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The Role of Teacher Education in the Science Literacy Development

By Eva Klemenčič[*], Mateja Ploj Virtič[±] & Janja Majer Kovačič[°]

One of the aims of education is to produce wise and responsible citizens who are aware of their impact on the environment and can address and solve daily life problems. From this point of view, science education leading to science literacy is helpful for all students, regardless of their future careers. In this paper, we first review the definitions of science literacy in the literature and present the strategies for its development. In Slovenia, we refer to the ongoing national project NA-MA POTI. Most of the strategies studied focus on primary and secondary schools. However, for the development of science literacy in primary and secondary education, teachers themselves must achieve a sufficient level of science literacy. The research was conducted with a small group of prospective teachers, focusing on three components of science literacy: asking research questions, making hypotheses, and designing an experiment. In addition, we analysed the curricula of the science didactics courses in the teacher education program. The findings show a great need for a systematic change in the curricula. Finally, proposals and ideas for improving the curricula for the didactics of science and the syllabus of the Subject teacher study program are presented.

Keywords: *science literacy, teacher education, didactics of science, didactics of technics & technology, curricula*

Introduction

The term "literacy" is widely used through the ability to read and write and, more generally, through the connotation that it can be used effectively in various aspects of life. It is common to speak of technological, scientific, and even political and social literacy (Fensham and Harlen 1999, Harlen 2000, Fensham 2002). Literacy means having sufficient knowledge and appropriate skills, regardless of profession, specialization, or occupation. Today, the importance of literacy is justified by growing concerns about spreading misinformation and conspiracy theories that contradict established scientific knowledge and findings (Howell and Brossard 2021, Sharon and Baram-Tsabari 2020). Therefore, the ultimate goal of literacy should be to teach people to think critically by instilling in them the joy of science (Britt et al. 2014, Fortus et al. 2022).

[*]Assistant Professor, Faculty of Natural Sciences and Mathematics & Faculty of Energy Technology, University of Maribor, Slovenia.
[±]Associate Professor, Faculty of Natural Sciences and Mathematics, University of Maribor, Slovenia.
[°]Assistant Professor, Faculty of Natural Sciences and Mathematics, University of Maribor, Slovenia.

So, what does it mean to be "science literate"? Since the term science literacy was used in the late 1950s, it has no precise definition, and we could define it as a kind of general education in science (Almeida et al. 2022, Matthews 2014, DeBoer 2000, Bybee 2010, Millar and Osborne 1998, Hodson 2003). This point of view was already highlighted at the "World Conference on Education for All" in 1990 by UNESCO, where the primary goal of science education was stated to be the promotion of "a world community of scientifically and technologically literate citizens" (UNESCO 1999, cited in Millar 2006).

Nowadays, we are confronted with frequent changes in various scientific fields that affect many aspects of our lives. Moreover, these changes affect daily decision-making processes at the individual and community levels. The ability to identify, address and solve science and technological problems is part of scientific literacy. For the development of science and scientific literacy, science education is essential. It is the key to positive societal changes, developing positive attitudes towards the environment, and engaging individuals in efforts towards sustainable development. In Slovenia, the ongoing national project "Scientific and Mathematical Literacy: The Development of Critical Thinking and Problem Solving" (from now on referred to as NA-MA POTI) addresses the importance of developing scientific literacy in formal education. At this point, through our research and this contribution, we would like to highlight the importance of the role of the teacher and his/her awareness of the importance of students' scientific literacy. Other authors also point out the importance of pre-service teachers promoting science literacy in their students (Pahrudin 2019, Al Sultan et al. 2018, Almeida et al. 2022).

Science education can specifically enhance the development of science and scientific literacy through careful curriculum design. In the report on the Beyond 2000 project in the UK, Millar and Osborne (1998) argue that the science curriculum should be seen primarily as a course to support scientific literacy development. On the other hand, it should also deliver sufficient science knowledge for aspiring students. By including problem-based learning and research-based learning in the teaching practice, science education could support scientific literacy development and advanced knowledge in science. Furthermore, some authors (Tarmo 2014, Miller 2001) suggest competence-based curricula, which are especially common in vocational education but point out the possibility of deviation from content and consequently poor knowledge. However, competencies are essential for lifelong learning and will have an even more significant role in the future. Science curricula should emphasize the process of research, rather than guided experiments where students do not think about the individual step of the research (Ploj Virtič 2022). Ploj Virtič highlighted the scientific research procedural steps as one of the most important elements of scientific literacy.

Literature Review

By popularizing the phrase "science" literacy, Hurd introduced as early as 1958 a label for the established notion that mastery of the (natural) sciences was essential preparation for modern life (Hurd 1958). As one of the most influential reformers of science education, he also posed the question that is as relevant today as it was then (Hurd 1958, p. 14): "Is it possible to develop a philosophy of education and design a curriculum that will prepare young people for the approaching period of global industrialization, characterized by great discontinuity in scientific and social development?". The general feeling that some scientific theories and findings are "good to know" is also spreading in educational research and discussions about science education. Hurd used the term "science and/or scientific" literacy primarily to define new goals in science education, as he did in his widely cited works "Science literacy: Its meaning for American schools" and "Scientific literacy: New minds for a changing world" (Hurd 1958, Hurd 1998). Similarly, Roberts and Bybee later claimed that scientific literacy and science literacy as a curriculum concept are closely related to science education (Roberts and Bybee 2014, p. 545). Miller (1983) propose three constructive dimensions of the concept of scientific literacy: (i) norms and methods of science, (ii) cognitive scientific knowledge, and (iii) attitudes towards organized science. Further, in their careful analysis, Norris and Phillips (2003) develop a convincing argument that "scientific literacy" must be based on the fundamental meaning of literacy as the ability to analyse and interpret texts. They have listed several different concepts of scientific literacy that appear in the science education literature, such as:

- Knowledge of the substantive content of science and the ability to distinguish science from non-science.
- Understanding science and its applications.
- Knowledge of what counts as science.
- Independence in learning science.
- Ability to think scientifically.
- Ability to use scientific knowledge in problem-solving.
- Knowledge needed for intelligent participation in science-based social issues.
- Understanding the nature of science, including its relationships with culture.
- Appreciation of and comfort with science, including its wonder and curiosity.
- Knowledge of the risks and benefits of science or
- Ability to think critically about science and to deal with scientific expertise.

Moreover, the same authors (Norris and Phillips 2003) point to a dual, related but different understanding of literacy that is nevertheless interrelated, i.e., literacy as primary goals on the one hand, and skill development, knowledge, learning, or education more broadly as higher goals on the other. Bybee (1997), DeBoer (2000), Bybee (2010), Bybee and McCreae (2011) argue that science literacy should not be defined in terms of specifically prescribed learning outcomes but should be defined broadly enough to pursue the goals of the individual science education programs in which it is used. Osborne (2007), on the other hand, problematizes that science education as practiced does not meet the needs of today's youth, arguing that today's science curricula and practices are primarily 'fundamental,' meaning that the focus is on educating future scientists rather than future citizens. Roberts (2007) has provided a clarifying discussion of scientific literacy, including political and intellectual perspectives. However, according to Laugksch (2000), the conceptualization of scientific literacy masks different meanings and interpretations associated with scientific literacy, for example, due to varying understandings of what the public should know about science and who "the public" is. The different meanings and interpretations can lead to the concept of scientific literacy being seen as a confusing concept. Furthermore, Roberts (2007) notes that some authors (though not all) treat the terms "science literacy" and "scientific literacy" as synonyms. Almeida et al (2022) also recently emphasized the same. DeBoer (2000, p. 582), on the other hand, believes that the terms are not uniform and have different meanings and definitions. Furthermore, DeBoer advocates using the terms as synonyms for the public understanding of science and simply talking about the exact science education. Feinstein (2011) suggests that an instrumental version of the term "science literacy" must be linked to the actual use of science in daily life - what is sometimes called public engagement with science. Holbrook and Rannikmae (2007) suggest that the term "science literacy" should be retained. However, it is necessary to link it to understanding the nature of science, personal learning characteristics, including attitudes, and the development of social values. The same authors also show that another crucial component in defining scientific literacy is an appreciation of the nature of science (Holbrook and Rannikmae 2009). It is evident that the use of both terms (science and scientific) has a long history in science education and has been used indiscriminately without a proper consensus on their meaning. As Laugksch (2000, p. 71) stated, "Scientific literacy has become an internationally recognized educational slogan, catchword, phrase, and modern educational goal." In addition, scientific knowledge is constantly growing and changing, making the terms "science literacy" and "scientific literacy" even more challenging to distinguish. As Britt et al. (2014) point out, instead of focusing on the difference between these two terms, educational research and discussion should focus on questions such as "What is science (scientific) literacy? Why are science texts challenging for readers? What do non-scientists need to know and do to consume scientific information - real or fake - from the internet? How can students be prepared to critically reflect on the information they find in inquiry-based learning activities?".

The Programme for International Student Assessment (hereafter PISA) has also highlighted problems in defining science and scientific literacy. PISA is an international comparative study of student knowledge and literacy. It requires students to extrapolate their learning, think outside the box, and apply knowledge in new situations (Schleicher 2019). Therefore, the focus is on literacy (especially reading, mathematical, and science), and competencies encompass knowledge, skills, and attitudes. In the PISA framework (OECD 2019), scientific literacy refers to "knowledge of science and science-based technology." The term "scientific literacy" indicates that PISA focuses on applying scientific knowledge in real-life situations related to science and technology. PISA defines scientific literacy as:

- Explaining phenomena scientifically.
- Evaluating and designing scientific inquiry.
- Interpreting data and evidence scientifically.

Scientifically literate individuals must acquire content, procedural, and epistemic knowledge to address, understand, and explain phenomena; to identify features of scientific inquiry and apply methods, practices, and strategies in designing, conducting, and evaluating scientific investigations; and to identify, justify, and consider questions, procedures, and claims. Details can be found in PISA 2018 Assessment and Analytical Framework (OECD 2019).

Science Literacy Development within NA-MA POTI

In Slovenia, NA-MA POTI addresses the importance of developing science literacy development and connects the main actors in formal general education: the National Education Institute Slovenia, all three public universities in Slovenia, and 97 educational institutions (kindergartens, primary and secondary schools).
The role of the universities is to:

- Cooperate in defining science literacy and mathematical literacy.
- Elaborate didactic approaches, strategies, and recommendations for the vertical development of science and mathematical literacies.
- Elaborate methods and tools to assess progress in the development of science and mathematical literacies.
- Evaluate didactic approaches and strategies.

The project's main objective is to develop and implement pedagogical strategies for developing science and mathematical literacy, critical thinking, and problem-solving. The project aims to support sustainable vertical development of science literacy of children and students in preschool, primary and secondary education. It also aims at the horizontal effect of other literacies, such as reading, digital, and financial. To equip and support teachers, members of the project's working groups develop didactic approaches and materials for implementation and organize workshops and seminars. Each working group has its focus: science literacy, mathematical literacy, critical thinking, authentic problems and gamification, a supportive environment for a positive attitude towards science and mathematics, and teamwork.

This paper focuses on science literacy, within which scientific literacy is also developed. Science literacy encompasses knowledge and skills related to science and attitudes towards science. It manifests in applying knowledge and skills to solve problems, interpret natural phenomena, acquire new knowledge, and gain new insights. Within NA-MA POTI, the definition of science literacy includes awareness of how science and technology shape our environment, a willingness to cooperate, and the ability to communicate and transfer knowledge. For evaluation purposes, science literacy needs to be standardized. Therefore, we present three building blocks of science literacy as defined in NA-MA POTI (Bačnik et al. 2022):

1. Science and Scientific Explanation of Phenomena.
2. Scientific Research in Science, Interpretation of Data and Evidence.
3. Attitude towards Science.

The first building block aims at students' ability to recognize, explain, and evaluate science and technology phenomena, processes, and laws, as well as their interrelationships and dependencies in systems. The second building block focuses on describing, planning, conducting, and evaluating research (experiment, product manufacturing). It also deals with the students' ability to analyse, evaluate, and present data and formulate relevant conclusions. The third building block focuses on developing appropriate, proactive attitudes (values, beliefs) towards nature, environmental protection, science, and research. Each building block is divided into more minor elements, as shown in Table 1.

Table 1. *Building Blocks and Elements of Science Literacy after Bačnik et al. (2022)*

Building block		**Elements** The student…
1 Science and Scientific Explanation of Phenomena	1.1	… recalls, connects, and applies knowledge to describe and explain science and technology phenomena using professional terminology
	1.2	… obtains relevant information using different sources to explain concepts and phenomena
	1.3	… identifies, uses, and creates (scientific) explanations of phenomena, including different representations, models, and analogies
	1.4	… identifies and explains the possible use of knowledge and its impacts and consequences for individuals, society, and the environment
2 Scientific Research in Science, Interpretation of Data, and Proofs	2.1	… identifies and assesses contents (topics, problems, phenomena) that can be scientifically researched within science and identifies the research problem
	2.2	… formulates research questions
	2.3	… formulates appropriate predictions/hypotheses for research (experiment, product manufacturing)
	2.4	… plans the research (experiment, product manufacturing) step-by-step
	2.5	…ensures the safe and responsible implementation of the research (experiment, product manufacturing) by appropriate use of accessories (measuring devices, apparatus, laboratory equipment …)

	2.6	… edits, analyses, and interprets obtained data
	2.7	… analyses and critically evaluates the implementation of research, suggest improvements, and reports the research results
3 Attitude towards Science	3.1	… acts as a part of nature and takes care of a responsible attitude towards nature and the environment
	3.2	… develops and demonstrates an appropriate attitude towards science and scientific research

For each element, we set descriptive criteria to assess a student's level of science literacy. The descriptive standards are different for the levels of education (pre-school, primary, and secondary) and are vertically graded. The descriptive criteria for each element at each level of education represent the highest expectations for the development of science literacy. We present descriptive criteria for two elements of the second building block: 2.3 Formulating appropriate research hypotheses (Table 2) and 2.4 Planning Step-by-step Research (Table 3).

Table 2. *Descriptive Criteria to Evaluate Students' Ability to Formulate Research Hypotheses After Bačnik et al. (2022)*

Education level		**Descriptive criteria** The student…
Pre-school education		… predicts what will happen, what will be observed, and what will be results (and why)
Primary education	First triad (Grades 1-3)	… predicts what will happen and what will be results based on the research questions and experiences … formulates hypotheses by asking questions such as "how and what would happen if …" … recalls personal experience or pre-knowledge to clarify hypotheses
	Second triad (Grades 4-6)	… predicts what will happen and what will be results based on the research questions … formulates hypotheses by asking questions such as "how and what would happen if …" and considers what is changing and what is remaining constant … justifies hypotheses based on personal experience or pre-knowledge
	Third triad (Grades 7-9)	… formulates hypotheses based on the research questions and pre-knowledge … formulates hypotheses that include dependent and independent variables using sentences such as "If … then…" … evaluates hypotheses and distinguishes between hypotheses and unsubstantiated predictions … recognizes dependent and independent variables from a given hypothesis

Secondary education		… formulates scientifically testable hypotheses based on the research questions … formulates hypotheses that include dependent and independent variables … evaluates hypotheses from the expert's point of view and concerning a research question … formulates hypotheses that can be scientifically verified in terms of current (school) conditions … infers to the research question based on given hypotheses and recognizes

As can be seen from Table 2, pre-school education focuses on asking and answering questions about what will happen when certain phenomena are observed. The phenomena should be appropriate for pre-school children, e.g., the floating and sinking of different objects in water ("Which object floats on the water? Why?") and the melting of ice ("What happens to ice cubes at room temperature? Why?"). By the end of primary school, students should be able to make predictions, formulate hypotheses based on their experience and knowledge, and recognize dependent and independent variables. This is also the last stage of compulsory education in Slovenia. At the end of secondary school, we expect students to be able to formulate scientifically testable hypotheses based on the research questions and evaluate them. When training students in hypothesis formulation, we start by asking simple questions and then build up to questions that lead students to form relevant hypotheses that can be proved or disproved. The descriptive criteria for other elements of the building blocks have a similar vertical gradation. Therefore, in Table 3, we focus only on the descriptive criteria for the secondary level, which is of interest to us.

Table 3. *Descriptive Criteria in Secondary Education to Evaluate Students' Ability to Plan Research Step-by-Step after Bačnik et al. (2022)*

Education level		**Descriptive criteria** The student…
Secondary education		… plans the research, identifies external factors, dependent, independent and controlled variables (constants), and predicts their interactions … obtains information on the safe and ethical implementation of the research, predicts possible hazards, and plans appropriate security measures and protection (including data collected) … designs a research plan, selects qualitative or quantitative approaches to data collection (including digital technologies) according to the research purpose and is aware of the subjectivity and objectivity of obtaining data … plans honest research and is aware of its importance and restrictions/limitations … proposes appropriate sampling and research samples considering statistics (size, structure, randomness,

		representativeness, exclusion criteria) … plans and selects the right accessories (measuring instruments) and a fair and reasonable number of measurements/repetitions depending on the research type … plans, identifies, and justifies the control research (experiment, test) and distinguishes between controlled and control experiments … knows the reasons for measurements' uncertainties and that each measurement has limited accuracy (systematic and random errors) ... justifies the importance of research repeatability

By the end of secondary school, we expect students to be able to plan safe and honest research using appropriate measurement tools, measurement, and data collection methods. In addition, we expect students to be aware of research limitations and the importance of repeatability and accuracy of research.

Science education in Slovenia has a good starting point since the science-related subjects are throughout the whole duration of compulsory education. Furthermore, many schools are included in the development projects to enhance science, math, digital, and entrepreneurship competencies (Klemencic et al. 2022). Comparative analysis of science subjects and mathematics curricula by Kácovský et al. (2021) shows curricula in Slovenia have higher percentages of learning outcomes requiring conceptual and procedural knowledge. However, analysis pointed out lower percentages of learning outcomes requiring higher levels of cognitive processes (analysis, evaluation and creation). In addition, as argued by Boujaoude (2002), science curricula should have scientific literacy topics to support the development of science and correspondingly scientific literacy. Furthermore, curricula should thus determine not only the content of the course but also suggest the teaching methods and strategies. Similar impulses can be found elsewhere in the world. For example, Al Sultan et al. (2018) and Pahrudin (2019) emphasize that curriculum designers should prioritize the dimension of scientific literacy in the curriculum.

Moore et al. (2021) show the role of curriculum materials, which consist of schemes of work, lesson plans, class activities, and assessments, on teacher professional development using keyword analysis.

The Aim of the Study

The project NA-MA POTI focuses on the science literacy development from pre-school to the end of secondary education, meaning it excludes tertiary education. To develop science literacy in primary and secondary education, teachers themselves must achieve a sufficient level of science literacy. As the subject didactics of science and technology, the authors set themselves the following goals:

- to evaluate the level of science literacy of prospective science and technology subject teachers, and

- to analyse the curricula of subject didactics of natural sciences and technology, whether they contain elements that enable the development of science literacy in students, prospective science and technology subject teachers.

The study focuses on the components of science literacy, specifically on two elements of the second building block (see Table 1): formulating scientifically testable hypotheses and designing an experiment to test the hypotheses. Based on the synthesis of the findings, we intend to find opportunities to improve the curricula of subject didactics in teacher education, which will contribute to raising the science literacy of prospective science and technology teachers.

From the literature review, we found that the topical issue of scientific literacy is widely discussed. However, our research is one of the first to highlight the role of teachers in developing students' scientific literacy. By improving teacher education, raising teachers' awareness of the importance of scientific literacy, and teaching them how to develop it in students, we highlight the uniqueness of our contribution.

A Brief Presentation of the Teacher Education in Slovenia

One must briefly understand the educational vertical to understand the concept of teacher education. Slovenian pre-tertiary education is therefore presented in Table 4. In addition to pre-tertiary education in Slovenia, Table 4 also shows which types of teacher education are required for teaching at individual levels of education. In this paper, we discuss prospective subject teachers, and for a more straightforward idea of which part of the educational vertical they will be able to teach, they are marked in bold.

Table 4. *The Pre-Tertiary Education in Slovenia*

Pre-tertiary education		**Qualification required to teach at this level of education**[1]	**Study program to get the required qualification**
Compulsory Basic education: Primary school (9 years)	Primary school (Grades 1-5)	primary teacher (one teacher is teaching all subjects)	Primary teacher education covers a wide range of areas (master study program – 5 years of study)
	Lower secondary school (Grades 6-9)	**Two-stream subject teacher** (math, physics, chemistry, history, technics and technology, sport,…)	**Two-stream subject teacher education. Students are studying two subjects, e.g., math & physics, biology & chemistry, … (master study program – 5 years of study)**

[1]The "subject teacher" education is marked in bold – these programs we deal with in this article.

Secondary education (Up to 4 years)	Vocational school (Vocational matriculation examination at the end of school) (3 or 4 years) or	**Mostly two-stream subject teachers** (math, physics, chemistry, history, sport,…)	- For the general subject: **Two-stream subject teacher education. Students are studying two subjects, e.g., math & physics, biology & chemistry, … (master study program – 5 years of study)** - For particular vocational subjects: After finishing the basic non-pedagogical program (e.g., mechanical engineering, wood processing…), the additional pedagogical program must be done to get a license for teaching. (3-5 years + license for teaching)
	High school-general upper secondary education (Matriculation examination at the end of school) (4 years)	**Dominated by the single-stream subject teacher** (math, physics, chemistry, history, sport,…)	**Single-stream subject teacher education. Students are studying one subject (master study program – 5 years of study)**

The subject teacher education regularly offers two options of study: single-stream and two-stream study. Alternatively, someone who completed master's studies in a non-pedagogical program (e.g., Biology, Mathematics, or Engineering) can enrol in a 60 ECTS pedagogical program to get a license for teaching. The subject teacher programs, whether single- or two-stream, consist of two major modules: (1) non-pedagogical module(s) (depending on the chosen field of study: math, physics, biology, …) and (2) pedagogical module which includes at least 60 ECTS in pedagogical subjects (such as psychology, pedagogy, work with students with special needs, general didactics, …) and teaching practice. In addition to general pedagogical subjects, subject-specific pedagogical subjects are also included in the pedagogical module. We call them subject didactics. Subject didactics connect subject professional contents with general didactics and discuss different ways of teaching, depending on the specifics of each subject profession. The development of science literacy is one of the competencies that have many opportunities to be developed within the subject didactics of science and technology.

The training of science and technology teachers in Slovenia is carried out at two universities: the University of Ljubljana and the University of Maribor. Our research was conducted at the University of Maribor.

Methodology

The qualitative study is expected to draw upon multiple (at least two) sources of evidence (Bowen 2009). Therefore, our study was conducted in two parts: (1) research on the science literacy of prospective science and technology subject teachers and (2) in-depth analysis of the curricula of subject didactics of natural sciences and technology.

The Research on Science Literacy of Prospective Science/Technology Subject Teachers

The qualitative research was conducted on the sample of 7 students in the third year of study, prospective science/technology subject teachers at the University of Maribor, in June 2021. Due to the very small number of students in the science and technology subject teacher program (Dolenc et al. 2021), our sample comprises as many as a third of all enrolled students. The sample was carefully selected (Shaheen and Pradan 2019) in such a way as to represent the different subject orientations of the study (Physics, Technics & Technology, Math, Biology, and Chemistry); see Table 5.

Table 5. *Study Orientation of the Students in the Research*

Student 1	Physics and Technics & Technology
Student 2	Math and Technics & Technology
Student 3	Biology and Chemistry
Student 4	Biology and Chemistry
Student 5	Math and Physics
Student 6	Math and Technics & Technology
Student 7	Physics and Technics & Technology

Students were invited to a "Scientific Research in Science and Technology" workshop. During the workshop, we followed the goals related to the elements of science literacy, and the content discussed the current field of energy, which connects science and technology.

The Description of the Workshop

In the introductory presentation, we presented to the students some theoretical starting points related to solar energy and its exploitation. They learned about the advantages of solar energy over other forms of energy and understood the different types of solar cells and their characteristics in detail. An experiment followed the theoretical work. Participants received work instructions - worksheets subject to qualitative analysis in the following procedure - as a pre-test. In the pre-test, the participants were placed in the role of a researcher who sought answers to research questions through various experiments. The first pre-test task on a 4-point scale (never, once, 2-5 times, and more than five times) checked previous experience with conducting experiments on science subjects, research assignments, at home, or elsewhere. The second task included two research questions (RQ1: "How to charge the phone battery using solar cells?", RQ2: "How to charge the phone battery using solar cells the fastest?") and required participants to set appropriate hypotheses (Hs) before starting the experiment. The third task required participants to plan the experiment step-by-step. After they had experimented, a comprehensive discussion and evaluation of the pre-test results were done. The debate highlighted important factors of procedural knowledge of scientific research in different case studies. In the post-test, the students were given new research questions and were asked to tackle them using the steps they had learned, without experimenting, this time. They were asked to set appropriate hypotheses and plan the experiment step-by-step.

Assessing Criteria and Coding of the Responses

Previous experiences with conducting scientific experimentation were coded into three categories:

(1) Beginner (students who never experimented).
(2) Moderately experienced (students who did not experiment more than five times in any of the listed activities).
(3) Expert (students who indicated that they had experimented more than five times in at least one of the listed activities).

As a starting point for developing criteria for assessing the progress of students' scientific literacy, we have summarized scientific research skills to be focused on in the study based on the descriptors for procedural knowledge developed in the national project NA-MA-POTI. The qualitative research was done on:

a) a student formulates a scientifically testable hypothesis(es) based on the research question and related knowledge, which includes a dependent and an independent variable;
b) a student designs the experiment by defining the variables (dependent and independent) to be studied.

The criteria (as follows) were developed for each procedural scientific research skill we focused on in the study.

Students' responses to the task "Set the Hypotheses (Hs) based on the research questions RQ1 and RQ2" were divided into seven categories:

- The Hs are not posed/not defined as an assumption.
- The Hs are not posed/there is just a list of factors.
- The Hs for the RQ1 are deficient. No variables are included.
- The Hs for the RQ1are relevant, variables included; the Hs for the RQ2 are not posed.
- The Hs for the RQ1 are relevant, variables included; the Hs for the RQ2 are not relevant.
- The Hs for the RQ1 are relevant, variables included, at least one relevant H for the RQ2 is posed.

- The Hs for the RQ1 are relevant, variables included, two or more relevant Hs for the RQ2 are posed.

Students' responses to the task "Design the Experiment to test your Hypotheses" were divided into four categories:

- The research plan is irrelevant/not possible to check the Hs.
- The research plan is deficient; variables are included.
- The research plan is relevant; variables are not included.
- The research plan is relevant; variables are included.

In-depth Analysis of the Curricula of Subject Didactics of Natural Sciences and Technology

For the second part of our study, we conducted a document analysis. Bowen (2009) listed many advantages of the document analysis method; one is that the documents are non-reactive, not affected by the research process, and remain stable and suitable for repeated inspections. The document analysis in our study is based on the deductive category application approach (Azungah 2018) focused on content analysis (Elo and Kyngäs 2008).

<u>Research Sample: Relevant Curriculum Documents</u>

To begin with, we analysed the list of competencies promised to graduates of the "Subject Teacher" study program. Further document analysis consisted of nine subject didactics curricula: Biological didactical practicum 1, Biological didactical practicum 2, Didactic of technology education 1, Didactic of technology education 2, Didactics of Biology, Didactics of physics 1 with practicum, Didactics of physics 2 with practicum, Chemistry Didactics 1, and Chemistry Didactics 2. In addition to general information about the subject, all curricula contain content, primary literature, objectives and competencies, intended learning outcomes, teaching methods, assessment methods, and lecturer's references. All curricula are compulsory subjects, depending on the field of study (e.g., a biology and chemistry student has Didactics of Biology, Biological didactical practicum 1, Biological didactical practicum 2, Chemistry Didactics 1, and Chemistry Didactics 2).

<u>Research Procedure</u>

At the initial stage, the research team used the building blocks presented in Table 1 to generate a list of science literacy-related search terms, so-called keywords, to be searched in the curricula of subject didactics of natural sciences and technology. The keywords were as follows: (1) experiment*, (2) hypothes*, (3) research*, (4) scientif*, (5) laborator*, and (6) manufactur*. Identifying science literacy topics in the documents was conducted by searching for the keywords.

Results

The research results of prospective science/technology subject teachers on science literacy, specifically on the ability to form hypotheses and plan experiments step-by-step, are summarized in Table 6. All participants are most experienced with conducting experiments, which is expected as they are in their third year of the "Subject teacher" study program. However, the results also indicate their experiences are related more to the content knowledge and less to the process of experimenting and researching. Overall, participants have poor prior knowledge of formulating appropriate hypotheses. We notice that students with study orientations in Math, Physics, and Technics & Technology had better prior knowledge and advanced more concerning students of study orientations in Biology and Chemistry. The opposite is true in designing the experiment, where students of Math, Physics, and Technics & Technology study orientations have a lower starting point. However, after the workshop, all participants show the ability to design a research plan that is comprehensive and relevant.

Table 6. *The Research Results on Science Literacy of Prospective Science/ Technology Subject Teachers*

Student	Previous experiences	"Set the Hs based on the research question RQ1 and RQ2"		"Design the Experiment to test your Hs"	
		Pre-test	Post-test	Pre-test	Post-test
Student 1	3	3	4	1	3
Student 2	3	3	7	1	4
Student 3	3	1	2	3	4
Student 4	3	1	4	4	4
Student 5	2	3	6	1	4
Student 6	3	4	7	2	4
Student 7	3	2	6	2	4

Table 7 shows the basic descriptive statistical analysis of the data collected and the calculated effect size Cohen's h, a measure of distance between two proportions. Effect sizes between 0.2 and 0.3 are considered small, values around 0.5 are considered medium, and values above 0.8 are considered large effect size (Cohen 1988).

In both cases, Cohen's h is large. We can interpret this as the sense that the planned learning activity statistically significantly improves the ability to hypothesise students' ability to plan a step-by-step experiment.

Table 7. *Descriptive Statistics and Cohen's h Effect Size (Cohen 1988)*

	Mean	Med	Mod	St. Dev	Sum (%)	Cohens' *h*
Previous experiences (categories 1-3)	2.86	3	3	0.38	20 (95%)	
"Set the Hs based on the research question RQ1 and RQ2" – pre-test (categories 1-7)	2.42	3	3	1.13	17 (35%)	0.78
"Set the Hs based on the research question R Q1 and RQ2" – post-test (categories 1-7)	5.14	6	4, 7, 6	1.86	36 (73%)	
"Design the Experiment to test your Hs" – pre-test (categories 1-4)	2.00	2	1	1.15	14 (50%)	1.17
"Design the Experiment to test your Hs" – post-test (categories 1-4)	3.86	4	4	0.38	27 (96%)	

Our in-depth analysis of the curricula of natural sciences and technology subject didactics and studies indicates the lack of science literacy topics. Table 8 presents the document analysis results of subject didactics courses and the list of students' competencies after the study program. It is essential to mention that students gain experience with researching, problem-solving, and experimenting within other subject-specific courses, where the focus is more on the content. On the other side, subject didactics courses emphasize process knowledge and prepare students to transfer knowledge as teachers.

Table 8. *Results of Document Analysis*

	*experiment**	*hypothes**	*research**	*scientif**	*laborator**	*manufactur**
List of competences	0	0	0	0	0	0
Biological Didactical Practicum 1	5	0	0 [1]	1	11 [a]	0
Biological Didactical Practicum 2 [2]	5	0	0 [a]	1	8 [a]	0
Didactics of Biology	0	0	2 [a]	2	0 [a]	0
Didactic of Technology Education 1	0	0	0	0	0	0

[1]The number of results is filtered - the results that are part of the form or lecturer's references are removed.
[2]The courses are taught in the 4th year and have not yet been attended by the students involved in the research.

Didactic of Technology Education 2 [b]	0	0	4	0	0	0
Didactics of Physics 1 with Practicum [b]	14	0	0	0 [a]	7 [a]	0
Didactics of Physics 2 with Practicum	13	0	0 [a]	0 [a]	4 [a]	0
Chemistry Didactics 1	0	0	0	0	0 [a]	0
Chemistry Didactics 2 [b]	0	0	0 [a]	0	0 [a]	0

The list of acquired competencies after completing the study program Subject Teacher does not include any of the selected keywords. Moreover, not one of the chosen keywords is in Chemistry Didactics 1, Chemistry Didactics 2, and Didactic of Technology Education 1 curricula. In addition, none of the subject didactics' curricula addresses hypotheses. Including selected keywords in curricula is the highest for study orientations Physics and Biology.

Discussion

The results on science literacy research of prospective science/technology teachers indicate shortcomings in students' knowledge and ability to formulate hypotheses based on research questions and design relevant experiments (see pre-test results in Tables 6 and 7). Interestingly, all students are highly experienced with experimental work, as they have many subject-specific courses intensive on laboratory and field exercises. Regardless, subject-specific courses focus on contents and less on the research process itself. Thus, students had difficulty formulating hypotheses despite their experience with experimental work. Previous research has confirmed that experimentation and teaching with active student involvement is not a guarantee of better results (Waldrop 2015). Scientific activities must be properly integrated into the teaching process, emphasising the research process and placing students in the role of independent researchers (Ploj Virtič 2022).

Similar hypothesis formulation results were also reported by Aydoğdu (2015) among prospective science teachers in Turkey, who used them to investigate the poor performance of Turkish 4th and 8th-grade students in the TIMSS science literacy survey.

Students with orientation in Math, Physics, and Technics & Technology performed slightly better (see Table 6), which might be because mathematics requires greater systematicity. At the same time, students of these orientations are more familiar with the variables (dependent and independent) and external parameters that affect interactions. Based on the curricula analysis, students do not address the formation of hypotheses within the subject didactics regardless of the study orientation. However, based on the research results, there is a visible upgrade in the post-test. The starting point in the ability to formulate hypotheses and the advancement after the workshop were lower for students of orientation in Biology and Chemistry. Therefore, it is somehow surprising these students were better at designing experiments when compared to students of Math, Physics, and Technics & Technology orientations.

The latter could be the implementation of practical exercises and experiments, where students, in most cases, only conduct experiments according to instructions, search for answers to research questions, and test given hypotheses. In this way, students have a deep understanding of the content of the experiments but do not have the opportunity to plan individual research steps independently. Therefore, we agree with Saat (2004), who wrote that science teaching needs to be redesigned to emphasize science process skills.

Based on the curricula analysis, it is expected Math orientation students have lower prior knowledge about experiment design, as it is less represented in curricula. However, students in Physics orientation have many experimental and laboratory exercises (see Table 8, "Didactics of Physics 2 with Practicum" and "Didactics of Physics 2 with Practicum") but still have a poor ability to plan relevant experiments. Despite the inclusion of practical exercises in the curricula, we can conclude that there are shortcomings because the experiments are more or less focused on the content, not the process. The latter is also indicated by the lack of hypotheses in the analyzed curricula.

At this point, we can confirm that the advices written in the PISA 2018 Assessment and Analytical Framework (OECD, 2019) and by Ploj Virtič (2022), which emphasizes the importance of procedural skills and content knowledge, are very well taken into account. Osborne's (2007) warnings that it is necessary to maintain an appropriate balance of essential content and scientific competencies in science education (and consequently in science curricula) that will enable the education of future scientists, as well as future responsible citizens, must be taken into account.

The limitation of the study is a small sample of prospective science and technology students. Nevertheless, they represent a third of all enrolled students. During research analysis, we found that previous experience with experimentation should be further categorized since all students fall into the "expert" category. In addition, the chosen research problem addressed in the workshop has also impacted the results, as some students can be more familiar with it. We should also point out that document analysis focuses on subject-didactics curricula, despite knowing science and scientific literacy can develop through other courses. In addition, we searched keywords related to the formulation of hypotheses and planning of an experiment. However, those are only two elements of science literacy defined in NA-MA POTI, meaning curricula could include other elements, for example, describing and explaining phenomena, editing, analysing, and interpreting data.

Conclusions

To develop science literacy through science education, it is necessary to train prospective science/technology subject teachers. The latter is a prerequisite for science literacy to continue developing. We note that tertiary education, which is responsible for educating prospective science and technology teachers, is not included in development projects such as NA-MA POTI. Consequently, science and scientific literacy are not intentionally included in the education process. The latter is also evident from the analysis of the curricula. The curricula focus on content knowledge and not on the comprehensive development of competencies, including skills and attitudes. As the curricula form the basis for teachers' preparation and delivery of lessons, the introduction of science and scientific literacy is essential. However, curricula are not a recipe to be followed without deviation. Teachers are more or less free in their choice of teaching methods and approaches and can thus promote the development of process knowledge and skills. Following the science literacy framework defined in NA-MA POTI, subject didactics curricula should contain elements of each building block shown in Table 1.

In response to our research findings, we propose a further in-depth analysis of the curricula and the study program as a whole about the development of science literacy development, as this is one of the goals that prospective science and technology teachers should achieve at the end of higher education. The curricula, especially for subject didactics, should include elements of science literacy. However, we must know that changes are also needed at the implementation level. For example, some curricula already include experiments and laboratory work but do not sufficiently promote the development of science literacy, as students mostly follow prepared instructions strictly. Therefore, we believe that more inquiry-based learning and independent problem solving could encourage the development of science and scientific literacy. In addition, we suggest that teachers encourage students (prospective science and technology teachers) to include some elements of science literacy in their lesson plans. This would lead to the conscious inclusion of elements of science literacy in classroom activities. If students get used to consciously including elements of science literacy, they are more likely to do so when teaching in schools.

The study aimed to highlight the importance of teacher training for the further development of science literacy. Currently, measures to support the development of science literacy are systematically implemented from preschool to the completion of secondary education, which means that tertiary education students are excluded regardless of their field of study. Therefore, higher education teachers in specific areas of study need to include science literacy content in the curriculum or adapt the delivery of classroom activities to support the development of science literacy.

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