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INVESTIGATING THE IMPACT OF SUPPORTIVE PROGRAMMES TO ENHANCE THE LEARNING TRANSFER OF TEACHERS

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CHAPTER 1

1.1. Statement of the problem

Recently, in the report titled “What students learn matters”, the OECD project named ‘Future of Education and Skills 2030’ has defined the ‘Time Lag" in education as the phenomenon that occurs when the contents, abilities, and key competencies the students are expected to master at the end of their school journey lie behind what jobs and real-life situations request them to know and to do[1].

What are the driving factors that may lead to this skill mismatch?

More than ever, against the backdrop of global environmental problems and social inequality that are worsening, the world is facing even greater change due to rapidly advancing innovations such as Artificial Intelligence, the Internet of Things (IoT), Big Data, robotics, and biotechnology[2].

In addition to digital and green transformation, the COVID-19 pandemic has posed enormous challenges to the global economy, society, and people's lives. UNESCO says that 1.6 billion students, including more than 200 million in higher education, were affected by school closures. Despite being unprepared for such a sudden change, educational institutions might have to move to emergency remote teaching overnight, shifting online to give lectures and adjusting to remote learning[3]. This is just a demonstration of the fact that not only is innovation driven by cutting-edge research, where new discoveries are often used in ways that change the way we usually do things, but it is also affected by the consequent modification of social, economic, and cultural backgrounds. We look for and use new approaches to cope with the changing needs and realities of society, thus influencing the context we live in[2].

The immense challenges we face may have sparked a societal shift toward “Society 5.0”, in which infrastructures and technology assist people in resolving social and environmental issues with an emphasis on sustainability, human worth, and resilience[4]. People would be interested in how technologies, discoveries, and ideas can improve business processes and results and how their application will affect organizations, institutions, and societies, making human progress more sustainable and humane[2].

In addition to basic skills, more and more personal skills are becoming important. Beside numeracy, scientific literacy, cultural literacy, citizenship, and digital literacy, soft skills such as effective communication, creativity, and critical thinking will also be increasingly in demand[5]. To thrive in a post-COVID world, youth and adults need to be able to learn a wide range of essential skills, and institutions have a responsibility to prioritise development to open up more diverse entry points into the world of work and boost countries' economies[6].

Education systems significantly influence the extent to which individuals and societies pursue success opportunities. The capacity of education systems to either ameliorate or perpetuate social and economic inequality is one of the most fundamental global issues of our time[7].

The 2030 Agenda for Sustainable Development provides a broad set of targets for the European Union's commitment to education. Sustainable Development Goal 4, providing inclusive and equitable quality education and promoting lifelong learning opportunities for all, inspires the EU's policy, which considers education as a fundamental human right, vital to addressing global challenges and achieving long-term development. Meeting the other SDGs, which include goals and targets for human development, environmental protection, prosperity, justice, and peace, is also strongly correlated with high-impact school education. Improving long-term educational outcomes is a top priority of the EU's strategy, which considers strengthening education systems. They serve as a flywheel for productivity, innovation and resilience and contribute to more inclusive communities[8].

Important EU policies are based on the idea that skills acquired through education, training and lifelong learning are at the heart of fair and well-functioning labour markets. The European Pillar of Social Rights and the Council Recommendation on Vocational Education and Training (VET) for Sustainable Competitiveness, Social Fairness, and Resilience are the primary initiatives to establish the principles and define the road map for the recovery and a just transition to a digital and green economy[8].

The European Skills Agenda 2020 emphasizes the importance of enhancing understanding of skills and bolstering national initiatives. The European Skills

Index (ESI) of Cedefop serves as both a tool for mapping performance and a report on the evolution of national skills systems.

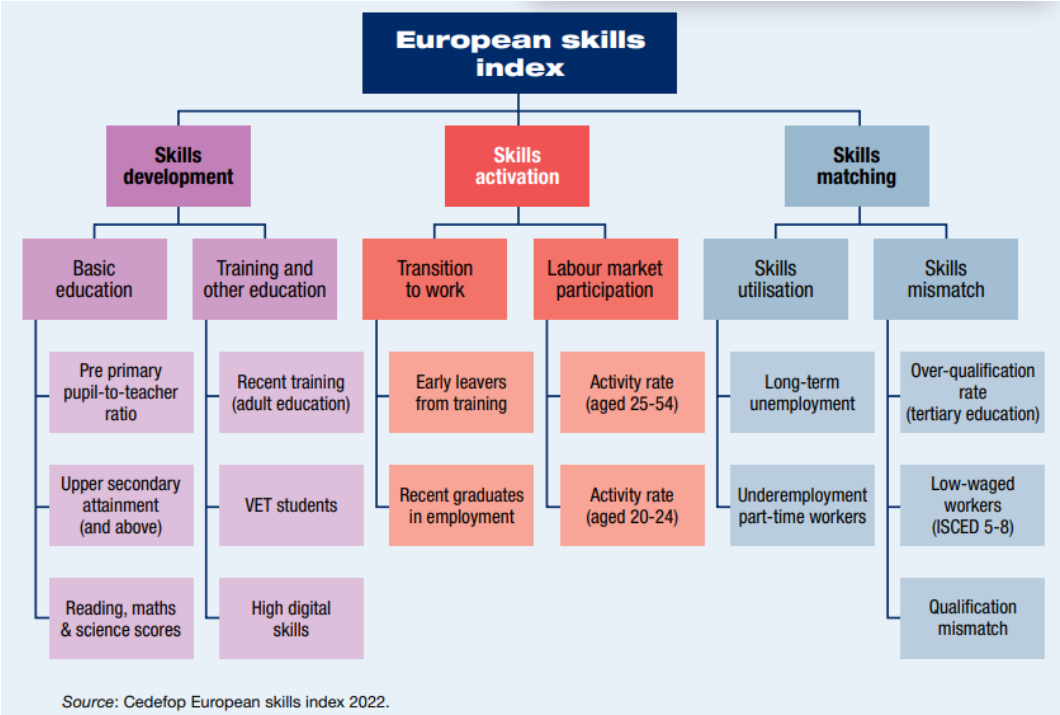


Fig. 1 - A scheme that summarizes the 'European Skills Index 2022'. Source: Cedefop.

Learning the necessary skills and competencies for the future is therefore the task of the educational world[9]. According to recent studies, the curriculum design and review process can be significantly enhanced by basing curriculum refinement on past and present facts that anticipate the future needs of society[10] and by considering the opinions of stakeholders to improve the level of its implementation[11]. Creating a unified vision for the student profile as intended student outcomes can also provide useful information when determining what must be modified to achieve the desired result[12].

While countries and schools have made significant strides in recent years towards a 21st-century curriculum that incorporates new goals such as digital literacy, sustainable development, cross-curricular content, and competency-based curricula, the results of such reforms are taking longer than expected to become visible, thus pointing out one of the four dimensions of time lag, the one depending on classroom implementation[12].

The size of the time lag is actually characterized by four dimensions: 'recognition time lag,' which is the time required to recognize the need for a curriculum change, 'decision time lag,' which depends on how long the entire process of formalizing the change takes, 'implementation time lag,' which occurs when curriculum reforms are not quickly or thoroughly adopted into classroom practice due to factors inhibiting or delaying their implementation, and, finally, 'impact time lag' which depends on the time needed for the results to become visible[13].

Since teachers are the primary curriculum implementers and their engagement with the curriculum directly affects the outcome of the reform, a sizable portion of the literature on curriculum implementation focuses on them. If they don't have the necessary skills, change won't happen, claims Fullan (2015)[14]. Kisa and Correnti expanded on the notion that teachers' limited knowledge or pre-existing beliefs and practices would obstruct a seamless implementation of the curriculum, contending that smart policy design takes into account stakeholders' capacity today as well as the aspirations to shape it in the future[15].

1.1. Curricula in renewed context.

Throughout history, the primary purpose of schools has been to help students develop a basic understanding that they can use to succeed in life and further improve their skills[10]. It has always been important to ensure that education is meaningful and relevant, emphasising the practicality of knowledge so that what is learned in school can be applied in different settings. The uncertainty of our ever-changing world makes it difficult to predict what education should aim to achieve; this is even more challenging when education is seen not only as a tool to react to and cope with changes in society, but also as a tool to define and build the future[16] [17].

The OECD's Future of Education and Skills project addresses this challenge, drawing on data from international and iterative surveys in several countries, and identifies two key questions to maximize the impact of the reform. The first focuses on the kind of knowledge students should develop to thrive and shape their world, and the second is inherent the way school systems should guide them in cultivating their skills[18]. Answering these questions is essential for revising curricula, avoiding

disappointing outcomes[19] and sustaining the implementation of curricular innovations[20].

With regard to the first question, globalisation, urbanisation, migration, climate change, resource depletion, the development of artificial intelligence, and technologies driving changes in work skills are common conditions that determine common areas of interest in curriculum design. Well-being, equity, sustainability and problem-solving skills to enhance learners' agency to successfully navigate an uncertain world are pillars of curriculum reform in many countries[18]. However, curriculum refinements are also a national affair because they are linked to the particularities and values of the societies to which they are tied[21].

In the literature, the term 'curriculum' involves more than one nuance. According to Taba (1970), a curriculum is a plan for learning[22]. It explicitly organises the objectives and content of teaching and learning and is often reflected in concrete curriculum materials. In other words, it is a set of guidelines for what students should learn and what should be taught by the education system[21]. However, it can also refer to a single lesson, a course or an educational programme. Stoll et al. (2006) interpret it as materials or documents used for teaching and learning, such as guidelines or textbooks[23]. Saavedra and Steele (2012), on the other hand, take a broader view, including other components that influence design and implementation, such as teaching methods, class size, timetables, learning objectives, assessment and examination practices[24].

Gouëdard et al. suggest that two models of curriculum can be identified[21]. They differ according to the focus of design, which can be either 'product' or 'process'. The product model is outcome-oriented and based on the definition of learning outcomes in the cognitive, affective and psychomotor domains[25]. This facilitates the definition of learning objectives and, consequently, the selection of the structure and content of instruction, making it easier to measure achievements through testing[26].

The process model, on the other hand, shifts the focus from the outcome to the process of learning, which aims to develop students' skills holistically through appropriate learning experiences in which students engage in individual and personalised learning to solve targeted problem situations[27].

Both models have limitations. The first can be associated with a narrow experience where learning follows a predetermined map of outcomes to be achieved; the second may be less prone to measurement and accountability, leaving considerable room for teacher interpretation[28].

Based on the model, teachers can approach its implementation by designing three types of curriculum: content-based, objective-based, which focuses on students' tailored behavioural goals, and competency-based, where learning is contextualised in real-life situations, implying problem-solving to develop skills that are transferable to the real world[21].

In this perspective, the need of developing lifelong learning skills that would enable people to adapt to new contexts, has provoked a shift from a content-based curriculum to a competency-based curriculum[29;30]; here learning implies an emphasis on integrated performance-oriented abilities to navigate a world full of uncertainty[31]. Such an approach implies a shift in the teaching paradigm from a teacher-centred to a learner-centred one, which requires investment in training and capacity building for teachers to embrace the development of new approaches to teaching and learning and new material resources.

1.2. The European Education Area

School education was included as part of the Community's action program outlined in the Maastricht Treaty of 1992. The treaty encouraged cooperation among member states in education, while maintaining the states' sole responsibility for their respective educational systems. The goal of this cooperation was to achieve a high level of quality in education. However, the EU's ability to lead such initiatives was limited due to the principle of subsidiarity [32]. The European Union (EU) regards education as a form of "soft" legal power, indicating that the EU can suggest or advise on matters relating to education but lacks the legal authority to enforce binding regulations, directives, or decisions. The Lisbon Strategy of 2000 led to the creation of a new governance mechanism for Europeanization, with the goal of advancing cooperation in education and training through a comprehensive lifelong learning framework[33]. However, as noted by Symeonidis, Francesconi, and Agostini, despite the common goal of addressing the COVID-19 pandemic, the responses to the crisis differed among European societies and underscored the need for more unified actions by EU institutions[34]. As a result, the pandemic forced

Europe to temporarily halt its governance mechanisms for education, revealing their limitations, and revert to strong state-centric policies[35]. In this scenario, the pandemic, which has revealed and amplified inequalities in Europe[36], could lead to a reconsideration of the social aspect of European education policy. The concept of the European Education Area (EEA) was first supported by the Member States in 2017, but after taking office in 2019, President of the European Commission Ursula von der Leyen pledged to make the European Education Area a reality by 2025[37].

The Commission has identified six ways to improve the quality of education, which are:

- Increasing inclusivity and gender sensitivity in education and training
- Supporting the transitions to green and digital learning
- Improving the skills and motivation of educators
- Strengthening higher education institutions
- Considering education as part of a more influential Europe in the global context [37].

As stated in the "Council Conclusions on European Teachers and Trainers for the Future" from June 2020, teachers are considered essential to the European Education Area. They have the responsibility of promoting the European aspect of education and helping students develop a sense of European identity and belonging. Teachers are recognized as crucial figures in supporting learners to understand and experience the value of being part of Europe[38].

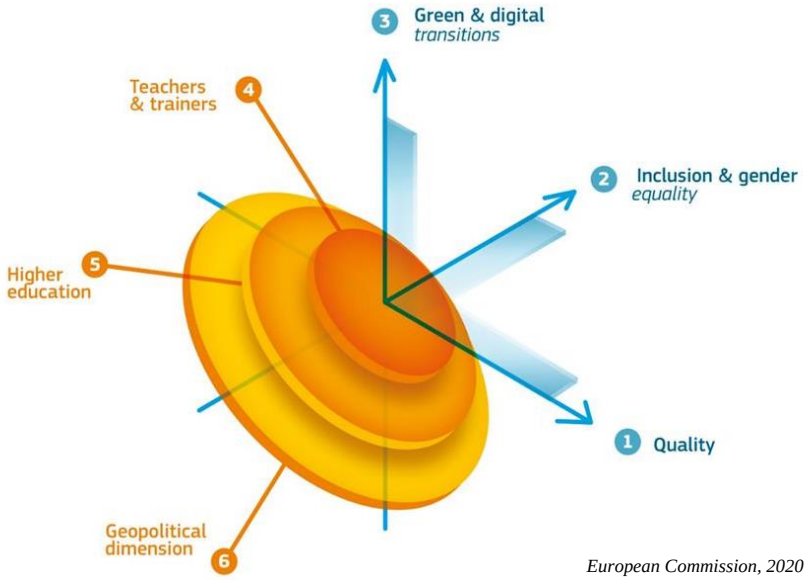


Fig. 2 – Six dimensions to consolidate the achievements towards The European Education Area

1.3. The teacher's roles and responsibilities in EEA

Teachers play a crucial role in the growth of students by developing both knowledge and practical skills necessary for their future as individuals. They not only impart academic knowledge but also inculcate values, life skills, and behaviours that help students become responsible citizens[38]. Teachers can either enhance or hinder student motivation, and while they are not the sole factor that determines the success of an education system, their quality is imperative[39].

Due to the constant changes in society, the field of education and training is facing new challenges and demands. Teachers and trainers are expected to keep pace with these changes while also performing various administrative tasks, extracurricular activities, professional development courses, and relationships with parents, students, and other stakeholders[39]. Consequently, it can be difficult for teachers to balance different aspects of their workload, "while simultaneously developing and maintaining the quality of their teaching and students' learning outcomes"[38]. However, the increase in workload is not the only factor affecting teachers' ability

to adapt to change[40]. Other well-documented factors include systemic issues that imply difficulties in transferring the content of reforms to the unique environment of schools[41] and lack of support during implementation[42]. Indeed, although guiding materials may aid teachers and assist with implementing a new curriculum, they alone are inadequate to alter the ideas and beliefs of teachers regarding the new content[43]. Consequently, it is recommended that well-crafted curriculum guidelines should be accompanied by opportunities for professional development to guarantee improved outcomes. This would enable teachers not only to comprehend the new content but also to incorporate it effectively into their teaching practices[44]. Indeed, according to Harris, beliefs, attitudes, and values are interconnected with teachers' agency in determining the outcome of the reform process[11].

The implementation of educational reform can be impeded by resistance to change among teachers. Despite efforts by researchers, policymakers, and educational leaders, successful implementation of educational reform is not consistent[45].

Citing Ford, Snyder claim that resistance to change can be a complex phenomenon, and change-leaders may misinterpret teachers' behaviours as resistance, while they are supporting the organization's goals according to their beliefs. In particular, such occurrence can be referred to veteran teachers who have great commitment and psychological ownerships in the organization[46]. Goodson et al. highlight that frustration and resistance may be generated when changes impact relationships thus implicating social nostalgia or when they decrease teachers' autonomy implicating political nostalgia[47]. Although it may be a challenging and time-consuming process, having clarifying conversations to understand the meaning of an initiative at the local level can enhance the ownership and successful implementation of change through shared leadership[48]. Moreover, Jonker et al. cite many studies that have shown that promoting teacher collaboration is crucial for school improvement and ensuring the sustainability of educational reforms. The benefits of teacher collaboration include enhancing the professional development of team members, promoting reform ownership, improving the quality of curriculum design, and facilitating the successful implementation of designed materials [49]

The Council of the European Union acknowledges that there is a requirement to enhance the competencies of teachers and trainers. This would involve not just

equipping them with the knowledge and skills to respond effectively to changes, but also inspiring them to take a proactive and creative approach to their professional endeavours[38].

The Council Conclusions represent a step forward when compared to the Education and Training 2020 policy document that, as noted by Filippi and Argwal, has few policies that relate to transforming teachers from instructors to designers, even if emphasis was posed on the importance of professional development. In their paper, with regard to the science education, the authors put forward the idea of Inquiry Based Science Education as a mean to change the role of teacher "[…] as a "facilitator" in the classroom, rather than the sole "owner" of information"[50]. Students are encouraged to explore, to ask questions and seek information on their own. The role of the teacher is crucial in developing students' capacity of applying the scientific discovery process[51] and an in-depth understanding of STEM content. Both are critical to the development of students' potential for innovation in the future. Consequently, ongoing professional development is a valuable approach for transforming teachers from instructors to designers of IBSE learning experiences[50].

Another relevant key point of Conclusions suggests that national policies must be informed by the needs of teachers and trainers, education research, and the broader learning community[38].

Pedaste et al. (2014) suggest that recognizing students' "must have" transferable abilities, frameworks such as the Partnership for 21th Century Skills actually provides an essential basis for teachers education. Thus, to guide students to succeed in work and life teachers "should be critical thinkers, problem solvers, good communicators and collaborators, literate in information technology, flexible and adaptable, innovative and creative, globally competent, and environmentally literate."[52]

The same framework has been used to assess the exhibition of 21st century learning practices across lesson plans designed by teachers working in exemplar US STEM schools[53]. Indeed, the framework was designed through structured dialogue with relevant stakeholders and identifies the following areas of interest against the fluid definitions of "21th century skills": key subject skills, life and career skills, learning

and innovation skills, and information, media, and technology skills[54]. A similar comprehensive framework has also been proposed in the EU. The Joint Research Centre (JRC), which is the European Commission's science and knowledge service providing independent scientific advice and support to European Union policy, has recently published documents that provide a common ground for learners and guidance to educators by advancing a consensual definition of sustainability as competence, as well as those of digital, life, and entrepreneurship skills.

Moreover, to promote healthy lifestyle, inclusive education, equality, equity, non-discrimination and the promotion of civic competences teachers should be able to deal with multicultural and multilingual environments as well as to adequately support students with special needs and disadvantages[55].

1.4. Curriculum implementation

The successful implementation of a curriculum depends to a large extent on the teachers who are responsible for its enactment[13]. In recent decades, a more autonomy-centred approach to curriculum revision has involved teachers in the design and implementation process at an early stage in order to build a diffuse sense of the reform that would reduce potential backlash against curriculum change[23]. Thus, the traditional view of curriculum design and implementation as a top-down approach has given way to a more bottom-up approach that recognises teachers' agency and autonomy[21]. Similarly, the concept of 'implementation fidelity' has been replaced by 'implementation integrity', which measures the extent to which teachers' adaptations of materials are consistent with the aims and principles of the curriculum[56]. According to Fullan (2015), the impact of implementation becomes visible as long as new practices and/or new goals are put into practice in the classroom. He further asserts that the process is influenced by three main aspects: materials, teaching approaches and beliefs[48]. In particular, beliefs influence what teachers consider important to teach in a new curriculum[57], and when they are aligned with curriculum reforms, teachers are more likely to implement the required teaching practices[21]. In addition, linking the knowledge and practices of the new curriculum with the existing curriculum would improve understanding and consequently implementation[58].

Many reforms rely on teacher learning and improved instruction to increase student learning. In fact, education reform is often synonymous with teachers' professional development[59]. However, for innovation to take place a "whole school approach" is often a requisite that implies schools being interactive systems that can learn and change[60].

Innovation of schools is a multi-faceted occurrence that is impacted by various factors at each level of the education system. Schools play a crucial role in implementing new teaching methods and organizational procedures, and act as intermediaries between other participants involved in creating innovative learning environments[61].

The report "Study on Supporting School Innovation Across Europe" identifies effective innovation in schools as a multi-stage process. This process begins with an internal reflection aimed at understanding students' needs, followed by the development of a shared vision and strategy that is supported by teaching and learning objectives and an implementation plan. The next stage involves experimentation and implementation, followed by an analysis of the data to improve the process further. The sustainability of innovation depends on how well it is integrated into the school culture and the extent to which students, school staff, parents, and local stakeholders positively perceive the quality of the improvement brought to the learning environment[55]. A critical factor in developing such an infrastructure necessary to support school development, change, effectiveness, and improvement is school leadership[62,63]. On the one hand, school leaders can guide schools in creating a culture that initiates and supports innovation[64]; they are characterized by their attitudes to work in a team and their capacity of mobilizing the school community[55]. On the other hand, distributed leadership can improve school outcomes[65] and enhance the participation of school staff in the decision-making process, even those teachers who are not in charge of any formal role[66]. Teachers' leadership, enthusiasm, and commitment are essential to maintaining students' motivation to learn and experiment[67]. Their capacity to innovate is also affected by the quality and availability of Initial Training Education and Continuing Professional Development programs that would provide them with support which, as well as favorable working conditions, would enable them to ensure a safe

learning environment, positive relationships with students, collaborative practices with peers, adequate resources, and a common purpose in improving students' outcomes[68].

1.5. Teachers' professional development

Professional development for teachers is essential for determining the efficacy of policies for teaching practice [69,70] and for enhancing student outcomes.[71]. In the literature, the concept of CPD can encompass a variety of activities, including workshops, local and national conferences, courses, and individual learning. The past decade has witnessed the emergence of more nuanced perspectives that define CPD as an interactive and social activity based on discourse and community practice. According to Desimone, research provides substantial evidence that effective professional development (PD) for teachers should consist of five key factors. Firstly, it should be focused on the content of the subject (a) and engage teachers in active learning, avoiding passive lectures (b). PD initiatives should be aligned with the curriculum and goals of the school, as well as the needs of teachers and students (c). Thirdly, the activities must be ongoing throughout the year and account for at least 20 hours of contact time (d). The final component of professional development should be collective participation, in which groups of teachers from the same grade, subject, or school build an interactive community (e) [71,72].

A teacher activity that falls under the professional development umbrella and is gaining momentum in educational practice is the involvement in a development or improvement process[73,74] for example, designing or choosing new curricula or textbooks or assisting with the school improvement plan. In collaborative design teams, teachers and often also with experts from the educational design, educational research, and educational content domains, create new curricular materials such as courses, lessons that would then be tested and used in classroom practice. Projects that involve collaborative design have different aims. At one end of the spectrum, professional development is seen as the primary aim. At the other end of the spectrum, the emphasis is on curriculum innovation[75]. As I previously mentioned, when emerging as a result of stakeholder sensemaking , such collaborative design can results in sustainable and successful implementation[21]. In school-based collaborative design settings, teachers collaborate to set goals and improve their

practice[76], acting as active agents and initiators of change[75]. In such approach, their role of “change agents" might vary from being merely adapters to being innovative creators. In collaborative design, the team uses design-based research to make decisions based on expected outcomes, and then observes how the design functions in the classroom. If there are any problems with a new teaching method, the design team collaborates to discuss them. This process is aimed at practical application: designing, enacting, and evaluating materials that guide students' thinking and are useful in practice [77,78].

1.6. The Italian model: schools’ autonomy

The education system in Italy is based on the principle of subsidiarity, both vertical, when the State delegates authority to subnational and local public offices, and horizontal, when it comes to the relationship between authorities and citizens, as established through the modification of the Title V of the Constitution (Law n. 3/2001). As a result, in the fields of education, while the State retains exclusive authority over general issues and ensures that essential standards are upheld by all educational institutions, schools, which are acknowledged of the status of autonomous institutions (Bassanini Law, 2000), have been granted decision-making power over aspects such as learning objectives and methods, teaching and research activities, and the development of curricula up to 20% of teaching hours. The remaining 80% of curricula are determined at the national level from the decision of the Ministry. Schools are also responsible for managing their own administrative staff and are required to develop and implement their own "Educational Formative Plan" (PTOF) which currently lasts three years. The School Council is responsible for approving the plan, which contains a comprehensive description of all to-be-implemented activities and is aligned with the improvement objectives derived from the previous cycle's self-assessment report.

In Italy, the idea of "curriculum" was firstly introduced in 2000 through Ministerial Decree 234 of June 26th, titled "Regolamento recante norme in materia di curricoli nell’autonomia delle istituzioni scolastiche".

The concept of competency is a pillar of curriculum development and a driving force behind the process of change. It is defined as “the development of complex capacities that enable students to think and act in various fields of activity […]. It

consists of achieving knowledge in action, the result of a sound knowledge base that can be put into practice and used to explain what is happening"[79].

The International Bureau of Education (UNESCO) says that a competency-based curriculum focuses on the important outcomes of learning, such as knowledge, skills, and attitudes that students can use when engaging with real-life context. This type of curriculum is designed and adapted in order to match both the needs of the students and the society they are living in. The expected outcomes should be progressively developed by means of activities and learning environments capable of eliciting such a set of key abilities that can then be applied across different subjects or within a specific subject.

Even if the multiple interpretations of the concept of competence can lead to confusion and raise concerns, in the purpose of this study, competency-based education is seen as a direct development of the traditions of activism and constructivism. This approach aims to overcome the notionistic, passive, and transmission-based understanding of knowledge. The key theoretical reference is John Dewey, who remarkably anticipates the main aspects of competency-based education[80].

In recent years, even if competencies have become an institutionalized pedagogical paradigm, both at the EU and Italian Ministry of University and Research (MIUR) level, a real shift in the paradigm of teaching such abilities still presents a number of fundamental issues and challenges that have yet to be fully addressed. In particular, the Italian reception of competency-based approach might have exacerbated the theoretical and practical difficulties inherent the implementation of a curriculum design based on competences[81].

According to the model of educational effectiveness[82], school education is conceived as an integrated system consisting of four levels nested within each other according to non-deterministic relationships: 1) individual student learning; 2) classroom teaching; 3) school organization; and 4) the national school system. Consoli et al. highlighted that the hierarchical structure that should provide guidance and control measures between levels, seems to have generated some criticalities in three main areas: curriculum planning as to the lack of clear and

defined teaching objectives, evaluation practices as to the lack of formative and improvement-oriented evaluation, and the poor alignment between teaching strategies and learning opportunities outlined in the formal curriculum. It will be argued that these limitations are a reflection of intrinsic difficulties in the competence-based approach to teaching as it is currently configured, and that Italian policy decisions can further exacerbate these difficulties[80].

Specifically, in a socio-constructivist view, competencies are closely tied to the creation of learning environments that are not simplified but instead pose complex and challenging problem-solving situations. This approach allows for active, collaborative, and reflective knowledge building by students. The focus is on creating real-world scenarios for students to engage with and encourage them to develop their skills and abilities in a more meaningful way[83].

Despite efforts to innovate by experimenting with new methods and strategies as witnessed by the project Avanguardie Educative (AE) of Istituto Nazionale di Documentazione, Innovazione e Ricerca Educativa (INDIRE), traditional forms of teaching based on the transmissive model characterized by teachers' lectures and subsequent oral or written summative assessment persist, as evidenced by the Talis survey results[80].

1.7. Purpose of the study

The aim of this study is to investigate the impact of supportive programmes to enhance the learning transfer of teachers who are dealing with curriculum refinement. This research has been conducted at two different levels: small scale school level and large-scale national level. The school-based programme was developed to maximize the impact of professional development initiatives through collaborative lesson planning to increase opportunities for peer support and knowledge integration to promote learning transfer in civics education. Whereas, the AMGEN Biotech Experience, a pre-existing national program, has been designed to provide teachers with both theoretical knowledge and laboratory practice to integrate both inquiry-based science education and biotechnology experiences into classroom practice.

A design-based research (DBR) methodology was used for both levels of intervention. DBR is regarded as a research methodology that aims to address the gap between research and practice in formal education.

The hallmark of DBR is its iterative design process. In this process, a researcher works hand in hand with practitioners to design, implement and evaluate educational interventions. This approach allows for a continuous process of refinement and improvement, ensuring that the intervention developed is tailored to the specific context in which it is used[84].

The study is based on a mixed approach using both quantitative and qualitative research tools. The combination of quantitative and qualitative data provides a more complete picture by integrating the benefits of both methods.

According to the aims of the study, and considering that it consists of two different projects, different tools were used to measure the effectiveness of such programmes.

With regard to the school-based project, we considered the participation of teachers and, consequently, the design and implementation of the cross-curricular learning scenarios as the first outcome. However, we looked at the impact of implementation on student learning outcomes in terms of both grades and perceptions. We also

explored teachers' perceptions of ‘mutual learning' and 'knowledge integration'. In both cases, the perceptions of the participants were surveyed by two validated questionnaires.

For the national project, we considered the assessment of teachers' performance after the training using a separate sample post-test design. Teachers' perceptions were also surveyed at different points during the training using a validated questionnaire to gain insight into the training process.

1.8. Research questions

The purpose of the study was to answer the following question:

1) To what degree did the programmes support teachers to approach the curriculum implementation?

To better outline this quite general question other specific questions should be answered to better explore further implications of both projects.

For the school-based project:

a) Did the teachers perceive ‘Mutual Learning’ and ‘Integration of Knowledge’ as components of the planning and preparation of the lessons?
b) Is there any impact on students’ outcomes?
c) What is the students’ perception of new teaching methods applied by the teachers?
d) Are there any differences across the considered cycles?

For the national project:

e) What were the teachers’ perceptions of improvement resulting from the training?
f) Did the teachers find the training relevant to their teaching profession?
g) Did the teachers perceive any obstacles to classroom implementation?
h) Did the teachers gain a significative amount of knowledge after the training?

1.9. Expected outcomes and significance of the study

The expected outcomes of this research have the potential to provide valuable insights for the improvement of the programmes under study and to provide guidance that can enhance the transfer of learning among teachers, leading to an increase in their effectiveness in adapting to changes related to their role.

The research aims to identify key features to focus on when designing infrastructures for peer support, knowledge integration, collaborative planning, lesson preparation, curriculum alignment and innovation of teaching approach that could lead to effective and sustainable professional development.

Alongside this finding, the relevant features of the national sustained and supportive programme, involving partners from academia and industry, to support teachers' readiness to implement advanced biotechnology and inquiry-based activities in the classroom will be highlighted.

In the Italian context, the results of both projects can serve as a crucial reference for informed decision-making in the areas of guidance, policy, and funding allocation. In addition, the study has developed teaching materials and tools that can be used in schools to further develop the education system.

1.10. Organization of the study

Chapter One sets the stage for the study by introducing the challenge of implementation time lag and delving into the purpose and significance of the research. It offers a comprehensive review of the current state of the art and literature, exploring the context, the crucial role of teachers, and the vital topic of professional development. Drawing upon this overview, the chapter examines prior studies and highlights the essential elements of effective and sustainable professional development aimed at implementation.

Chapter Two outlines the research design and details the development of both the infrastructure and content, informed by literature, school reforms, and teachers' needs.

In Chapter three, data related to the both the projects, addressing the overarching question and answering the project-specific ones will be analysed and discussed.

Finally, in the Conclusions (Chapter four), the key findings of the thesis are summarized, along with their implications and prospects.

1.11. Ethical considerations

All information obtained during the research have been considered confidential. Approval from the school board of teachers and inclusion of the project in the Triennial Education Formative Plan were acquired. The confidentiality and privacy

of all students involved in the study were of utmost importance and strictly maintained throughout the research process. No personally identifiable information was shared or disclosed in any way, ensuring the safe and secure handling of sensitive information.

CHAPTER 2

2.1. Methods and Instruments

In both the studies of this research project, the researchers collaborated with in-service teachers to support their professional development, aiming at maximizing the learning transfer in classroom practice.

2.2. The research design

Design-based Research (BDR) is an iterative, interventionist, theory-oriented and practical method. While traditional, experimental research is conducted to highlight the effect of an isolated variable to test and refine theory, DBR is conducted to refine both theory and practice [84,85]. In their review, citing Anderson and Shattuck (2012), McKenney and Reeves share the conceptualization of DBR as a methodology "situated in real educational context, focusing on the design and testing of interventions, using mixed methods, involving multiple iterations, stemming from partnership between researchers and practitioners, yielding design principles, different from action research, and concerned with an impact on practice" [86,87].

Thus, DBR involves researchers taking on the roles of curriculum designers and theorists. As designers, they enter the context as knowledgeable experts with the goal of creating and refining educational designs based on previous research principles. These designs may include curricula, practices, software, or tangible objects that can benefit the learning process[84].

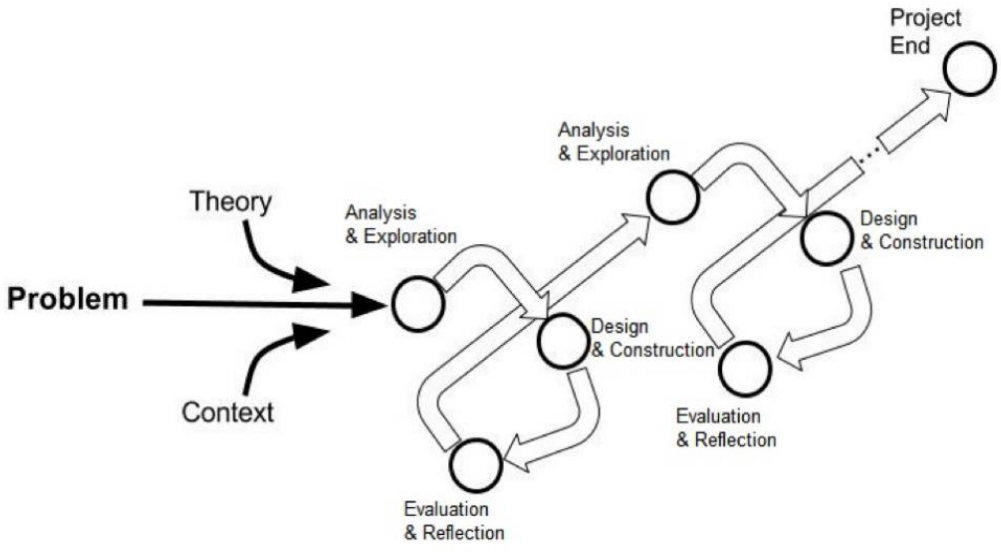


Fig 2.1 - The Iterative Process of Design-Based Research (Armstrong et al., 2020)

The preceding model depicts the cyclical procedure that begins with the analysis and investigation of a given problem. Researchers and participants then work together to design and develop interventions based on the obtained results. The subsequent phase involves the evaluation and reflection of the outcomes, which enables researchers to establish a link between the actions taken and the results obtained. This iterative process emphasizes the significance of careful and continuous evaluation at each stage, thereby facilitating the identification of improvement areas.

2.3. School-based experiment

In this study, the phases of the DBR cycle and the school cycle are completely intertwined. The law n.80 /2013 established the "National System of Evaluation (SNV)" to assess the efficiency and effectiveness of the education and training system in order to improve the quality of educational offerings and learning[88]. The process implies the schools undertake iterative cycles consisting of three phases. The phases respectively aim to 1) self-assessment, 2) improvement and 3) dissemination of achieved results, through comparable indicators and data, to promote transparency and accountability. In the light of the needs emerging from the analysis of the school results and on the basis of the general objectives established from the Ministry of Education, each school builds a "three-year plan for educational provision" that can be revised and improved periodically to match newly emerged instances. Usually, at the beginning of each school year, the plan is refined with updated projects.

2.3.1. The school and the participants

The school participating in the project is a Biotechnology High School located in Jesi, a town in the province of Ancona, in the Marche Region. Being provided with really well-equipped laboratories, it has a strong inclination towards hands-on approach. In addition, the school is deeply connected with Regional Institutions such as the University of Camerino and has international partnerships to provide students with opportunities for intercultural exchange. The student population varied along the period (2 years) from 485 to 445 respectively in the school years 2020/2021 and 2021/2022. The table 2.1.1 shows the number of students involved according to class of attendance, gender and year.

Table 2.2.1 – Students involved in the project.

Class	Third		Fourth		Fifth	
	F	M	F	M	F	M
2021	10	27	30	10	22	40
2022	34	38	13	7	41	35
Sub-total	44	65	43	17	63	75
Total	307					

With regard to the teachers involved in the project, their profiles are shown in the Table 2.2.2.

Table 2.2.2 - Characteristics of the 10 participating teachers.

Teacher	Subject	Years of experience
1	Chemistry	> 15 years
2	Chemistry	> 15 years
3	Chemistry	> 15 years
4	Chemistry	> 15 years
5	Anatomy, Physiopathology, Hygiene	1 - 5 years
6	Science, Chemistry	> 15 years
7	Infomation Technology & Communication	> 15 years
8	English	> 15 years
9	English	> 15 years
10	Italian Language & Literature	> 15 years

2.3.2. The Triennal Plan for Educational Provision (PTOF)

The two basic programmatic documents for defining resources and the educational project in schools are the PTOF and the annual programme. These documents have been redefined in the light of the prevention and protection measures required to contain the Covid-19 virus during the pandemic. The didactic programme for the 2020/21 and 2021/22 school years was affected. The updating of the PTOF in these academic years was of particular importance, given the impact of the COVID-19 epidemic, which triggered the adoption of the Integrated Digital Education and related Guidelines for Integrated Digital Education, approved by Ministerial Decree No. 89/2020. The second aspect for which the law required changes to the plan related to the introduction of the cross-curricular subject Civic Education according to Guidelines specifications, approved by Law No. 92 of 20.08.2019[89]. Furthermore, in line with the European objective of creating a European Education

Area, the school developed two different strategic plans to promote internationalisation, on the one hand, and sustainability and environmental education, on the other. On the basis of the objectives contained in the three-year plan for the provision of education, the school plan for the professional development of teachers was drawn up by the Teachers' Committee and approved by the School Council. In accordance with the school's vision and strategy, the professional development courses were aimed at developing teachers' knowledge and skills in the areas of interest. However, it should be noted that teachers could attend PD courses not included in the school's PD plan based on their perceived needs.

2.3.3. Civics: the law and guidelines

2.3.3.1. *Co-teaching and coordination of activities*

According to the law, at least 33 hours per year must be dedicated to teaching civic education. The law emphasizes the importance of collaborative planning and the development of progressive teaching activities based on previously defined learning goals. Teachers must also keep track of the time spent on each activity to ensure that the minimum annual requirement of 33 hours is met.

2.3.3.2. *Evaluation*

The law states that learning outcome of such cross-cutting subject should be periodically assessed. All the members of the Class Council are in charge of teaching and assess Civics, also by planning interdisciplinary paths. The assessment methods must be consistent with the aim of developing competencies, skills, and knowledge identified in the planning phase. Accordingly, tools such as rubrics and observation grids can be used by the teachers when assessing students' achievements. The law also states that the teaching staff, in their experimentation autonomy, can develop new practices to assess and develop the identified learning objectives, including them in the school curriculum.

2.3.4. Educational, cultural, and professional profile of the student

According to the law, some relevant integrations were operated to the educational, cultural and professional profile, a document that describe all the expected outcome at the end of the school journey:

- To participate in the cultural debate.

- To understand the complexity of existential, moral, political, social, economic and scientific problems and formulate reasoned personal responses.
- To become aware of the situations and forms of youth and adult discomfort in contemporary society and to behave in such a way as to promote physical, psychological, moral and social well-being.
- To respect the environment, care for it, preserve it, improve it, assuming the principle of responsibility.
- To make choices of participation in public life and citizenship consistent with the sustainability goals enshrined at EU level through the 2030 Agenda for Sustainable Development.
- To work in favour of eco-sustainable development and the protection of the country's identities and productive excellence.

2.3.5. Collaborative Design of Learning Scenarios and implementation

Following a pilot project carried out before and during the early stages of the COVID pandemic, collaboration with school staff began in September 2020. Collaborative design of cross-curricular learning activities and materials were carried out for a total of 26 hours along two different cycles. Each session consisted of 2-hours workshops focused on the co-creation of learning scenarios aimed at developing and then assessing knowledge, skills and competences related to the new subject, Civics[76]. To promote a multicultural approach, in compliance with the Ministry Decree[90] No 88/2010 and the need of supporting internationalization, the majority of activities were designed according to criteria of Content and Language Integrated Learning (CLIL) methodology, an umbrella term including active learning approach when learning both subject content and a foreign language[91]. According to our hypothesis, in Teacher Design Teams, as those which performed in this study, we expected integration of knowledge and mutual learning would enable the teachers to overcome difficulties and to develop a sense of ownership of the curriculum refinement[92]. Accordingly, through active and collaborative learning, educators could learn to manage group dynamics and develop their intellectual and social skills from working and learning together, so far, one of the less studied features of Teacher Design Teams[49]. The subsequent classroom implementation of the designed activities was the means by which to assess the

extent of transfer of teacher learning into classroom practice and the quality of the design according to the pragmatic paradigm[93]. What makes such an approach functional to this study is the focus on the analysis of products that are formatively evaluated by end users for improvements along iterative cycles[94].

In order to guide the design and document the process, learning scenarios were designed and implemented. A learning scenario (LS) is defined as a curricular design that helps teachers to reflect on a precise set of knowledge, competences, and skills that they want to develop[95]. It can specify the roles, activities, resources, tools, and services needed to support learning. In this case study, teachers were provided with a template for designing a LS. The template has been slightly modified by adapting the backbone of a resource developed in the framework of a European project called EduRegio. The template consists of many sections with corresponding instructions to guide the completion process. A complete list of all the sections is given in Fig. 2.2.3

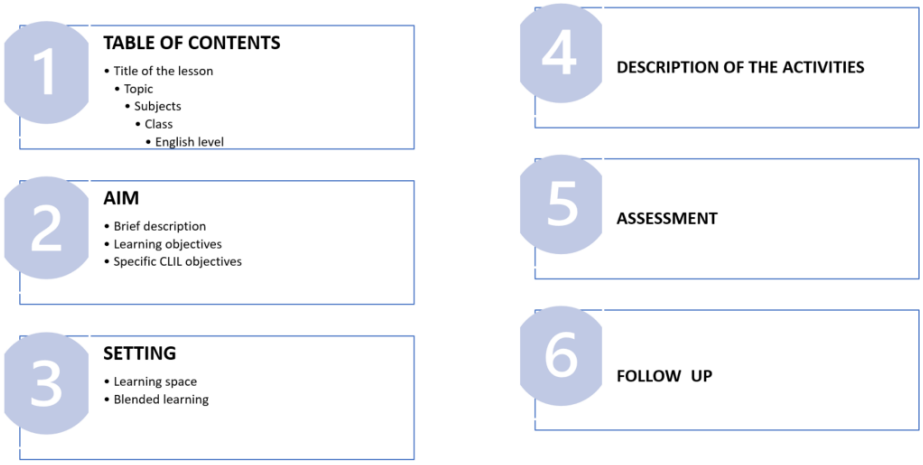


Fig 2.2.3 - The section of the template that was used to guide the design of the Learning Scenarios

The design of LS allowed the teachers to reflect on learning goals, type of assessment, methods, and techniques to maximize the impact of PD previously undertaken. The design of new materials such as videos, readings, tasks, rubrics and assignments for both testing and "authentic evaluation" completed the whole planning. The revision process was mutually carried out by peers and the researcher on the basis of the requirements that were established in the overall design of the study showed in the Table 2.2.3.

Table 2.2.3 – Main teaching features to be included in LS design.

Real-life topic connected to Civics syllabus
Active and collaborative learning
Formative assessment
Connection to STEM careers

In Table 2.2.4 both project progress and participation over the considered period are shown.

Table 2.2.4 – Project progress and participation over the period

1st year	2nd year	3rd year
Pilot project	Collaborative Design of learning scenarios	Collaborative Design of learning scenarios
Teachers: 2	Teachers: 7	Teachers: 10
Classes: 2	Students: 139	Students: 162
	Learning Scenarios: 3	Learning Scenarios: 5

2.3.6. Data collection

As previously mentioned, the activities consisted of co-creation of LSs within Teachers Design Teams (TDT) and subsequent classroom implementation of the designed activities according to the workflow chart (Fig 2.3).

Teachers' perceptions were surveyed by means of validated scales, to explore the adequacy of collaborative design in favoring "Mutual learning" and "Integration of Knowledge"[92]. Pre-teaching and post-teaching scores were used for computing the average difference in terms of students' learning outcomes both within and between the cycles.

Whereas students' perceptions were surveyed to explore the adequacy of the targeted design products through the lens of end users. The questionnaire, which was newly tested in the pilot project to assess its internal consistency, was obtained by adapting a validated tool[96].

Essential data were gathered for each participant student: gender, grade (third, fourth or fifth year), course specialization, pre-test and post-test scores obtained, and perceptions of the activities carried out. To safely treat sensitive data, an identification code was assigned to each student by the teachers, so that the data were anonymous. Among the 307 students included in the study, 6 were not able to submit the final questionnaire.

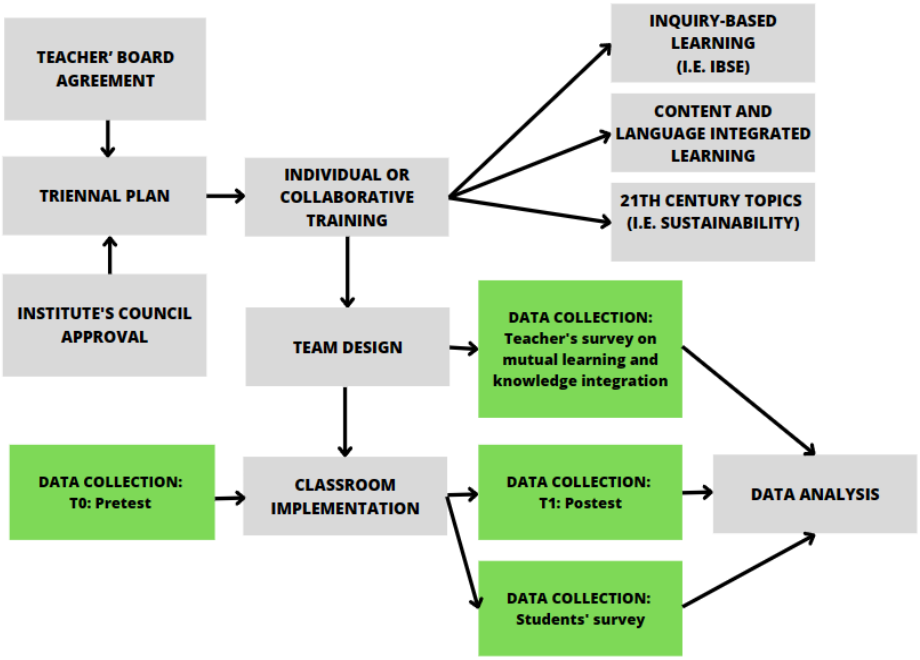


Fig. 2.2.3 Project workflow chart: in green tools and timing of data collection.

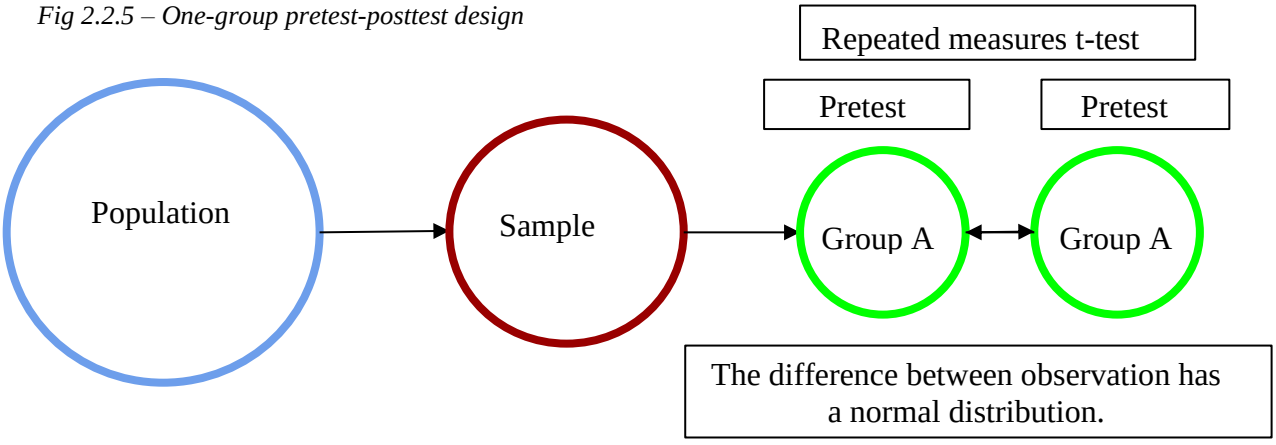
2.3.7. *Mutual learning and integration of knowledge*

A first validated questionnaire was administered at the end of the design process to collect the perceptions of teachers with regard to the constructs of "Mutual Learning" and "Integration of Knowledge". The transdisciplinary design integrates diverse perspectives, knowledge, and methods to generate new insights and solutions that are relevant and useful for addressing real-world problems. Straub et al. (2021) propose that mutual learning is a behavioural capability that facilitates the integration of knowledge. Correspondingly, mutual learning involves elements of exchange and co-creation between individuals from diverse backgrounds, while knowledge integration emphasizes the establishment of shared comprehension and mutual agreement for collaborative research and development endeavours[92].

2.3.8. Pretest and posttest scores comparison: cycles analysis

According to the iterative approach of DBR, to gain insight into the process, we could compare the scores of two cycles, both before and after the classroom implementation. In addition, for each cycle, a comparison of pretest and posttest scores was conducted using one-group pretest-posttest pre-experimental design. Although, as noted by Campbell et al., this design lacks built-in control for threats to internal validity, leaving room for several plausible explanations for any observed outcomes in addition to the effect of the independent variable, it serves the purpose of exploring the impact of collaborative and cross-curricular design[97]. However, to corroborate the results, further information was gathered surveying the students' appreciation through surveys. According to this design, results of tests administered by the participant teachers before and after the implementation of the learning scenarios were compared. In other words, teachers 'lectured as usual' on a different topic of the subject and assessed the students and then, after experimenting with the learning scenarios they had designed together, they assessed the students again. The experimental design is detailed in fig. 2.2.4

Fig 2.2.5 – One-group pretest-posttest design



Means and standard deviations (SD) were used to carry out t-tests and paired data versions as well as univariate comparisons when appropriate. To identify any predictor of the effect of LSs implementation[98], a multiple linear regression model was employed to explore factors that could predict posttest scores such as: (i) gender, (ii) class, (iii), pretest scores and (iv) course[99]. Adjustments were made for the aforementioned factors, and data were analysed to assess the association between variables. IBM - SPSS was used for all analyses, and a two-tailed *p* value of less than 0.05 was considered significant for all tested hypotheses.

2.3.9. Innovation in teaching practice based on students' perceptions.

As mentioned in the introduction, teachers in Italian schools have to deal with curriculum refinements. Some of these are quite recent, such as the introduction of a cross-curricular subject to develop teachers' teamwork skills and to raise students' awareness of the challenge of sustainable development. The aim of this approach is to develop students' ability to combine knowledge from different areas of interest and to link the relevance of advances in science, technology, mathematics and engineering to improving our lives[100]. Other reforms, even if already integrated in the theoretical framework, are not thoroughly implemented in classroom practice. Recently, the Ministry of Education has re-emphasised the importance of introducing CLIL methodology in all grades of Italian schools. It is one of a wide range of methodologies aimed at promoting active and collaborative learning and the development of intercultural skills, which require innovative learning environments based also on the use of digital tools [101]. Indeed, such competence-based curricular reforms overlap and converge towards a shift from a teacher-centred teaching paradigm to a student-centred one. The design of the LSs and their implementation with the students aimed at maximising the learning transfer from the PD in order to bridge the existing gap between theory and practice. The questionnaire used in the study was adapted from a tool used in a previous study[96], where it was used to clarify key aspects of inquiry-based learning. It was validated in the preliminary phase of the research by administering it to 62 students in order to test its internal consistency. The aim of the post-implementation survey was to collect data to understand the extent to which students perceived innovation and their level of appreciation of the overall experience in terms of organisation, workload and teachers' ability to create a positive climate for learning, by pooling

scores from a 10-point Likert scale consisting of 19 items. A comparison was made between the pooled scores obtained in the two cycles in order to highlight any significant differences. The second section of the questionnaire was designed to highlight the essential features of teaching. Students were asked to select the activities they had practised the most during the implementation. Dichotomous data were obtained by selecting items from a list. Items from the list allowed students to describe both common and innovative teaching approaches. Descriptive statistics were used to provide an overview of the whole implementation process.

2.4. *The "AMGEN Biotech Experience"*: *an initial study of effectiveness of the ABE Italy site's program*

2.4.1. The Amgen Biotech Experience (ABE)

The ABE programme is a science education initiative created by the Amgen Foundation in the 1990s with the primary goal of promoting excellence in science education and fostering a commitment to innovation, particularly in biotechnology, among the next generation. Since its inception, the programme has grown to become a global initiative, reaching more than 1.6 million students and teachers in 31 countries. The ABE program provides teachers with free, cutting-edge biotechnology curriculum materials and professional development training. The curriculum includes hands-on laboratory activities, which enable students to learn about the scientific principles and techniques that are used in the biotech research laboratory. The program also includes online resources and tools, such as interactive simulations and videos, which supplement the laboratory activities and reinforce the acquirement of the key concepts. One of the unique features of the ABE program is its emphasis on real-world relevance and applications. The curriculum is designed to connect the classroom learning to the broader context of biotechnology research and development. For example, students may learn about the use of recombinant DNA technology to produce life-saving medicines or the application of genetic engineering to enhance crop yields and improve food security. Another notable aspect of the ABE program is its commitment to equity and access. The program aims to reach students from diverse backgrounds and communities and to provide them with opportunities to explore the biotech field. To this end, the program has partnerships with a range of organizations, such as community colleges, universities, and STEM education networks, which help to support outreach efforts and provide resources and mentorship to participating teachers and students.

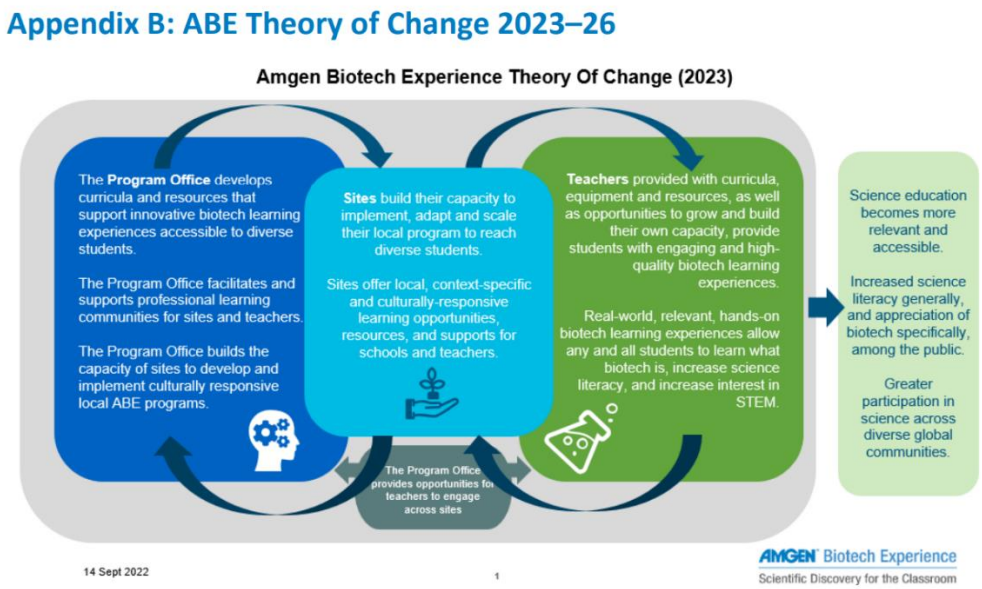


Fig 2.4.1 – ABE theory of change (AMGEN,2023)

2.4.2. The ABE Italy site

The ABE Italy site is committed to promoting "The art of teaching to ignite the passion for science", as reflected in its well-known motto. The site is managed by the National Association of Science Teachers (ANISN) in collaboration with various partners including the University of Naples "Federico II", the Institute for Biosciences and Bioresources (IBBR) of the National Research Council and the University of Camerino. The programme uses the scientific and educational expertise of these organisations, as well as their state-of-the-art facilities and resources, to offer innovative teacher training programmes that integrate a curriculum that allows students to explore the steps involved in the development of biotechnological therapies. In addition, the Professional Development Initiatives (PDIs) focus on both alignment between the ABE and the school biology curriculum, and Inquiry Based Science Education (IBSE), supporting the broader goal of promoting scientific literacy. In-presence workshops point to build up teachers understanding of cutting-edge science applications to raise the interest of students in STEM careers and to enable them to implement lab protocols with their students. Then, participating schools receive a free loaner kit of research-grade equipment and supplies to carry out advanced science labs experience. Further assistance is provided to teachers to implement the ABE laboratories in their respective schools. The sustainability of this extensive programme is ensured by the development of a multi-level and dynamic architecture at the site, which will

capitalise on lessons learned, reinforce effective strategies and actions, and introduce new ones as needed to address the evolving challenges of the site holistically. DBR approach would fit to develop both theoretical and practice knowledge to assess and improve through iterative cycles and by means of well-structured tools the effectiveness and the impact of ABE on teacher learning transfer and classroom implementation[84,85].

The program started in 2017 whereas this study is collocated at the end of the second triennial grant. Even if the program can be considered already a well-established experience, the Covid-19 pandemic has influenced the potential results, inhibiting the implementation phase because of the restrictions. Thus, this pilot project aims at taking a snapshot at the beginning of new phase that presumably would lead to normalization.

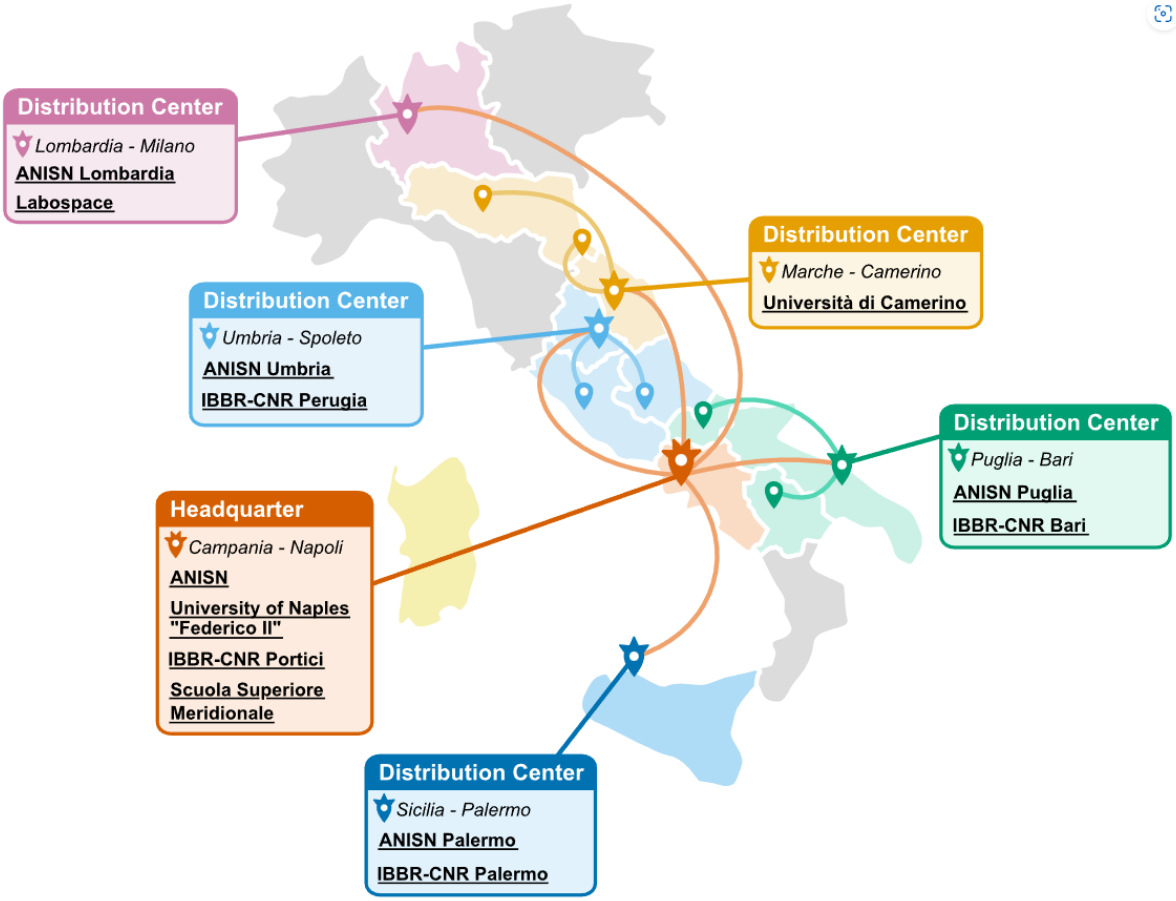


Fig 2.4.2 – ABE architecture

2.4.3. Natural science and ABE curriculum alignment

2.4.3.1. Natural science curriculum

In accordance with Law No 89/2010, high school students are expected to possess fundamental disciplinary knowledge and typical methodologies of natural sciences, including the scientific inquiry strategy, by the end of their studies. This method of inquiry is considered a formative and orientational aspect of science teaching and learning, as it provides students with cultural and methodological tools for a deep understanding of reality. The law further emphasizes the importance of the experimental dimension in science education. Laboratory activities are seen as a privileged opportunity for students to "do science" by organizing and executing experimental activities. These activities can also be carried out in class or in the field. Teachers are expected to identify core activities that guide students in developing essential knowledge and abilities in the subjects. By the fifth year, students are expected to engage in a cross-curricular approach that focuses on the structure and function of biologically relevant molecules. Emphasis is placed on biological and biochemical processes in current real-world situations and their relation to current topics, particularly those related to genetic engineering and its applications.

2.4.3.2. *The ABE curriculum and the daisy model*

Although ABE has developed a wide range of materials integrated into new curricula to address the needs of teachers and students in different contexts, this study will refer to the main curriculum typically developed for trainee teachers newly involved in the program. As stated on the website, the Foundations of Biotech labs were designed to introduce students to biotech techniques and concepts, and these labs allow students to explore recombinant DNA technology. The sequence of activities is presented in Table 2.3.2.

In the Complete Genetic Engineering Sequence, students learn how to use recombinant DNA techniques to introduce new genes into an organism and produce new proteins. In this sequence, students create a recombinant plasmid with a red fluorescent protein gene from a sea anemone and then transform *Escherichia coli* with the plasmid. This process is analogous to the production of human therapeutic proteins such as insulin or human growth hormone. The entire activity can be adapted based on the target audience and time constraints.

The toolkit for this curriculum includes guides for teachers and students, timing for execution, a PowerPoint presentation, an audio guide, a list of reagents, and instructions for reagent preparation. Additionally, a Learning Management Platform called "LabXchange" developed in collaboration between the AMGEN foundation and Harvard University, was created to host lab simulations and materials for integrating existing resources. The materials are translated into various languages, including Italian. Teachers receive online training to explore the potential of the platform, where they can create virtual classrooms and assign activities to support students' learning. The platform can also serve as a source of learning for teachers.

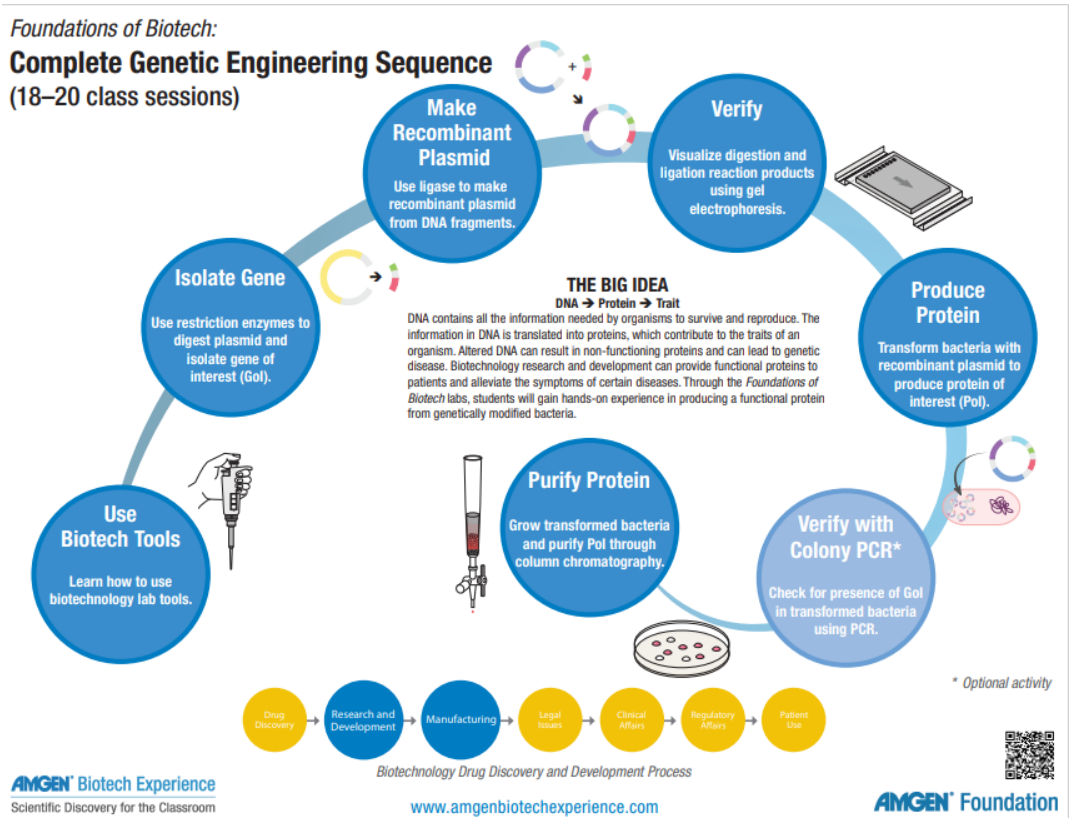


Fig 2.4.3 – Foundation of biotech: the sequence of the labs (Source: AMGEN)

The Italian ABE site is distinguished by a noteworthy feature, which is the integration of Inquiry Based Science Education (IBSE) with the ABE labs (Table 2.2.2). This integration, commonly referred to by ABE staff as "the daisy model," was primarily established through the expertise of trainer teachers. Currently, the integration is being further developed thanks to the contributions of both veteran

teachers and Master Teacher fellowships. These experiences aim to enhance the ABE learning offering.

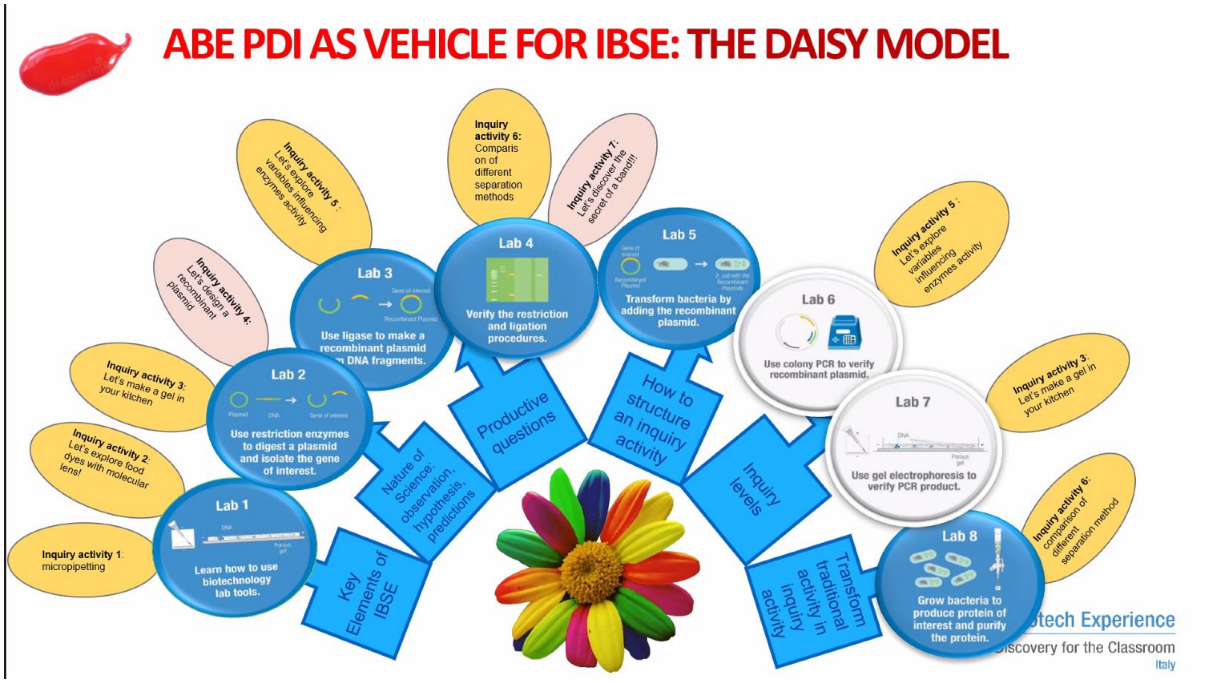


Fig 2.4.4 – The daisy model: IBSE and ABE labs integration (Source: AMGEN)

2.4.4. The description of the program

The ABE training program is an ongoing initiative that comprises two phases. The first phase involves blended training for science teachers, who are selected through a public call on the platform provided by the Ministry of Education (MI). The second required phase involves teachers implementing the program with their students in school. The online phase lasts for 10 hours and is held virtually, while the subsequent in-lab training spans two days and is held at the laboratories of the University "Federico II" of Naples and at the University of Camerino. The experimentation with students and documentation of the results completes the entire activity, which takes a comprehensive amount of 60 hours each year.

The ABE training program has several objectives, including the development of teachers' knowledge of biotechnology to enable them to teach it effectively in class, without oversimplifying the subject matter. This, in turn, will help students understand the potential and limitations of biotechnology. The program also seeks to innovate scientific subject teaching methods by implementing inquiry-based teaching and learning (IBSE). It aims to promote the use of experimental techniques suitable for biotechnology, which will stimulate students' interest in the subject. Additionally, the program aims to bridge the gap between schools and academia

and facilitate international exchanges with prestigious scientific institutions. Finally, it aims to foster collaboration and cooperation within the school community, indeed one of the criteria for selection is the application of at least two teachers from the same school, and between schools to maximize the impact of professional development initiatives (PDIs). In the light of the features described above, the program shows all the features that Desimone consider essential for PD to enhance teaching practice and students' learning outcomes[71].

2.4.5. The participant teachers

The professional development initiative targeted secondary school teachers working in twelve different Italian regions: Campania, Lombardy, Lazio, Puglia, Molise, Umbria, Marche, Abbruzzo, Emilia Romagna, Sardinia, Sicily and San Marino. Data were collected regarding the specialization, kind of school, years of experience and gender (Table2.3.1). The majority of teachers were biologists, while the remaining participants, with the exception of biotechnologists, might be not really into biotechnologies belonging to different fields of specialization. Most of them could be considered expert teachers, having at least more than six years of experience. The most represented were teachers working in scientific lyceum.

Table 2.4.1 – Participant teachers

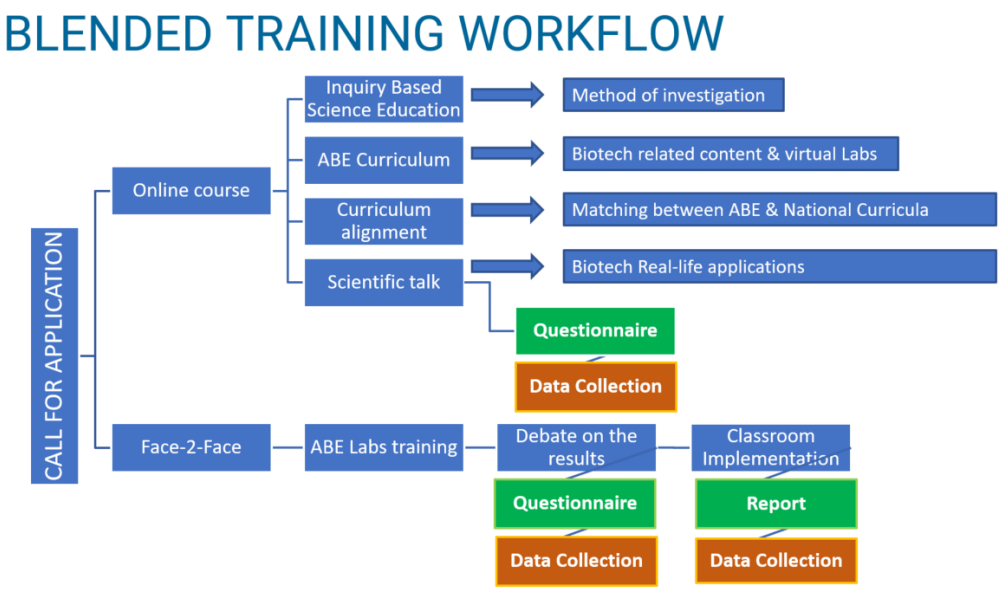
Specialization	
Biology	37
Agricultural Science	4
Natural Science	8
Chemistry	7
Agritech Science	2
Others	8
Environmental Science	4
Geology	4
Biotechnology	3
Years of experience	
From 1 to 5 years	8
From 6 to 10 years	22
From 11 to 15 years	14
More then 15 years	33
Type of school	
Scientific lyceum	44
Other lyceum	14
Technical Institute	14
VET School	5

Gender	
Female	61
Male	16

2.4.6. *Data collection*

To gain insight into the process, a mixed-methods approach was used to collect both qualitative and quantitative data. A validated questionnaire was administered at the end of each phase of the training to survey teachers' perceptions of the effectiveness of the ABE labs and their willingness to implement them in the classroom. To measure the knowledge and skills gained from carrying out the lab sequence in the ABE curriculum, a test was administered after the in-lab training. Finally, data were collected to assess the degree of participation in the implementation phase even if the final reports were still in progress.

Table 2.4.2 – Workflow chart: tool and timing for data collection



2.4.6.1. Post-training questionnaire

To answer the main research question, we integrated response from different tools. The questionnaire was used to survey teachers' perceptions of constructs research found having strong relationship with learning and the application of knowledge and skills in the workplace[102]. In particular, the questionnaire was characterized by a few items to rate on an ordinal scale ranging across 5 levels of agreement and a few open-ended questions. In the Table 2.3.2 are shown the constructs that were surveyed.

Table 2.4.3 – Workflow chart: tool and timing for data collection

Construct	**Rationale**
Learning (Ordinal scale)	Ratings their knowledge on the ordinal scale, respondents are given the opportunity to compare their knowledge before and after the training, thus, they express the perceived understanding and learning as a result of the activities carried out.
Relevance (Ordinal scale)	Learner perceptions of utility and relevance are highly linked with learning
Characteristics of training (Multiple chioce)	If learning is structured so that learners have an opportunity to engage, their learning and understanding can be enhanced above all if the training provide opportunity to practice new skills and reflect on or discuss subject matter.
Intent to Use or Apply (Ordinal scale/ Open ended question)	Measuring a learner's intent to use or apply what they have learned is an important gauge of whether the training has been effective. Research suggests that prompting a learner to identify how they will use training helps solidify concepts.
Suspected Barriers to Use or Application (Multiple choice / open-ended question)	To obtain additional detail from learners about the barriers they suspect they will encounter when back on-the-job, would improve opportunity to provide after training support.

2.4.6.2. Quasi-experimental Two-group comparison

A test was designed to measure the gain in knowledge after the training. Initially, a first draft of the tool was tested with a few members of the staff. Afterwards, refinements were made before its administration to the broad audience of program participants to test its capacity of detect differences in the gain of knowledge among the control and the experimental group. The test included all the main content covered during the in-lab training, such as the use of micropipettes, restriction enzymes, and ligase to create a recombinant plasmid, as well as the use of gel electrophoresis to visualize ligase and digestion products. A simpler version of the pretest-posttest design was used where pretest measurements are omitted. This design controls for maturation, testing, regression, selection, and pretest-posttest interaction. The design notation is shown in figure 2.4.4

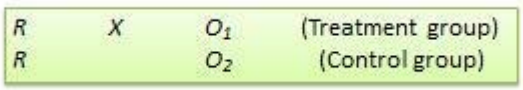


Fig 2.4.4 – Two groups quasi-experimental design

The participants were divided into two groups, the control group took the test before the training whereas the experimental group took the test just after the conclusions of lab activities.

The training effect is measured simply as the difference in the posttest scores between the control and the experimental group. To explore statistically significant difference, a 2-indipendent groups t-test was conducted [103,104].

CHAPTER 3

3.1. Results and discussion

3.2. School-based experiment

3.2.1. Mutual learning and integration of Knowledge

The analysis of the results takes into account results emerging from a survey that involved all the teachers who took parts into the TDTs, even those that implemented their LS in the lyceum. A two-part, 10-point Likert-type scale was administered to 24 teachers participating in the collaborative workshops. The "Knowledge integration" subscale consisted of 8 items (Cronbach $\alpha = .720$); the "mutual learning" subscale consisted of 12 items (Cronbach $\alpha = .932$). In the analysis of the questionnaire data, the degree of mutual learning and knowledge integration was determined by calculating mean scores for each dimension. In addition to mean scores, the standard deviation was calculated as an indication of the dispersion of scores within teams. Table 3.1 shows the descriptive statistics for the scale within the total sample. All variables had high means and reached the theoretical maximum of 10. The minimum scores were all above the theoretical midpoint of 5.5. According to the research question (1.d Did teachers perceive 'mutual learning' and 'integration of knowledge' as components of planning and preparing lessons?), the high scores for the two constructs indicate that the TDT members perceived the collaborative design to be effective both in terms of the process, through active listening, seeking in-depth clarification, engaging in productive discussion, and in terms of the intended outcomes, as a shared understanding of participants' perspectives when working towards the same goal[92]. This result is in accordance with previous studies that were carried out by Straub et al. to explore collaborative approach to foster innovation and educational change in school-based teaching and university-based teacher education[92]. Furthermore, as Brouer et al. suggested in the conclusions of their study on mutual engagement, shared repertoire and joint enterprise in teacher teams, this results highlight that when teacher teams, supported by school leaders and experts, focus on interdependent determined group goals, which achievement is paced by regular meeting, structured tasks stimulating a critical reflective attitude, communities of practice can promote teachers perceptions of mutual trust and drive effective improvement in teaching. Conversely, the absence of a well-defined structure, effective management, and skilled leadership may result in unforeseen negative consequences[105].

Table 3.1 – Descriptive statistics

Characteristic	min	Max	Mean	SD
Mutual learning	4	10	8,16	1,60
Knowledge integration	4	10	8,90	1,21

3.2.2. ***Students' Pretest and posttest scores comparison***

A paired samples t-test was performed to compare pretest and posttest scores in the whole sample. There was a significant difference in scores between pretest (M = 7.2, SD = 1.13) and posttest (M =7,6, SD = 1.00); t (306) = -5.973, p = .000.

Means comparisons showed that students performed significantly better when teachers implemented the LS they had designed.

When comparing the scores of each cycle, the paired samples t-test showed similar results. There were significant differences in scores between pretest and posttest for both cycles. Details are shown in Table 3.2. The chart in fig. 3.1 shows a decrease in the difference in the second cycle even if pretest and posttest means remain significantly different.

Table 3.2 - Paired samples t-test

Year	Pretest MD (SD)	Posttest (SD)	t	*p*
2020/21	7,14 (,90)	7,50 (,07)	t(139)= -3,347	,001
2021/22	7,28 (1,06)	7,85 (1,04)	t(168)= -5,387	,000

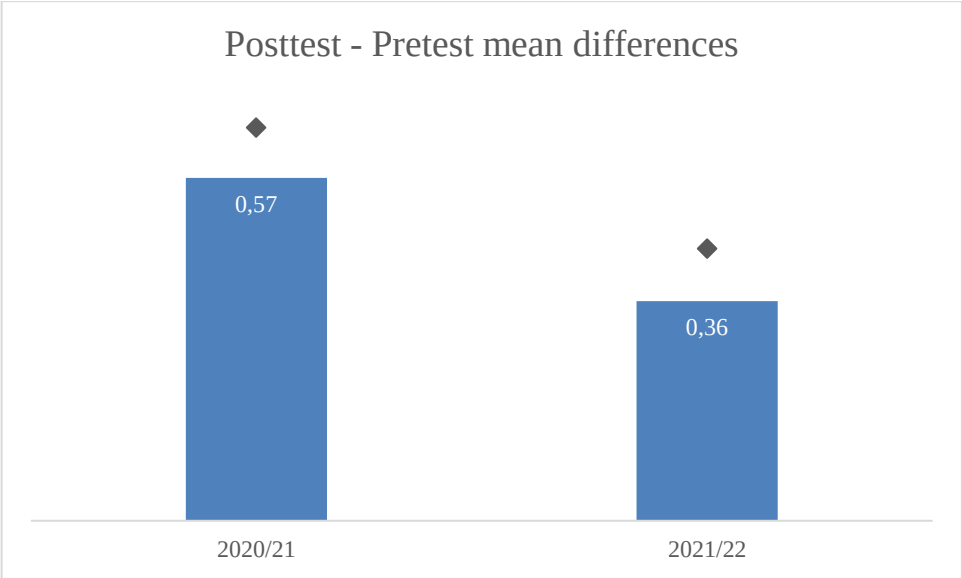


Fig 3.1 - Difference between posttest and pretest means in the two cycles.

When comparing means according to the class of attendance, posttest resulted in better outcomes, but differences were not steady statistically significant. Mean and standard deviations are shown in the table 3.3. In fig. 3.2 mean differences per year and class highlight a good degree of variability.

Table 3.3 – Years of attendance and means comparison: paired samples t-test

Year	Class	Pretest MD (SD)	Posttest (SD)	t	*p*
2020/21	Third	7,14 (1,04)	8,69 (|1,19|)	t(36)= -5,160	,000
2020/21	Fourth	6,72 (,78)	7,54 (| ,76|)	t(39)= -5,160	,000
2020/21	Five	7,53 (1,11)	7,56 (| ,83|)	t(61)= - ,200	,842
2021/22	Third	7,28 (1,00)	7,37 (|1,03|)	t(71)= - ,621	,536
2021/22	Fourth	6,60 (1,76)	7,77 (| 1,04|)	t(19)= -2,606	,017
2021/22	Five	7,15 (1,11)	7,55 (| ,80|)	t(75)= -2,810	,006

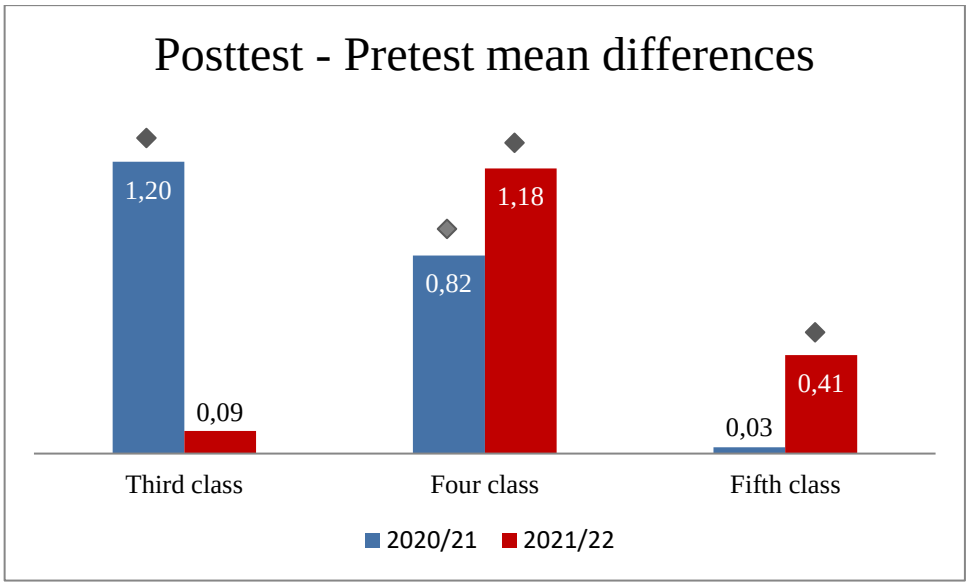


Fig 3.2 - Difference between posttest and pretest means according to year of attendance

With regard to research question, (1.a Is there any impact on students' outcomes?), even if the purpose of the study is not to compare traditional teaching with new teaching approaches, it was of paramount importance to explore the impact of the implementation of peer reviewed LSs on academic results. The development and assessment of competences imply the design of learning activities that should reproduce the natural complexity of real-life in problem-based situations[81]. Students should be involved in active, collaborative and reflective practice. Lower-achiever students and, in general, students who are not accustomed to socio-constructivist approach to learning might feel puzzled about managing too much information, thus resulting in even scarce learning[80]. For instance, although prior research have provided evidence on the effectiveness of learning based on inquiry[106,107], other studies suggest that too much "discovery learning" can be less effective than the teacher-centred approach[108]. On the basis of results obtained, this was not the case. Despite the weak experimental design, which does not allow to infer cause-effect relation between the variables, a general gain of knowledge emerged by comparing posttest and pretest scores, suggesting that the objectives teachers had established in their design activity had been pursued by the students. Furthermore, academic achievements suggest a coherent alignment of outcomes, tasks, selection of materials and setting of learning objectives during collaborative design. Results also suggest teachers were able to balance old and new approaches in classroom practice. Indeed, the implementation of LSs implied opportunities for

students to be engaged in activities that the merely transmissive approach would not have imply, thus presumably the role of teacher shifted from lecturer to facilitator and mentor[51].

To gain insight in the process we further explored difference on the base of gender. To compare posttest scores in females and males, a two-sample t-test was performed. As shown in fig, 3.3, in the first cycle, there was a significant difference in means between females (M = 8,07, SD = 1,02) and males (M = 7,59, SD = 1,02); t(137) =2,772 , p = ,006.

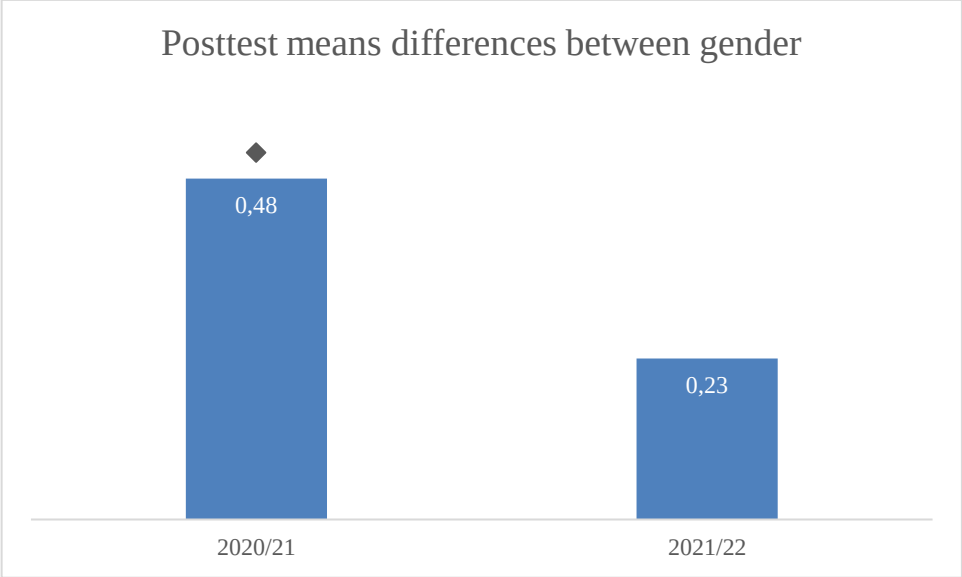


Fig 3.3 - Posttest means differences show that females performed significantly better than males in the first cycle.

As previously mentioned, real-life and problem-based situations, often associated with inquiry based learning and project based learning, the kind of activities that teachers implemented in this study, might have triggered the interest of girls involving higher commitment according to previous research findings[109]. Group collaboration could be effective in supporting girls willingness to take risks, promoting their initiatives when questioning and experimenting in the investigation stages, thus favoring an in-depth understanding[50,110].

Another important information was obtained by comparing posttest scores of the two cycles. To this aim, a two-sample t-test was performed. As shown in fig, 3.4, there was a significant difference in means between the first cycle (M = 7,85, SD = 1,04) and the second cycle (M = 7,50, SD = 0,94); t(305) =3,088, p = ,002. The same trend emerged for pretest means comparison across the cycles but in that case the difference was not statistically significant. What should be noted is that in the first cycle, due to Covid restriction, school activities were far less intensive. During the second cycle, the process of normalization led to the progressive integration of a bulk of activities that were previously suspended. Both students and teachers might have been affected by such occurrence.

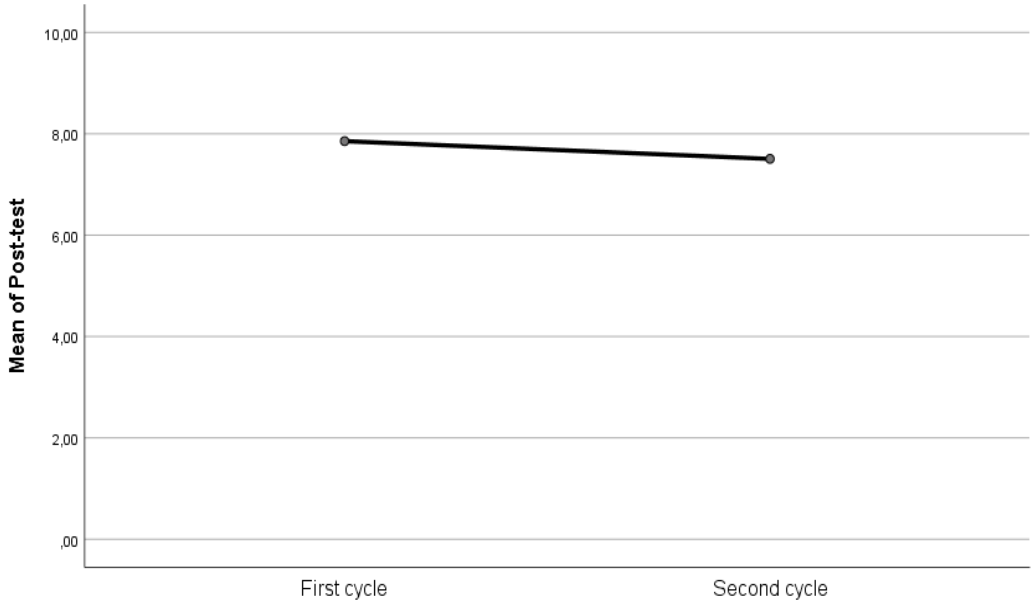


Fig 3.4 - Posttest means difference between cycles shows a significant decrease in scores in the second cycle.

Finally, to identify the effects of predictors, multiple linear regression modelling was performed. The fitted regression model was:

Posttest score = 7,454 + (,178*Pretest score) + (,304*year of implementation) + (,294*gender) - (,253*Fifth Class). The overall regression was statistically significant (R2 = ,110, F(1, 306) = 15.508, p = ,000).

It was found that four factors significantly predicted post test scores, values are shown in Table 3.4

Table 3.4 – Multiple linear regression model: Beta values and significance for each predictor

Factor	β	p
Pretest score	,178	,000
Year of implementation	,304	,006
Gender	,294	,009
Fifth Class	- ,253	,023

The model puts in evidence all the previous results. In addition, students attending the fifth class seemed less sensitive to the LSs implementation. Their improvements were quite mild in posttest scoring. They could have had a more structured approach to learning resulting in a quite stable gain of knowledge despite the teaching approach. Despite the difficulties in isolating the impact of the initiatives we have implemented, which might affect most of the research project in education, considering the complexity of the school, which for instance rarely applies innovations one at a time, by comparing the two cycles in our study, we can open a discussion based on the nature of teacher learning and improvement. The experience of the two years was designed to include most of the features that research has found to be effective, based on some reliable studies conducted to date[111,71]. But research also tells us that most of the relevant learning experiences for teachers take place in the classroom and in the school communities. Consequently, it might not be functional to measure the impact on pupils when teachers have just started to apply what they have just started to learn; classroom practice should be considered as part of the improvement process[78]. However, both the generally positive students' results, even with some differences between the cycles considered, and the continued participation and commitment of the teachers were significant indicators that the path taken was capable of producing the desired results. Such results should be sought not only in terms of knowledge gain, but also in terms of attitudes, skills and competences that were underpinned by the teachers in planning and implementing, and by the students in participating in classroom activities. Of course, there are some limitations to our study, such as the small sample size and the context, which can be seen as unique to each school, but

focusing on the characteristics of the initiative, the overall design of the study aimed to explore the extent of teachers' learning and transfer, integrating multi-level inquiry to provide a more complete insight into the process. Thus, we would demonstrate the extent of change in classroom practice by exploring students' perceptions of innovation practices.

3.2.3. Innovation in teaching practice based on students' innovation

Not all the students took the surveys due to students' non-attendance or contingent issues related to the school organization. The sample size for this study was 301 students, which represented 98% of the participants.

In the section two of the questionnaire we included items for measuring the awareness of the students about the different tools and the different ways to learn used during the implementation of the learning scenarios.

Figure 3.5 shows that the tools/activities that students declared were applied the most in LS implementation were: 1) Group work (94%), 2) Small group debate (83%), 3) Teacher's lecture (80%) 4) Contents reworking (68%), 5) Learning from my peers (61 %) , 6) creating a learning product (60%). Individual work and use of textbooks resulted in lower frequency, respectively 38% and 7%. According to these results, students "depicted" an in-between situation. Indeed, even if the teachers lectured, meaningful collaborative activities were carried out if 61% of students claimed to have learned from their peers. Presumably, considering the high share of students that claimed group working and debating being characteristic features of classes, room was left for developing social and communication skills as well as critical thinking[55]. According to Bloom's taxonomy, progressively higher order thinking skills were stimulated in learning, reworking the contents to create a learning product. Less remarkable but indicative were the shares of students that claimed having opportunity for in-depth understanding and confuting misconceptions. However teachers must be less prone to let the students decide by their own how to carry out the activities (20%). The "use of the textbook" was the less practiced activity which is perfectly normal considering that no textbooks were adopted for teaching Civics, and the materials were selected and modified during the design phase by the teachers.

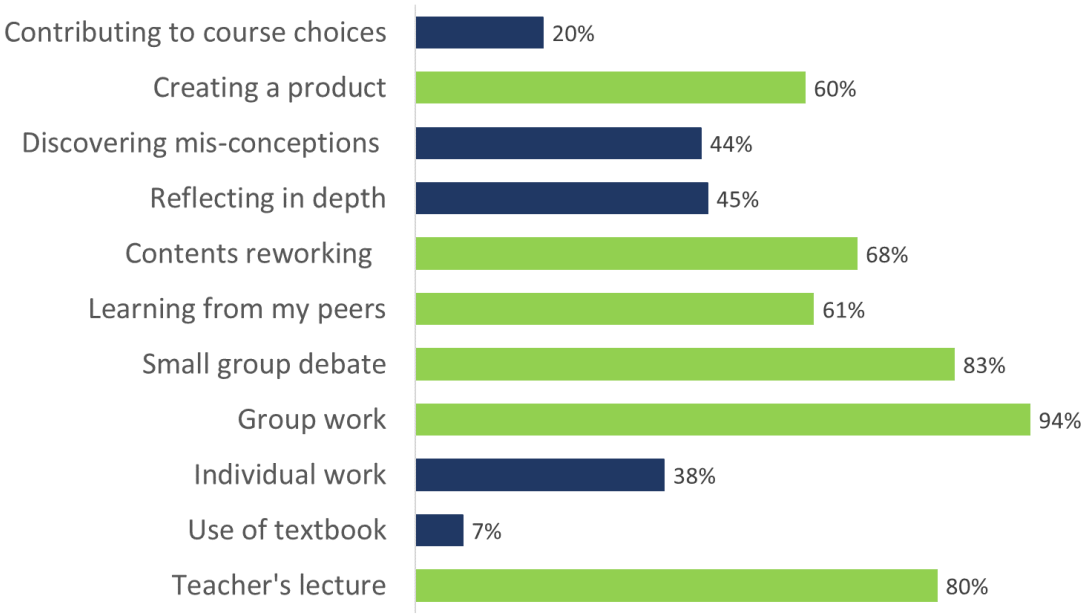


Fig 3.4 – Most used tools and activities during LSs implementation.

The second section of the questionnaire consisted of likert-type-10 points scale of 19 items (Cronbach α = .895). Students reported their level of agreement on statements related to innovation and their level of appreciation of the overall experience in terms of organization, workload and teachers' ability to create a positive climate for learning. Table 3 shows descriptive statistics for all items. Most of the variables had high mean values and reached the theoretical maximum of 10. The mean values were in most cases above the theoretical middle of 5.5, with the exception for three items. As to the items "It was difficult to organize individual work" (Min = 4,43) and "The work was demanding" (6,03), in both cases middle range scores were desirable to know that student did not suffer for the lack of textbook or, as to second items for an unbalanced workload that would have hindered students[112]. With regard to the item "This work method is a waste of time" (3.01), we surveyed the students' perceptions of usefulness of the activities implemented. The low score in this case has a positive connotation. However, the three items resulted in quite high values for standard deviation indicating moderate to high differences in response behaviour. On the other hand, some items revealed a high degree of appreciation. The teachers seemed to be at ease in the role of facilitator creating a conducive environment (8,62), indeed learners claimed being active learners during the activities (8,19). Learning engagement could depend on both the interest raised by the relevance of the topics (8,15) and the perceived utility

of the knowledge gained thanks to the learning path (8,13). Moreover, the results of the second section of the questionnaire were consistent with the previous findings with regard to the opportunity of developing social and life skills. According to research question (What is the students' perception of new teaching methods applied by the teachers?), the high values for all the items indicate that students assessed their participation as an effective and engaging experience. In general, this provides some empirical evidence that the given collaborative format of TDTs is considered suitable for fostering teachers learning transfer in classroom practice.

Table 3.5 - Descriptive statics

Item (n)	Descriptive Statistics	N	Min	Max	Mean	SD
1	The teacher created a conducive learning climate	301	1	10	8,62	|1,422|
2	The activities made me an active learner	301	1	10	8,19	|1,523|
3	The topic was riveting	301	1	10	8,15	|1,602|
4	What I learnt will be helpful for my future	301	1	10	8,13	|1,527|
5	The learning materials used were interesting and useful	301	1	10	8,01	||1,666|
6	I expressed my ideas	301	3	10	7,97	|1,638|
7	The content is covered in depth	301	1	10	7,88	|1,429|
8	I love this work method	301	1	10	7,77	|1,531|
9	You were engaged at work	301	1	10	7,73	|1,731|
10	The class debated relevant issues	301	1	10	7,64	|1,75|
11	My knowledge/skills has/have improved	301	2	10	7,61	|1,469|
12	The activities were open to student initiative	301	1	10	7,6	|1,772|
13	This approach stimulated my interest	301	1	10	7,59	|1,588|
14	I compared my views with classmate(s) and teachers	301	1	10	7,44	|2,035|
15	I learnt things useful in everyday life	301	1	10	7,35	|1,965|
16	Room was left to reflect on what was being done	301	1	10	7,33	|1,889|

17	The work was demanding	301	1	10	6,03	|2,173|
18	It was difficult to organize individual work	301	1	10	4,43	|2,489|
19	This work method is a waste of time	301	1	10	3,01	|2,235|

Previous research by Kelly (2012) and Shernoff (2013, 2016) suggests that challenging activities, goals for students, and adequate support, such as strong teacher mentorship, are critical to improving student engagement and learning[113–115]. These findings are consistent with our own research, which suggests that student-centred projects that address a range of issues are essential to cementing strong teacher-student relationships, as evidenced by the survey results (Table 3.5). As mentors, teachers should invite students to find their own solutions, avoiding the role of content provider. Instead, they should act as co-learners, making it clear to students that they don't know everything about the subject, thus supporting and challenging their learning process at the same time[116].

Our research findings are also in line with those of Cazden (2001), who suggests that students' interactions with peers and teachers in communicating their ideas are crucial components of the learning environment. In this respect, the LS designed by the teachers should have encouraged communication and interaction, emphasising the importance of student engagement in the learning process[117].

To provide a more detailed answer to the research question (1.d What is the students' perception of new teaching methods applied by the teachers?), whether students attending different years showed differences in their degree of appreciation, a one-way ANOVA has been calculated. Table 3.6 shows descriptive statistics related to the items that showed statistically significant differences.

Table 3.6 - Descriptive statistics

Class	Third		Fourth		Fifth	
Items	Mean	SD	Mean	SD	Mean	SD
(1) The teacher created a conducive learning climate	8,87	1,218	8,4	1,647	8,68	1,424

(2) The activities made me an active learner	8,6	1,114	7,98	1,654	7,94	1,667
(6) I expressed my ideas	8,45	1,391	7,67	1,535	7,83	1,785
(7) The content is covered in depth	8,11	1,171	7,95	1,671	7,38	1,432
(8) I love this work method	8,25	1,152	7,36	1,384	7,85	1,739
(9) You were engaged at work	8,23	1,402	7,44	1,825	7,53	1,838
(11) My knowledge/skills has/have improved	7,94	1,392	7,39	1,327	7,53	1,557
(13) This approach stimulated my interest	8,06	1,178	7,2	1,732	7,65	1,697
(14) I compared your views with classmate(s) and teachers	8,00	1,793	7,37	2,268	6,68	1,971
(17) The work was demanding	5,74	2,114	6,48	2,321	5,58	2,069
(19) This work method is a waste of time	2,49	2,019	3,59	2,193	2,67	2,295

Further examination of multiple post-hoc comparisons revealed some differences between the groups of students (Table 3.7; Figure 3.5). Pupils in the fifth class found the work more demanding and less productive than their younger colleagues. According to their perceptions, students attending the fourth class experienced less exhaustive and collaborative lessons than their peers. Notably, the participants who found the experience particularly satisfying and useful were students in the third year of attendance, resulting in a higher average score across all items that indicated a positive approach to the experience.

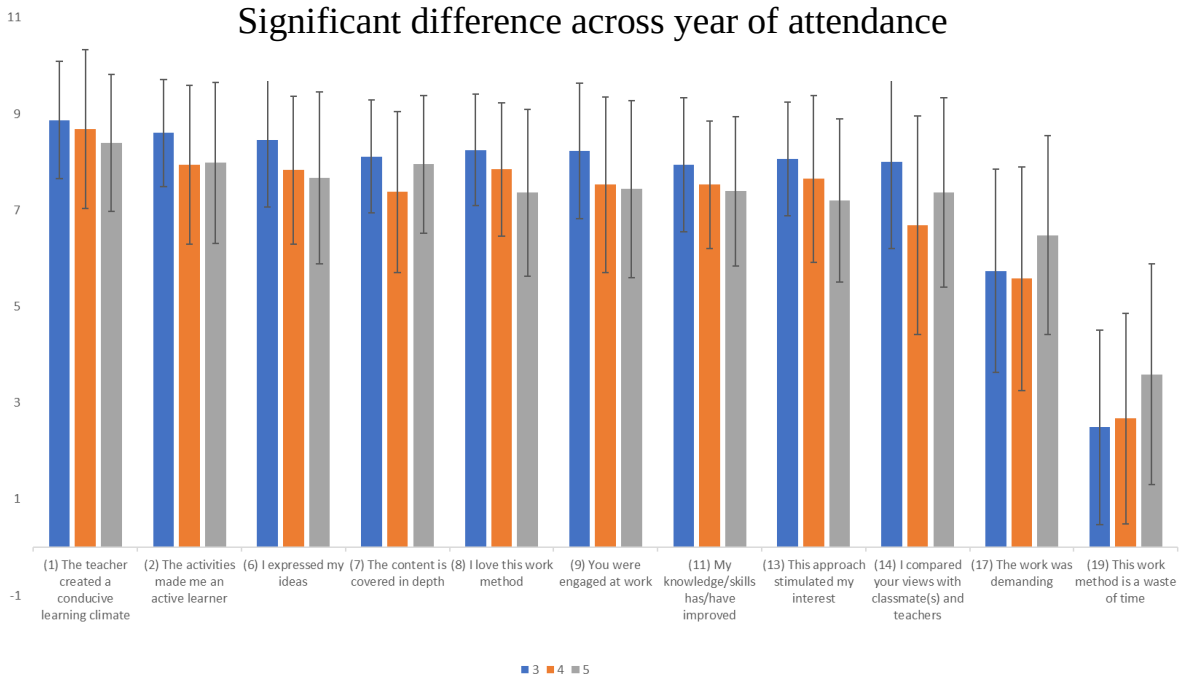


Fig 3.5 – Post-hoc comparisons revealed differences across the groups.

The results might highlight some nuances in approaching a quite different learning experience.

Younger students could feel more at ease engaging in interactive activities that gave them opportunity to consolidate new friendships; indeed, at the beginning of the third year students are newly grouped according to the specialization they chose at the end of the second year. They are facing new and more interesting subjects with new teachers, the first two years of the upper secondary school can be seen as a in-depth review of content they have already studied in the first grade secondary school. Thus, they could be prone to commit themselves in tasks that require them to be active. Conversely, older students could feel less attracted by new teaching approach being accustomed to common teaching that, especially in the fifth years,

is seen as the most economic way of covering the whole syllabus thus allowing the students and teachers to face the final exams having the perception of higher chance of obtaining better results. However, as previously mentioned, ratings of items across groups showed trend that revealed a good degree of appreciation of the teaching activities carried out.

Table 3.7 - Descriptive statistics

Multiple Comparisons		95% confidence interval				
Dependent Variable	Comparison	Mean Difference	Std. Error	Sig.	Lower Bound	Upper Bound
(1) The teacher created a conducive learning climate	3 & 5	,472*	0,186	0,034	0,03	0,92
(2) The activities made me an active learner	3 & 4	,663*	0,236	0,016	0,09	1,23
	3 & 5	,617*	0,197	0,006	0,14	1,09
(6) I expressed my ideas	3 & 5	,780*	0,211	0,001	0,27	1,29
	3 & 4	-,613*	0,253	0,048	-1,22	0,00
(7) The content is covered in depth	3 & 4	,728*	0,222	0,003	0,19	1,26
(8) I love this work method	3 & 5	,896*	0,195	0,000	0,43	1,37
(9) You were engaged at work	3 & 4	,703*	0,268	0,027	0,06	1,35
	3 & 5	,794*	0,223	0,001	0,26	1,33
(11) My knowledge/skills has/have improved	3 & 5	,548*	0,191	0,013	0,09	1,01
(13) This approach stimulated my interest	3 & 5	,854*	0,204	0,000	0,36	1,34
(14) I compared your views with classmate(s) and teachers	3 & 4	1,318*	0,313	0,000	0,57	2,07
	3 & 5	,629*	0,261	0,049	0,00	1,26
(17) The work was demanding	3 & 5	-,747*	0,282	0,025	-1,42	-0,07
	4 & 5	-,909*	0,323	0,016	-1,69	-0,13
(19) This work method is a waste of	3 & 5	-1,105*	0,287	0,000	-1,80	-0,41

time	4 & 5	-,924*	0,329	0,016	-1,72	-0,13

*. The mean difference is significant at the 0.05 level.

In order to answer research question (1.c), whether students showed differences according to their assessment of the activities carried out in the two cycles, a one-way ANOVA has been calculated. Fig 3.8 shows statistically significant differences between cycles in a few items with p- values > .05. Differences across the items seemed to follow a pattern that implied a decrease of level of agreement in 7 out of 19 items. Even if the overall identified trend can't be considered positive, the means were still well above the middle value (5,5), except for item 18 but considering the statement, also in this case, the low value confirmed a quite positive response. These results seemed to confirm the hypothesis that we had put forward when discussing the results of the comparisons of the mean post-test scores in the two cycles. Indeed, in the second half of the school year, most of the activities that had previously been suspended took place, presumably leaving less room for the activities to be carried out with the same accuracy (fig.3.6). Teachers may have felt compelled to save effort and time in order to deal with all the required activities that were newly introduced after the restrictions. To mention the most important ones, the final exam was returned to its original format, even if the committees were all internal, the school work programme for the students of the fourth class took place since the end of May.

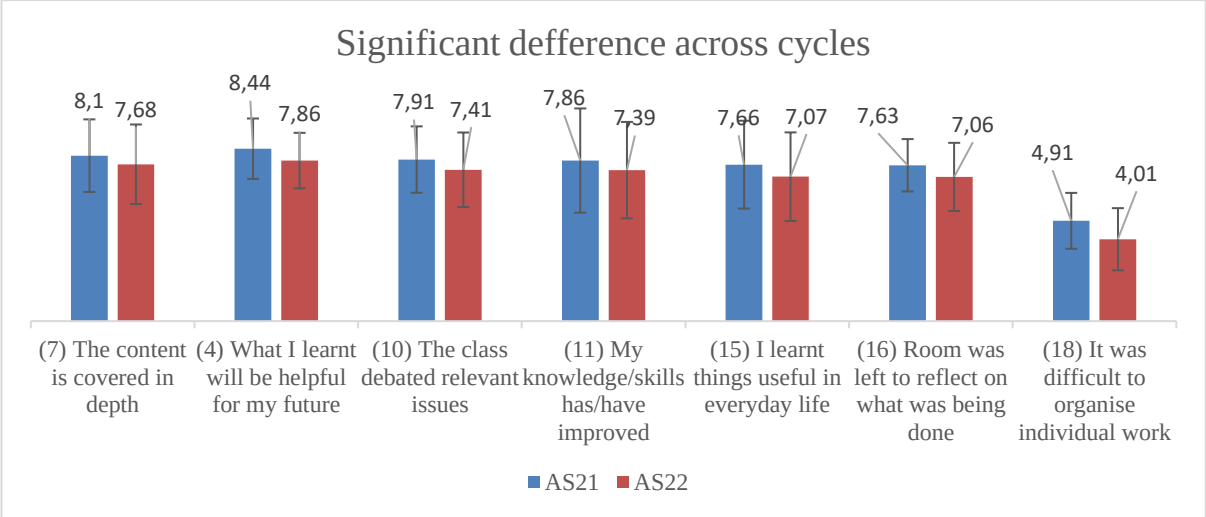


Fig 3.6 – Post-hoc comparisons revealed differences across the groups.

Descriptive Statistics	2021		2022			
	Students (n=139)		Students (n=162)			
	Mean	SD	Mean	SD	t	*p*
(2) The content is covered in depth	8,1	1,48	7,68	1,36	t(299)= -2,372	,015
(4) What I learnt will be helpful for my future	7,63	1,77	7,06	1,95	t(299)= -3,251	,002
(2) The content is covered in depth	8,1	1,48	7,68	1,36	t(299)= -2,372	,015
(10) The class debated relevant issues	7,91	1,62	7,41	1,83	t(299)= -2,561	,011
(11) My knowledge/skills has/have improved	4,91	2,55	4,01	2,36	t(299)= -2,788	,006
(15) I learnt things useful in everyday life	8,44	1,28	7,86	1,67	t(299)=-2,979	,003
(16) Room was left to reflect on what was being done	7,86	1,36	7,39	1,52	t(299) = -2,453	,015
(18) It was difficult to organize individual work	7,66	1,83	7,07	2,04	t (299)= -3,012	,003

3.3. *The "AMGEN Biotech Experience"*:

3.3.1.1. Post-training questionnaire

To assess the effectiveness of the training as to ABE curriculum and Inquiry-based science education, teachers were asked to rate their knowledge before and after the training twice. Data were collected at the end of the online phase and after in-lab activities of the program.

All 77 teachers who participated in the online training completed the survey whereas, due to personal reasons, four teachers were unable to complete the training, and two other teachers did not take the survey after the in-lab training, thus only 71 teachers participated in the final survey.

In terms of inquiry-based science education, after the training most of the teachers claimed themselves being moderately knowledgeable, accordingly they considered their abilities improved. In addition, the number of participants claiming to be 'very knowledgeable' was more than quadrupled after the online training (figure 3.2.1).

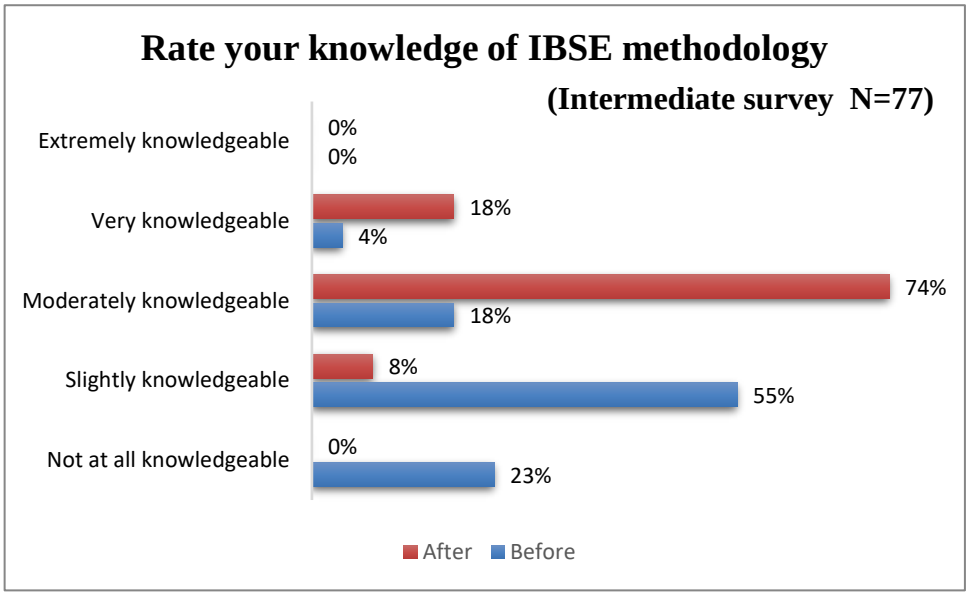


Fig 3.2.1 – Teachers' perception of gain of learning regard to IBSE after the online phase

When asked to rate their knowledge of the topic related to the ABE curriculum, a significant proportion of participants considered themselves to be at least "moderately knowledgeable" already before the training. Just under half of the participants claimed to be "slightly knowledgeable" or "not knowledgeable at all," with 31% and 18% participants falling into these categories, respectively. After the online training, the majority of them perceived an improvement of their knowledge. The share of those who felt very knowledgeable about the topic was almost triplicated (figure 3.2.2). Results emerging from this first survey suggest that the design of the online course met the aim of using technology for delivering and facilitating learning. Presumably, consisting of synchronous interactive activities and asynchronous simulations and individual learning on the LabXchange platform, the arrangement might have favoured both trainees, those who were better equipped to engage in online and self-directed learning and those that might have find valuable the coaching role of the instructor as highlighted in previous studies[118,119].

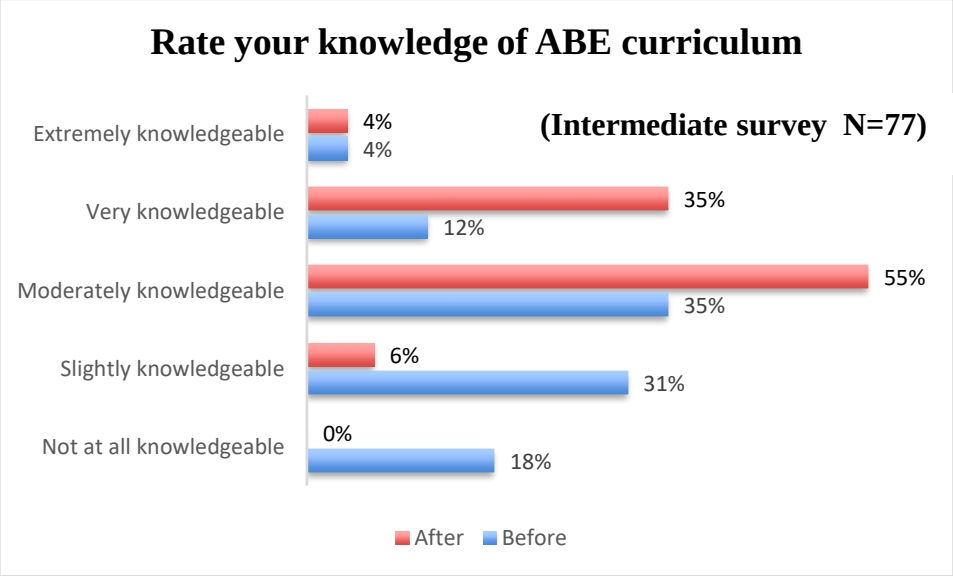


Fig 3.2.2 – Teachers' perception of gain of learning regard to the ABE curriculum after online phase

As to IBSE, the final survey yielded similar results to the intermediate survey. Teachers who rated themselves as very knowledgeable at the end of the first phase seemed to have consolidated their confidence in their skills, whereas the majority of those who felt less prepared at the beginning of the course might have gained a better understanding of the complexity of the inquiry-based approach. However, after the in-lab phase, a high share of participants declared their knowledge improved (figure 3.2.3). Similar results were obtained in their study by Ahokosky

et al. (2017) when exploring teachers' self-efficacy beliefs, perceptions of inquiry learning after a two-days long training aimed at improve inquiry teaching skills[120]. Indeed, prior research has demonstrated that teachers' experience and exposure to inquiry learning affects their confidence of implementing the method in classroom[121]. Despite such a positive response, it would be fundamental to remember that, as Anderson (2002) pointed out, preparing teachers for inquiry teaching is more than a technical matter[122]. The process by which teachers acquire a new approach to teaching is influenced by beliefs, values and understandings about the nature of science, the role of the teacher in the classroom and the role of students in learning. In addition, as accounted in the premise of this study, teachers base their practice on empirical experience of what works in the classroom rather than on theories[123]. Consequently, the extent to which teachers would use inquiry could be mediated by some other factors emerging from classroom experience and by the opportunity to solve issues within the school context, (i.e. parental resistance, unresolved conflicts among teachers, lack of resources, time management) also thanks to sustained support from the ABE program.

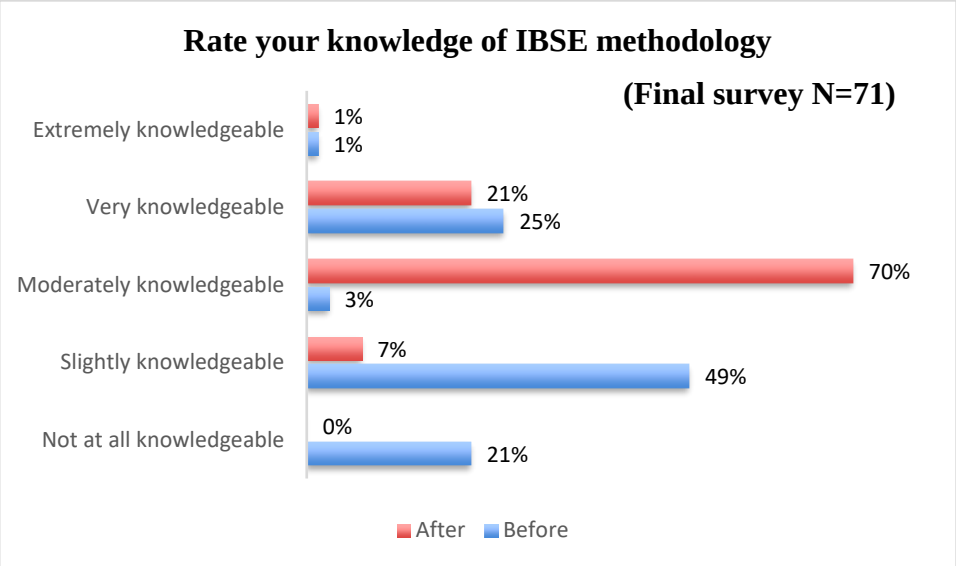


Fig 3.2.3 – Teachers' perception of gain of learning regard to IBSE after the in-lab phase

With regard to ABE curriculum, the final survey results demonstrated further improvement compared to the intermediate survey. The percentage of participants who rated themselves as "not knowledgeable at all" was nearly halved prior to the in-lab training with respect to the previous survey, while the other categories did not show a relevant difference. However, by the end of the training, over half of the participants rated themselves as at least "very knowledgeable." At the conclusion

of this training phase, it is noteworthy that instructors successfully executed the complete sequence of ABE laboratories. In a manner consistent with their future roles as instructors, they underwent a learning experience characterized by comparable uncertainties, obstacles, and errors, while being provided with opportunities to consult with professionals and interpret misleading results. Mac Donald (2014) underscores the significance of the training experience when it comes for teachers to transfer their learning. His study on Transfer of Learning highlights several factors arising from prior research that could act as catalysts for facilitating transfer of training into classroom practice[124]. Most of them were embedded in the program design. In particular, supported by the results of the survey, the professional development program was reflective of the demands of the job. The learning environment was practical, and the activities were geared towards practicing to improve comprehension and enhance transferability. Moreover, learners were equipped with strategies to deal with expected errors. According to earlier studies, providing teachers with training programs could be advantageous in addressing their hesitancy in adopting inquiry-based learning in their classes. In fact, combining training courses with high-quality instructional materials might be the most effective approach to reduce teachers' insufficient academic background in science[120].

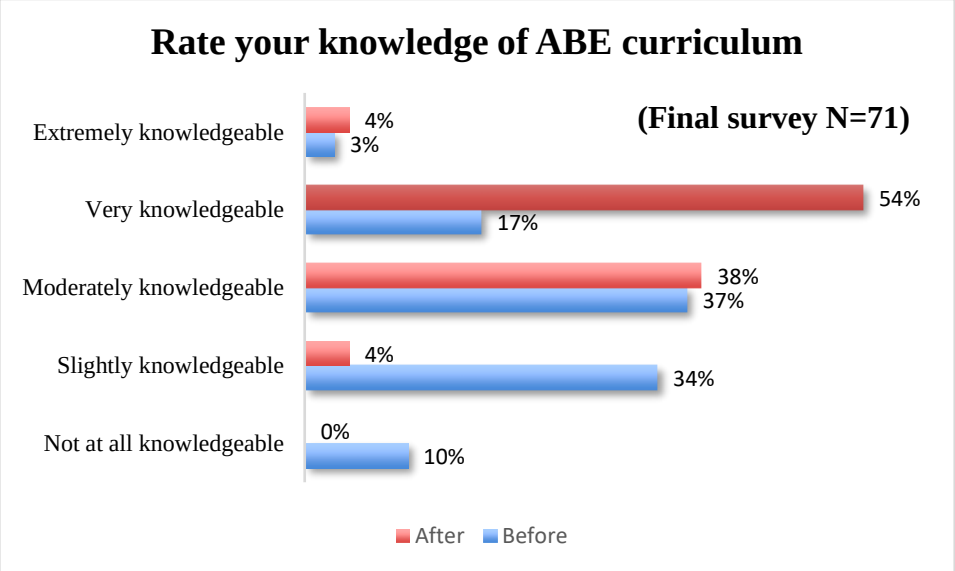


Fig 3.2.4 – Teachers' perception of gain of learning regard to the ABE curriculum after in-lab phase

Accordingly, the construct of "Relevance", just another catalysing factor which pertains to learners' perceptions of the usefulness and applicability of course

content, indicated that participants deemed the biotechnology teaching and methodology course to be focused on relevant skills and subject matter (figure 3.2.5).

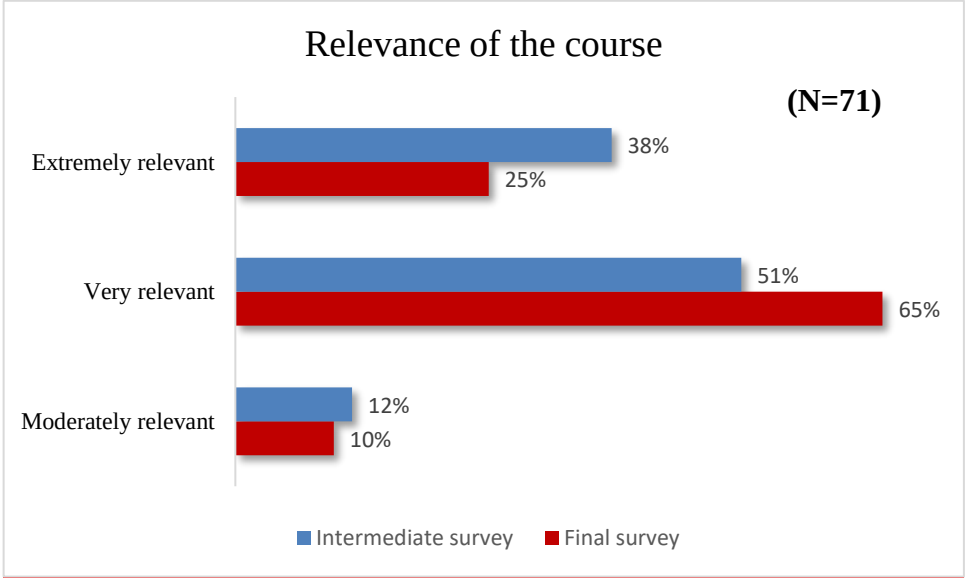


Fig 3.2.5 – Teachers' perception of course relevance at the end of the fist and second stages of the training

Most of the participants found the course was well balanced including active and collaborative learning (figure 3.2.6) Thus, teachers had opportunities to learn by applying theory in practice both online, for instance when asked to collaborate to re-shape a common science lesson in the form of inquiry, or when carrying out the ABE labs and debating on results. As indicated by Bell et al., an active learning approach, which involves the trainee as an active participant in the learning process, is more suitable for addressing the nature of work and training. While behavioral approaches may be effective in developing habitual expertise, they are less effective in instilling the required flexibility and adaptability for the increasingly complex and dynamic work environments, schools included[125].

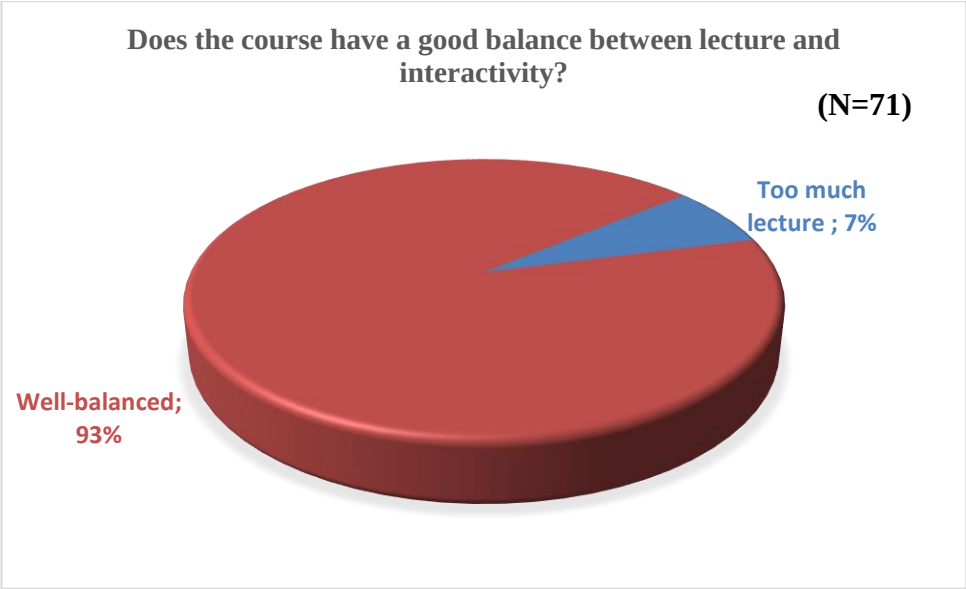


Fig 3.2.6 – Teachers' perception of the structure of the course: the activities were balanced including practical and collaborative opportunities for learning.

Consistent with the results obtained from other items, participants generally agreed on the usefulness of the content of the ABE program, with the majority expressing a willingness to implement the curriculum in their classrooms (figure 3.2.7). Although the degree of appreciation varied across the main features of the training, both the ABE laboratories and the inquiry-based approach were considered relevant for professional development. Answering specific question, 90% (64) of teachers expressed an intention to implement laboratory activities with their students, while 36.6% (26) expressed an interest in incorporating inquiry-based science education (IBSE) into their classroom activities. Additionally, some teachers showed interest in integrating ABE labs with IBSE, as suggested during the course. When asked to identify the most important aspect of the training for their professional growth, 58% chose laboratory practice, highlighting the practical hands-on experience gained during the course. 17% found the guidance provided by researchers and trainer teachers to be significant, while 15% found the entire training activity to be relevant. Furthermore, 12.6% found the IBSE training to be beneficial for their professional development.

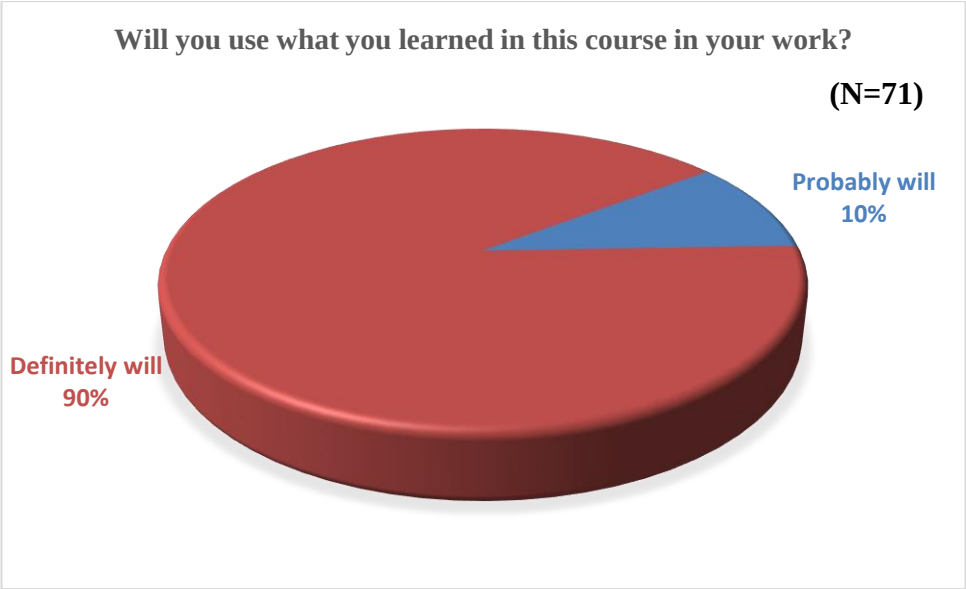


Fig 3.2.7 – Teachers' intention to use what they learnt during the course.

When asked to hypothesize all the factors that might prevent them from using the content of the course, most of the respondents (86%; 61) did not consider any impediments. However, among those who reported encountering barriers, the percentage of teachers who claimed to need further training was the highest (17%; 12). Lack of resources was also perceived as an impediment (7%; 5). As for "Lack of opportunities" "Unwilling colleagues" (1.4%; 1), and "Classroom management" (3%; 2), these were seen as barriers by only a small percentage of participants. The results obtained seemed to outline a situation were, as theorized by Desimone in her study on the impact of PD, core features of professional development such as content focus, active learning, coherence, duration and collective participation could have increased teachers' knowledge and skills as well as their attitudes and beliefs thus enhancing their willingness to introduce innovation in their teaching[126]. Indeed, as regard to teachers perceived self-confidence in transferring learning in practice, similar results emerge from relevant and extensive studies around professional learning and policy reform[66] based on Talis survey, where, when asked, the majority of teachers who underwent formal content or pedagogical training reported that their education prepared them well for their work as teachers.

Asking them 'How could this course be improved to make it a more effective learning experience?' we would like to ask for suggestions that teachers might have developed from their experiences as teachers and learners. According to Guskey

(2000), participants' reactions are relevant in evaluating the process behind the professional development[127]. Since this was an open-ended question, a basic content analysis was conducted, and categories (tags) were created to capture the concepts expressed by teachers[128].

After the online training, 45 out of 75 participants provided feedback. At this stage in their training, teachers feel the need for less intensive training. In their opinion, more extended training would increase opportunities for better understanding. They also feel that they need more training, especially face-to-face training in the lab, to fill the knowledge gap. This is quite plausible considering that the questionnaire was completed after the first step of PD.

At the end of the course, 58 out of 71 participants left feedback. Teachers suggested to prolong both the phases, online and in-presence, thus diluting the effort and favouring in-depth comprehension. This results seems to confirm that blended forms of learning can effectively combine face-to-face social context of classroom learning and the cost-effectiveness and flexibility of online learning; even if as stated from Noe et al., the results can depend on factors that can vary across different situation such as the kind of targeted contents and competences, in this case developing online the basic knowledge of the topic was propaedeutic to in-lab activities were teachers could train skills and competences in real context[129]. In addition, a good share of the participant claimed to be interested in deepening their knowledge around IBSE. In general, teachers manifested the intention to underpin a continue development process that would give them the opportunity to play an active role by integrating each other knowledge under the guidance of experts. Less frequent suggestions were related to in-school support by the researchers (3), and the need of a narrowed focus to deepen only a few of the topics engaged (2).

3.3.1.2. Quasi-experimental two-group comparison

To measure the effectiveness of the in-lab training in improving the knowledge related to ABE curriculum and lab protocols, a comparison of the results between the control and the experimental group was carried out. A two-sample t-test was performed. Despite a slight improvement after the in-lab training, there was not a significant difference in means between control (M = 14,6,07, SD = 3,51) and experimental group (M = 16,1, SD = 3,50); t(71) =-1,914 , p = ,060. However, this occurrence might be due to the lack of sensitivity of the tool used that should

undergo to further revision and also to the timing of testing. Indeed, after the intensive training, teachers could need time for contents reworking. Although there was no significant improvement in knowledge by the end of this stage, this results would be less important than the correlation between teachers' self-efficacy beliefs and training transfer has been identified as a crucial factor. Research has shown that this outcome is as significant as an in-depth understanding of the subject matter. given that teachers must restructure the content and envision classroom scenarios before implementation. Thus, the implementation process consists of two sub-stages: class preparation and actual implementation, the latter being a critical component. In accordance with Gueskey's assertion, teacher learning occurs every time a lesson is taught[127].

3.3.1.3. Early Data of Teachers' ABE labs implementation in the schools

Early data from the distribution centres across the country reported that most of the 38 involved schools had already implemented the ABE labs or were implementing when the data were collected. According to the information 71 out of 73 participants to the training implemented at different degree with their students. Variation may refer to the number of students involved and the type of activity carried out. Variations occur depending on the number of classes and the age of the students involved by each teacher. However, the number of students experiencing the Foundation of biotech curriculum was around 2768, with an average value of 39 students for each trained teacher. The results seemed to confirm data emerging from the other tools used in the project pointing out the effectiveness of the program in enabling the teachers to carry out complex lab activities with their students.

4. CHAPTER 4

4.1. Conclusion: Learning transfer of teachers in the school-based project

The purpose of this study was to examine the extent to which the programmes supported teachers in their approach to curriculum implementation. To this end, four specific research questions were formulated. First, the study aimed to determine whether teachers perceived 'mutual support' and 'integration of knowledge' as integral components of lesson planning and preparation. Second, the study examined the impact of programme implementation on student outcomes. Thirdly, it assessed students' perceptions of the new teaching methods used by teachers. Finally, the study examined differences between the cycles considered.

The results of the study suggest that when teacher design teams are supported by school leaders and experts, when they focus on interdependent group goals, and when they are guided by regular meetings and structured tasks that stimulate critical reflective thinking, they can foster their perceptions of mutual trust and belief in reforms that promote effective improvement in teaching. Although the study acknowledges its weak experimental design, which does not allow for the inference of a cause-effect relationship between variables, it does explore the impact of the implementation of peer-reviewed LS on academic outcomes, and the results show an overall gain in knowledge, suggesting that the goals set by teachers during their design activity were pursued by students. Moreover, the academic outcomes suggest a coherent alignment of outcomes, tasks, choice of materials and setting of learning objectives during collaborative design, with teachers able to balance old and new approaches in classroom practice.

According to students' perceptions, the shift in the teacher's role from lecturer to facilitator and mentor during the implementation of LS provided students with opportunities to engage in activities that would not have been possible with a purely transmissive approach. The study also highlights the effectiveness of inquiry-based learning and the importance of involving students, especially girls, in active, collaborative and reflective practices.

In terms of differences between years of participation, while all participating students responded positively to the usefulness and overall management of the learning activities, younger students seemed to be more at ease with the

instructional innovation, while older students perceived the renewed context as challenging and less meaningful for their growth than other students. Moreover, the differences between the two cycles, both in terms of outcomes and perceptions, appear to be moderately significant and may depend on the normalisation of activities after the restrictions that left more room during the first cycle of experimentation.

The readiness of teachers is a key factor in ensuring that proposed changes are implemented smoothly and effectively but their attitudes and motivation are therefore crucial to the innovation process. Teachers can be better prepared to implement innovation in schools through relevant internal training, collaborative initiatives such as professional learning communities, and initiatives that support teacher distributed leadership and help them to make sense of the reform and built their ownership of the change. However, it is important to note that no professional development activity works well in all circumstances. As in this project, effective school leaders need to begin all professional development efforts with a clear focus on learning and learners; recognise the critical importance of core elements such as leadership, collaboration, management of activities, focus on reforms and the needs of trainees, and evaluation of results, and then work to find the most appropriate adaptation of these core elements to specific contexts. Further research is needed to explore these findings in more detail and to better investigate the impact of implementation on teachers' ability to elicit better students' outcomes and the sustainability of the infrastructure in the long term. Moreover, qualitative data could be collected through classroom observations and interviews, to point out correlation across students' outcomes, observed learning transfer of the teachers and their perceptions of learning transfer.

4.2. Conclusion: Learning transfer of teachers and the AMGEN Biotech Experience

The objective of this study was to evaluate the effectiveness of an online professional development program designed to help teachers when implementing the ABE curriculum and incorporating inquiry-based science education into their classroom activities. The study investigated whether the program supported teachers in approaching curriculum implementation, whether the training was relevant to their profession, whether they perceived any obstacles to classroom

implementation, and whether the training increased their knowledge. The study employed a mixed-methods approach, including surveys, tests to explore the gain of knowledge, and early data from classroom implementation. The findings suggest that the ABE lab training program was effective in supporting teachers in implementing the curriculum. Analysis of the survey data indicated that the training program positively impacted the teachers' self-efficacy beliefs and their ability to plan and implement lab activities.

The results showed that most teachers considered themselves moderately knowledgeable about inquiry-based science education after the training. Similarly, the majority of teachers perceived an improvement in their knowledge related to the ABE curriculum after completing the training. The blended course design effectively used technology for delivering and facilitating learning, consisting of synchronous interactive activities and asynchronous simulations and individual learning on the LabXchange platform.

The training program was reflective of the demands of the job, well-balanced in design, and provided a practical learning environment with activities geared towards improving comprehension and transferability. Active and collaborative learning opportunities were provided throughout the course. Combining training courses with high-quality instructional materials may be the most effective approach to address teachers' insufficient academic background in science.

The quasi-experimental two-group comparison revealed that the training did not significantly improve teachers' knowledge of the ABE curriculum and lab protocols. This finding may be due to the tool's lack of sensitivity or the timing of testing. However, the correlation between teachers' self-efficacy beliefs and training transfer was identified as a crucial factor in the implementation process. Teachers need to restructure the content and envision classroom scenarios before implementation, requiring time and effort. Despite variations in the number of students involved and the type of activity carried out, early data from distribution centers across the country showed that most trained teachers had implemented the ABE labs in their classrooms. The number of students experiencing the Foundation of biotech curriculum was approximately 2768, with an average of 39 students for each trained teacher. This result confirms the program's effectiveness in enabling teachers to carry out complex lab activities with their students. However, the extent

to which teachers will use inquiry-based teaching in the long term could be influenced by other factors arising from classroom experience and the opportunity to solve issues within the school context, supported by the ABE program.

The findings suggest that the effectiveness of the programme could be further enhanced by improving the tools used to assess teachers' knowledge and by involving them in focus groups aimed at self-reflection.

Future research could focus on deepening our understanding of teachers' use of inquiry in their classrooms. Further analysis could help us to understand the developmental relationship between teacher and student inquiry and how each provides foundational knowledge for the other. Finally, future research needs to examine the differences that subject area, experience level, attitudes and school context make for both teachers' conceptualisation and implementation and their impact on students' outcomes.

4.3. Concluding Remarks

In agreement with previous research improvements in education are not possible without well-structured and well-implemented professional development[105], therefore the experimental design took into account the features that scholars consider necessary to increase the chances for a PD initiative to be effective in improving both teachers' skills and students' outcomes. According to a recent review by Hubert et al. (2022), which considered the most relevant literature in the field since 2000, the most appropriate features a PD must have are the followings: focus (to be read as content and pedagogy), active learning, collaboration, coherence of content, duration and coherence of context. Moreover, Hubert at al. underlined as the presence of all these features in the design of PD initiatives can't be taken for granted[130]. In this study, the impact of PD initiatives showing all those requisites has been explored and the approach considered two different levels of inquiry.

At the school level, the focus was on creating conditions to support teachers in improving their ability to teach a competency-based curriculum, while addressing the implementation of reforms such as the introduction of a cross-curricular subject, Civics. The design of the PD started from the consideration of school context, accounting for its community vision, its PTOF and the need of teachers to be guided

when making sense of new learning emerging from training that they underwent according to common goals of the PTOF, individually and collegially, before the project started. The project activities were aimed at designing lessons and materials for teaching the subject, so that teachers had an active role in integrating their knowledge and competences and, furthermore, they gained an insight into the process of teamwork, a relevant prerequisite for being able to offer guidance to pupils when they struggle with cooperative tasks as required by the lesson design. Teachers were involved not only in setting learning objectives, tasks and selecting and modifying materials, but also in considering what should have been the evidence of students' learning to correctly assess their results. This condition was necessary for our research process to explore the impact of the initiative in terms of students' learning. Even if the study relied on data from surveys aiming at evaluating the process of integrating knowledge of participants teachers, and the perceptions of students of innovative methods in their classes, the importance of the outcomes in terms of students' learning has been targeted, evidence can't be based only on self-reported data (i.e. questionnaires)[126,130]. Indeed, the literature in these areas argues for the need for studies to address the lack of knowledge about the relationships between teacher learning and student outcomes[105,126,130]. The iterative nature of the study was one of the most important features, which on the one hand allowed us to compare results across cycles, giving us a robust experimental design for comparisons, and on the other hand provided opportunities to improve the sustainability of the process, also basing adjustment on individual feedback from both teachers and students. Thus, this preliminary study provided a framework that, taking into account all the features that research has claimed to be of paramount importance for PD to be effective, was also capable of providing data for in-depth analysis.

To investigate the impact of a PD programme at the national level, given the importance for local school management to respond to teachers' needs to be updated with innovations in the subject being taught and to integrate the influx of educational research in order to increase effectiveness and sustainability in the long term, the results of the impact of the Amgen Biotech Experience Italy programme were considered. It consists of a network of experts from academia and research centres working together with the specific aim of influencing both the content and

practice of teaching biotechnology. The approach integrates inquiry-based learning as pedagogy to enhance students' engagement and outcomes. Cutting-edge discoveries in the field of biotech and their application in real-life context are presented to teachers that are then involved as learners in complex laboratory activities as final stage of a quite intensive blended course. As well as the school project, the program accounts for all the features for effective PD mentioned above, demonstrating the capacity of changing the beliefs of teachers and definitively impacting their self-confidence thus resulting in a high rate of teachers implementing the ABE labs in their schools.

To maximise the efforts of this preliminary study, the approach used at the local level has been integrated to explore the impact of the ABE programme on the teacher community and then the impact of teacher learning on student outcomes. By following the ABE training without having to start from scratch, the team of teachers in the sampled schools would be able to make sense of their new learning and thus contextualise their efforts and tailor their activities to the needs of the students. Such an approach provides a multi-level insight into the whole process, which could increase the chances of identifying causality between teacher learning and student outcomes at the local level. Indeed, even if it is acknowledged that

> "[…] The characteristics that influence the effectiveness of professional development are multiple and highly complex. It may be unreasonable, therefore, to assume that a single list of characteristics leading to broad brush policies and guidelines for effective professional development will ever emerge"[111],

by carefully analysing and describing characteristics related to context, programme, teacher team dynamics and student outcomes, it will be possible to provide evidence to improve the quality of PD initiatives. With the aim of collecting a more complete set of data, it is important for the follow-up of the project to develop a teacher portfolio, a tool that enables the trainee both to reflect on the relevant aspects of the process in their personal experience and to document their own growth over the period. Such a portfolio could also serve as a corpus for gathering further data to improve our knowledge of important aspects to consider in the next PDIs design phase.

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List of Publications during the doctoral course

TEACHER TRAINING AND TEAM WORKING TO INNOVATE TEACHING

M. De Mauro, D. Amendola, M. Angeletti, G. Gabrielli, A.M. Eleuteri

University of Camerino (ITALY)

Abstract

School experience affects pupils' level of educational attainment, their employment opportunities and definitively, their position in society. School should provide basic life skills and competences necessary for students' personal development. Panels of experts already provided a framework for knowledge, skill and expertise that students should master to succeed in work and life. To be effective, teachers need to keep practice under constant, critical review and adjust it in the light of students' outcomes and latest discoveries in the learning field. They must offer individualized teaching so that all learners achieve specific learning outcomes, whatever their particular learning needs, cultural and social background. Moreover, teachers face rapidly changing demands in their profession, the latest, is for example, Remote Emergency Teaching due to pandemic. However, the lack of a clear, transferable framework for developing and assessing creativity, competences, skills and knowledge is clearly problematic. As a consequence, meaningful learning is far from representing the pivotal outcome. Many previous studies were focused on testing the effectiveness of different methods more than the construction process of an engaged learning community. An engaged learning community provides both teachers and students the benefit of mutual support, integration of competences and the use of the broadest set of methods and technologies. The aim of my research is to find out whether training and collaboration among sample teachers will bring them to feel more confident in experimenting innovative teaching, also in the light of outcomes that students will achieve. Participants will be trained to plan and implement interdisciplinary learning scenarios based on principles of active and collaborative learning with the aim to foster both students' engagement and learning outcomes. I expect that, by working and learning in a collaborative way, teachers develop both their intellectual and social skills and expertise in managing opportunities to grow up their learning community. This research could provide meaningful evidence about the correlation between training, team working and teachers' willingness to innovate their teaching pattern

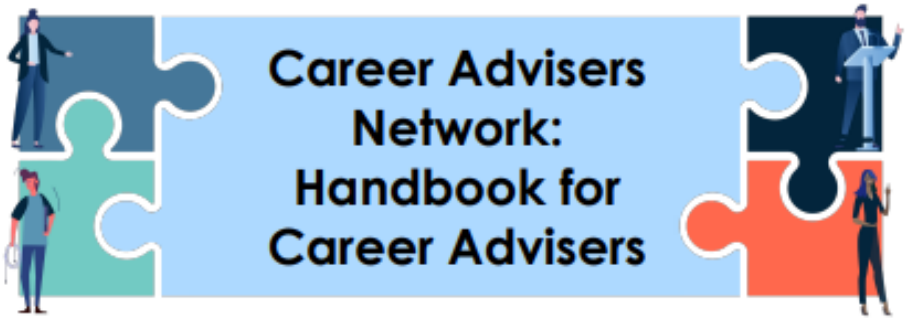
Keywords: Teamwork, transdisciplinarity, engaged learning community, real-life topic.

1 INTRODUCTION

In the 1900s, the White Paper "Teaching and learning - Towards the learning society" highlighted the centrality of education in the process of transforming our society with the aim of addressing the economic and social crisis that the newly formed European Union was facing [6]. The driving factor behind this crisis was the rapid development in the fields of science and technology [2]. This led to a modification in the concept of literacy as the ability to read, write and calculate for personal and society purposes. According to the UNESCO definition, functional literacy refers to a set of skills needed to function both on the personal and community level and to contribute effectively to the development of society [14]. The last ten years have been characterised by great opportunities in all the fields of knowledge despite some criticism. To use safely and productively the tools and technologies which scientific progress provides us with, to grow opportunities and equity for all, citizens need knowledge, skills and competences. Taking into consideration research evidence in related fields different panels of experts have already established, with almost similar results, the set of competences that each citizen needs to accomplish in the era of Artificial Intelligence [4][12]. According to these frameworks, the role of teaching professional is fairly complex. It implies that educators must be able to design learning pathways, which aim to develop this set of competences by integrating their fields of knowledge, to offer a holistic education [11][5]. As education has a key role in fostering learning, it is thus necessary to revamp the delivery of knowledge to keep up with society needs. In the light of evidence, experts and researchers have agreed on the urgency of shifting the traditional methods towards a more student-centred approach encompassing innovative teaching by shifting the focus of instruction from the educator to the learner, by imparting skills and practices which enable lifelong learning and autonomy in problem-solving and give a contribution to our communities and global economy [7] [9].

STEAM IT

AN INTERDISCIPLINARY STEM APPROACH



Career Advisers Network: Handbook for Career Advisers

EUROPEAN INTEGRATED STEM TEACHING FRAMEWORK

Co-funded by the Erasmus+ Programme of the European Union

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European Schoolnet · INDIRE · Ministarstvo znanosti i obrazovanja · República Portuguesa · University of Cyprus · IUL

The STE(A)M IT project (1) created and tested a conceptual framework of reference for integrated STEM education; (2) developed a capacity building programme for primary schools teachers and secondary STEM teachers, based on this framework, with a particular focus on the contextualization of STEM teaching, especially through industry-education cooperation, and (3) further ensured the contextualization of integrated STEM teaching by establishing a network of guidance counsellors/ career advisors in schools promoting the attractiveness of STEM jobs to their classes. (http://steamit.eun.org).

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TEACHERS TRAINING AND COLLEGIAL PLANNING TO REDUCE THE IMPLEMENTATION TIME LAG

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Rationale of the study: Spotlight Innovation in Teaching Practice Based on Students' Perception

Abstract

The aim of this study is to develop and assess the impact of a supportive infrastructure for teachers' collegial planning to maximize the outcomes of Professional Development Initiatives (PDI) to address recently introduced reforms. Participant teachers met regularly integrating knowledge and offering mutual support to create lesson plans consistent with the PDI contents. Students' perceptions were analysed to spotlight innovation features in classroom implementation. Data highlight a good degree of students' appreciation related to collaborative and student-centred lesson design.

Introduction

The 'implementation time lag' is the time needed to fully implement a revised curriculum. School curricula steady evolve according to social, cultural ed economic context[1]. Teachers need to upskill[2] continuously to met essential goals[3] for meaningful learning. To maximize the outcomes of individual teachers' training, this research explores the impact of an in-school supportive infrastructure for collegial planning[4] to improve the learning transfer from PDIs to teaching. To outline the impact of such an initiative students' perception[5] were surveyed to answer the following research questions:

- At what extend the teachers learning transfer happened in classroom implementation?
- Which is degree of students' appreciation towards the activities?

Material and Methods

Participants:

- 1 Technical High School
- 24 teachers
- 340 students

Activities:

Workshops to create lesson plans (26h)
Peer-rewiev of lesson plans
Survey of students' perceptions.

Results

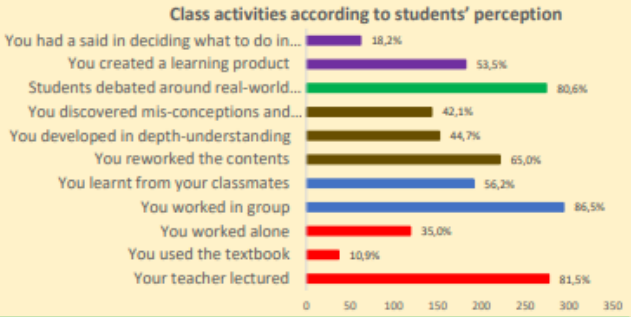

Chart 1 – Target based partition of activities: Entrepreneurship Skills oriented, Real-life oriented, Student-centred, Collaborative Skills oriented, Transmissive oriented.

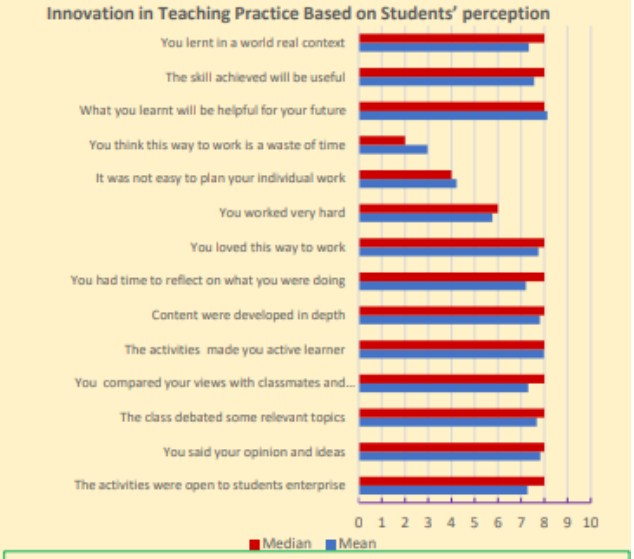

Chart 2 – Degree of effectiveness according to students' perceptions by 10-points Likert-type scale ranging.

Conclusion

Teachers implemented lessons that implied innovative features if compared with the mere transmissive model. Students reported to be involved in collaborative and meaningful activities aimed at deepening world-real related topic. Students declared to be provided with enough time to develop an in-depth understanding. The workload was not perceived as demanding. The teachers lectured also, it can be considered normal, if we assume that it is most used and economic technique experienced in schools. However, pupils felt active and encouraged to participate in debates and challenging tasks, such as the creation of learning products, that can be interpreted as an opportunity to develop their entrepreneurship skills.

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