people who went through clinical death are real	.537	.641
I think that magnetic jewelry like bracelets have healing properties for the body	.541	.632
Some numbers are luckier for me than others	.512	.619
I believe that after death the souls of people remain near their loved ones	.503	.619
The position of the planets has an influence on the events of everyday life	.484	.615

The second step in evaluating the questionnaire consisted of a principal components analysis. The approximate chi-square was 25859.118 (p = .000) indicating that the data were correlated and suitable for factor analysis. Based on exploratory analysis, four factors were retained, which explained 35.32% of the variance. However, results demonstrated heterogeneous factor loadings with 24 items loading on the 1st factor (ranging from .70 to .32), 5 items loading on the 2nd factor (ranging from .54 to .30), 4 items loading on the 3rd factor (ranging from .43 to .35) and 6 items loading on the 4th factor (ranging from .52 to .33). 4 items weren't loading on any of the four factors. This high heterogeneity was found in other studies on scientific literacy and scientific reasoning ability, as pointed out by Drummond and Fischhoff (2015). Table 1 illustrates the items with high item-total correlations and Factor 1 loadings, which will be discussed in last section of the paper.

4. Results

4.1. Overall results and differences among demographics

The 1st stage of the analysis included exploration of the overall descriptive results in relation to demographic indicators and SES, highlighting potential differences among subgroups. Notable results were also found within the section of scientific versus non-scientific topics/domains assessment and revealed that 64% of the respondents considered astrology to be scientific and 68% thought empiricism to be non-scientific; also, approximately half of respondents considered homeopathy and parapsychology as scientific domains. Due to the large number of items, Table 2. included a summary of selected distributions, which also showed significant associations in terms of gender, age, education and income.

The 2nd stage of the analysis consisted in extracting overall scores by aggregating total scores per respondent, computing the positive items with inverse-scored negative items. For the 1989 respondents who declared their field of study, results for the scientific literacy questionnaire were found ranging from minimum of 65 to maximum of 147 (m=107.53, SD=13.65).

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4.2. Differences across fields of study in relation to attitudes toward science and scientific literacy

The study included 37 fields of study, which were analyzed individually and then categorized into larger groups based on the Official Nomenclature of Undergraduate Study Fields (HG.676/2007) - Exact sciences, Economics, Nature sciences, Healthcare, Agricultural sciences, Engineering sciences, Social and political sciences, Law and legal sciences, Art, Architecture and urban studies, Humanities, Theology and Sports. The 37 fields of study were also matched with one of the three distinct groupings – "hard sciences", "soft sciences" and art. The distinction between types of scientific domains encountered demarcation problems, however, for the purposes of this study we accepted the terms "hard science" and "soft science", on the basis of perceived methodological rigor.

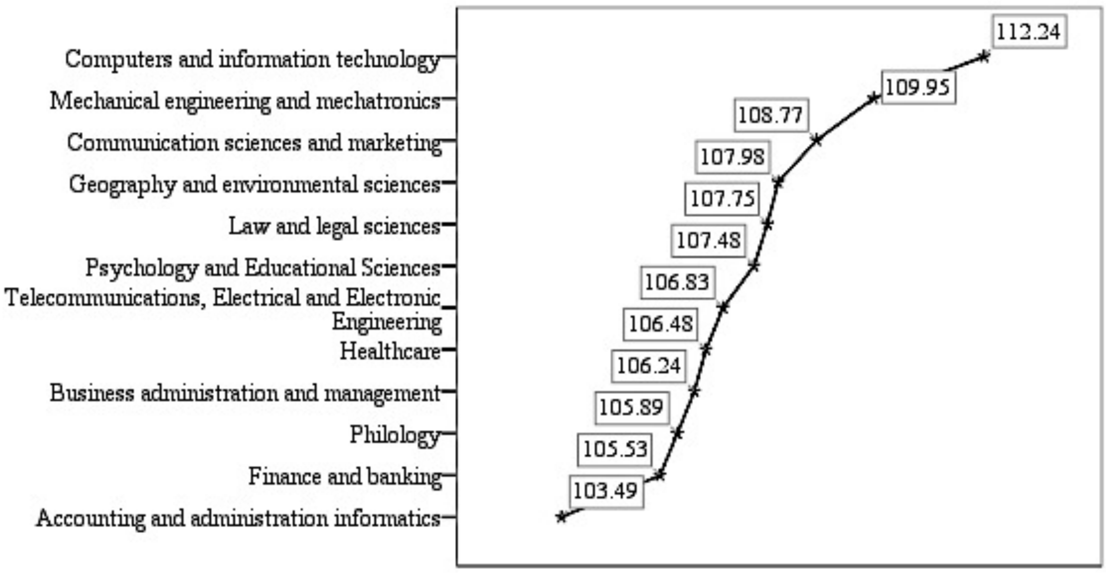

Fig.1. Distribution of means across fields of study

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Table 2. Overview of distributions for items with significant differences across gender, age, education and income

Items	***Frequency %***				***Pearson Chi-square Tests***			
	****	***	**	*	Gender	Age	Ed.	Income
Science moves us away from God	8.2	23.0	29.0	39.8	27.858	9.732	12.504	15.695
					.000*	.021*	.052	.206
Scientific research can endanger lives	12.6	42	32.7	12.6	10.592	7.386	14.974	13.162
					.014*	.061	.020*	.357
We should be more sceptical of discoveries and inventions	8.8	27.5	35.7	28	7.138	15.768	30.030	36.667
					.068	.001*	.000*	.000*
We should guide our lives based on religion, not science	6.9	19.1	33.6	40.3	13.643	1.675	10.938	68.833
					.003*	.642	.090	.000*
I think the month in which I was born has an influence on my personality	13.6	39.2	21.4	25.8	54.190	2.174	3.132	22.737
					.000*	.537	.792	.030*
It often happens to me to feel the negative / positive energy around me	20.6	39.5	22.4	17.5	89.470	3.257	1.483	41.149
					.000*	.354	.961	.000*
I think there are signs which are sent to us to warn us about possible future events	16.2	41.3	25	17.4	56.430	3.057	6.704	44.146
					.000*	.383	.349	.000*
I believe that the testimonies of people who went through clinical death are real	17.4	41.9	28.5	12.2	47.033	.658	6.741	23.865
					.000*	.883	.345	.021*
I think that miracles are more common than people expect	26.1	37.8	22.3	13.8	63.749	3.544	7.796	58.964
					.000*	.315	.253	.000*
Some numbers are luckier for me than others	10.4	27.1	29.5	33.1	23.896	2.790	4.757	48.587
					.000*	.425	.575	.000*
There are no coincidences, just messages sent with a specific purpose	14.7	33.5	32.1	19.7	39.490	.962	4.562	35.956
					.000*	.810	.601	.000*
I believe that after death the souls of people remain near their loved ones	11.3	31.4	29.6	27.8	39.249	2.014	11.711	70.841
					.000*	.569	.069	.000*
The position of the planets has an influence on the events of everyday life	11.1	32.4	29.1	27.5	24.823	3.917	12.647	41.032
					.000*	.271	.049*	.000*
I think there are people who have extrasensory powers	17.6	38.8	24.6	19	8.501	34.601	24.547	22.607
					.037*	.000*	.000*	.031*
Scientific researchers should be allowed to experiment on animals	13.1	36.2	28.8	21.9	78.519	43.997	36.876	37.872
					.000*	.000*	.000*	.000*
Faith healing is a valid alternative to conventional medicine	13.7	33.9	26.7	25.7	16.981	2.362	8.356	33.632
					.001*	.501	.213	.001*
We should not vaccinate our children because it is a dangerous practice with many adverse effects such as the development of autism	9.3	22.7	31	37.1	5.868	10.252	18.528	36.753
					.118	.017*	.005*	.000*
I think all medical treatments should be based on scientific evidence	46.5	38.4	11.8	3.4	2.826	2.848	13.602	24.053
					.419	.416	.034*	.020*
I do not think we should change the human body as God created us so	25.7	30	24.4	19.8	6.256	4.723	28.166	53.377
					.100	.193	.000*	.000*
People should regularly detox their bodies to eliminate toxins accumulated in the body	38.6	43.8	13.1	4.5	18.247	.974	2.975	14.049
					.000*	.808	.812	.298
I think doctors should rely more on intuition than on scientific research	5.6	18.9	34.3	41.1	8.617	21.659	17.074	18.723
					.035*	.000*	.009*	.095

**** = total agreement; ***=partial agreement; **=partial disagreement; *=total disagreement. Gender categories: male, female; Age categories: 18-25, 26-35. Education categories: highschool/vocational school, undergraduate/ college, postgraduate (MA, PhD); Income categories: None, < 1000 lei, 1000-1500 lei, 1500-3000 lei, > 3000 lei.

Results showed slight differences between broader fields of study in relation to scientific literacy, which proved to be significant results, assuming equal variance (Levene Statistic =1.13, $p > .05$; $F=3.16$, $p < .001$). However, using the larger conceptual distinction between “hard sciences”, “soft sciences” and art revealed no significant differences. This analysis identified respondents who studied architecture and urban studies as having the highest level of scientific literacy ($N=15$, $m=113.7$, SD=13.3), followed by: exact sciences (N=117, m=110.3, SD=13.2), engineering sciences (N=397, m=109.7, SD=14.4), law and legal sciences (N=129, m=107.7, SD=12.1), nature sciences (N=117, m=107.6, SD=12.1), social and political sciences (N=471, m=107.5, SD=13.5), humanities (N=161, m=106.6, SD=14.1), healthcare (N=166, m=106.5, SD=14.1), art (N=47, m=106.3, SD=13.9), agricultural sciences and veterinary medicine (N=41, m=105.9, SD=13.5), economics (N=298, m=105, SD=13.1), theology (N=8, m=103.1, SD=8.2) and sports (N=21, m=100.1, SD=9.8). Due to the large variation in subgroups, analysis was also performed on selected fields of study, out of the 37, which had a number of respondents higher than 80. Figure 1 shows means for fields of study with a total number of respondents of 80 or over (F=3.59, p <.001).

4.3. Attitudes toward science and scientific literacy in the Healthcare field

Analysis on the attitudes toward science and scientific literacy in the healthcare field was performed on a sample of 166 respondents, 57% of them were students (N=94) and 43% of them were young professionals (N=72). Data included the following healthcare specialties: Medicine (43%), Nursing (30%), Pharmacy (19%) and Dentistry (8%). As expected, concerning the positively formulated items, 70% of the total respondents were in total agreement with the statement “Science can improve human health”; 49% were in total agreement that “Scientific discoveries improve the quality of life for all” and 43% were in partial agreement; 42% were also in total agreement that “People should know how the scientific process works” and 55% of them were in total agreement that “All medical treatments should be based on scientific evidence”. At the same time, 30% of all healthcare professionals were in total agreement that “There are situations where medicine should not be used to extend a person’s life” and 20% of them were in partial agreement. 33% of them were in partial agreement that “Research should not be allowed to ‘rewrite’ the genetic code of living organisms”. 50% of respondents from healthcare areas were in total agreement that “We should not vaccinate our children because it is a dangerous practice with many adverse effects such as the development of autism” and 43% of them thought “There are people who can heal by touch and channeling energy”.

With regard to knowledge of methodological aspects involved in scientific research, data analysis revealed significant differences between healthcare fields. 40% of respondents from the nursing field thought statistics was used in scientific research to convince the public with regard to results and 38% of professionals in the pharmaceutical field declared that statistics were needed in order to publish research results. 65% of respondents from the medical field chose correctly when asked about the use of statistics – “Statistics facilitate the measurement of different variables”. 25% of pharmacy students and professionals also thought that hypotheses were personal beliefs about scientific phenomena.

In terms of overall mean scores, results showed significant differences between healthcare specialties (F=4.86, p<.05) with highest mean score found with Medicine (m=110.97, SD=15.47). Multiple comparisons showed that while healthcare as a broad domain showed a mean score of 106.48, students and graduates from the medical field demonstrated a mean score of 110.97 (See Figure 1). Also, results showed no significant differences in terms of gender.

5. Discussions and conclusions

Scientific literacy has been defined broadly as a set of skills necessary to discern between scientific facts and pseudoscience, between scientific information and other type of information and which allow the individual to understand how scientific knowledge is gained. In line with research on scientific literacy, we found that this broad conceptual framework has led to *methodological issues* and measurements challenges. Apart from the methodological aspects which must be addressed, results indicated two major topics which need further clarification: the relationship between *scientific literacy and science education*, and the relationship between *scientific literacy and attitudes toward science*.

As pointed out by Pardo and Calvo (2002), the lack of a coherent theory regarding the public understanding of science makes designing and conducting survey research on the subject a fruitless endeavor. Issues such as the combination of items which showed various degrees of generality, familiarity and salience for respondents, have proven to decrease validity and, perhaps, increase the perceived "deficit" in science knowledge. The questionnaire used in the present study revealed that items regarding attitudes toward science, more specifically, the integration of science into everyday life, proved to measure the same latent construct. Items regarding scientific knowledge seemed to show more heterogeneous distributions. Even more interesting results revealed that the items which haven't loaded on any of these factors seemed to refer to personal choices, rather than the "right choices based on science" ("There are situations where medicine should not be used to extend a person's life", "People should regularly detox their bodies to eliminate toxins accumulated in the body"). Other research on developing scientific literacy scales found low reliability and attributed it to known challenges with scenario-based items and the heterogeneous domain of scientific literacy (Drummond & Fischhoff, 2015).

Research on *science education* has demonstrated that scientific literacy was more than an educational output. DeBoer's (2000) review on the history of science education showed there have been numerous goals related to scientific literacy and he argued in favor of shifting the focus from specific educational outcomes to a domain with a broader scope, whose goals should be pursued in schools according to their suitability and using appropriate content and methodologies, and not aiming at "increasing scores on international tests of science knowledge". Research on scientific literacy in higher education has also proven that science education doesn't quite reach its goal of strengthening the level of scientific literacy in later life (See Chapter 2.2.). Studies on *attitudes toward science* have demonstrated that the relationship between scientific literacy and attitudes toward science was a non-linear relationship. Although the "deficit model" has been backed up by empirical data, research hasn't exactly found a high positive correlation between scientific knowledge and positive attitudes toward science (Sturgis & Allum, 2004). Moreover, the present study found a gap between what people accept to be scientific fact and what they choose to integrate into everyday life.

Given these results, we argue that science education's focus should be on developing scientific reasoning. In contrast to increasing the level of scientific knowledge, building cognitive and metacognitive skills would provide the basis for scientific literacy. Focusing on problem-solving skills through a process of hypothesize-test-conclude-reevaluate would facilitate scientific thinking. Future directions in research into scientific literacy in young adults should investigate the relationship between scientific reasoning and scientific literacy and how scientific reasoning influences the decision-making process in everyday life.

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