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Summary Comparative Research Overview

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AV Comparative Study Executive Summary

General Findings

- The aim of the AV project is to promote innovative mathematical learning strategies and techniques
- Teachers will be enabled to become guides, using real world mathematical tools with their students
- Mathematics teaching (and associated STEAM approaches) has been analyzed over four quite distinct national education systems and both differences and similarities were identified. A number of common patterns emerged:
    - A general decline in standards of mathematical competence in almost all population groups, but particularly so in the case of females, those with specific learning needs and other groups of non-traditional learners.
    - despite significant improvement in the mathematics curriculum for early-years students, real problems emerge with transition to secondary level where there is an accelerating concentration on examinations and testing systems.
    - Significant competitive pressures have been identified which detract from the general aim of creating what the ***Added Value*** project team described as "Sustainable Mathematical Competence and Numerical Literacy".
- Research has shown that using methodologies and strategies based on STEAM approaches (of linking science, technology, arts, engineering and mathematics) develops required competences, however application is quite uneven
- The PISA assessment and ranking system has helped to stimulate international comparative frameworks and to act as a rich source of evidence-based feedback to enable national educational bodies to set targets, evaluate teaching methodologies and set strategic goals for the enhancement and improvement of pedagogical, methodological, and assessment systems.
- Factors which lie at the heart of the ***Added Value*** project include: overcoming the negative associations of mathematics as a 'difficult' subject, integrating mathematical competence into everyday life and instilling a sense of wonder and enthusiasm for the joy of learning in mathematics (and associated scientific methods)
- ***Added Value*** partner countries' findings echoed the Irish research, which highlighted issues around the need for new teaching methods and resources; that much of the

teaching and learning in mathematics was didactic with relatively little emphasis on the explanation of concepts, and few opportunities for teachers to engage in problem-solving.

- Critical questions for the project were addressed by the gathering of appropriate information during the research process
- The shared information helped meet the expectation that where there is innovative practice in one or more countries, this may contribute to practice in other partner countries, through the creation of a synergy for learning across contexts and borders
- This shared information included
    - Identifying models of best practice in the teaching of mathematical and related subjects (STEM)
    - Determining the role of mathematics at a time of change
    - Examining teaching methods such as problem-based learning
    - Design based learning
    - Using mathematics in applied situations.
- These considerations align closely with the perspectives that inform the mathematics framework developed under PISA
- The definition and framework are heavily influenced by the realistic mathematics education (RME) movement, including the concept of mathematizing, the five-step process as outlined in PISA:

    1. Starts with a problem situated in a real-world context
    2. Organizes the problem according to mathematical concepts
    3. Gradually 'trims away the reality' by making assumptions about which features of the problem are important, and then generalizes and formalizes the problem
    4. Solves the mathematical problem
    5. Makes sense of the mathematical solution in terms of the real situation.

- PISA offers a useful framework that gives understanding of better practice and making mathematical competence accessible and relevant:
    - Emphasize a more interactive approach to teaching mathematics
    - Emphasize the full range of cognitive competencies (processes) during teaching
    - Implement a better balance of context-free questions and questions that are embedded in real-world contexts.
    - Emphasize more use of language in mathematics classes
    - Help students to develop mathematical knowledge in the context of solving problems.
- AV Project research shows that many blocks to engagement with the excitement and beauty of mathematics still remain, these include
    - the power of traditional conceptualizations of mathematics
    - rigid approaches to curriculum design
    - poor resources for teacher development
    - resistance to innovative deployment of digital technology resources.
- The need for creative and innovative formal and informal science education teaching and learning is strongly endorsed in all EU initiatives.
- The comparative findings from the research show that there is a demonstrated and ongoing need for tools, methods, resources and approaches which stimulate learning, captivate students and energize teachers.

Country Specific Findings

- The research illustrated differences and similarities in teaching strategies and supports for mathematical teaching across partner countries:
    - In The Netherlands there are useful supports, such as a Maths Coordinator in each school
    - In The Netherlands and Ireland maths is seen as a 'spearhead' or priority subject.
    - Textbooks still dominate despite moves towards more innovative methods by some teachers

    - In Spain less traditional schools (Waldorf Steiner and Montessori) have profound training in STEAM and all schools have free STEAM courses for teachers
    - In Ireland creative efforts are being made to link Maths to STEAM.
- Timetabling is limited across partner countries (from 45m to 1 Hour most days), class sizes reduce time available. In Spain the Waldorf schools work with breaks to enable organic learning, also pupils using project-based methods can spend more time on maths
- Resources vary across the partner countries:
    - Poland has basic facilities with interactive whiteboards, textbooks, some computers and traditional labs. Some use digital tools.
    - The Netherlands offers a range of equipment such as computers, concrete tools (measuring tools, blocks among others); parental support with special classes such as 3d printing, Lego League. Most Schools also provide tablets and digital tools.
    - Spain offers laboratories, microscopes, manipulative tools, and emphasise the use of project work interconnecting disciplines. Some use digital tools.
    - Ireland has a variety of resources including labs; textbooks. However, there are differences related to funding, type of school [private/public] and location. Digital tools are beginning to be more widely used.
- Teachers in each country have varying degrees of autonomy. In Poland teachers seem to be under pressure with exams and parental expectations of passing exams rather than understanding concepts. In Spain, there is considerable autonomy, for example one school does not use any textbooks. In Ireland, primary level affords more autonomy, second level moves in to exam requirement and consequent pressure.
- Preferred tools in Poland are physical ones, such as prepared items for fractions or geometry, teachers find it time-consuming to use these. In The Netherlands textbooks lead, with use being made of internet activities which save time with self-corrections. In Spain games such as Hopscotch, mandalas, and stories, with some schools using recycled objects. In Ireland web-based activities were favoured.
- Teaching methodologies in Poland and The Netherlands are mainly direct instruction with some individual/groupwork. Problem-based learning is increasingly being used in Poland. In Spain all agreed that manipulative methods, with visual, tangible

approaches are most effective. Irish methodologies use direct instruction, group and individual work, problem solving in teams.

- Polish teachers agree that the best motivational methods aim at awakening students' interests: through gamification, competitions. In Spain games are also useful, as in Ireland. Irish research shows that there should be some caution in use of games due to uncertainty regarding long-term sustainability of the learning, and the time used which perhaps detracts from exam focus at second level. In Ireland Coding and Robotics are popular tools.
- The use of real-life methodologies is limited due to time pressures, and it can be uneven although many teachers are enthusiastic regarding the concept.
- Excellent examples of real-life applications were provided by each partner, such as money-based situations, food and cooking, classroom and home spatial issues, statistics applied to sports results.
- The interlinking by teachers of maths with other subjects is uneven, in Poland a lot depends on personal relationships between teachers, in Spain there is a sharp divide in responses, with over half seeing clear connections [mainly the Waldorf/Montessori approaches] while the rest rarely do this. In the Netherlands sometimes it happens, the Maths Coordinator may facilitate teamwork/projects. In Ireland there often can be seen strong links, especially with engineering and science.
- Teacher and pupil relationships vary. In Poland it is felt that it depends on teachers' attitudes, and good relationships have to be worked on. In the Netherlands relationships are usually close, with a tendency towards a coaching role. In Spain over half of the respondents said that their relationship is built on a model of helping students develop questions rather than seeking answers. The relationship in Ireland at all levels is usually good and positive.
- The domains that interest teachers are based on real-life situations, are useful, build to more complex problems, and must be challenging. Sciences in Ireland are of interest.
- The challenges in teaching maths and related subjects are perceived in Poland as that they are seen as boring and not relevant. In The Netherlands the challenge is to support students to think critically and solve complex problems, also to ensure that rote learning and memorizing are given a place as they are necessary. Lack of access to adequate resources are a challenge in Ireland.

- Teachers perceptions of students' strengths and weakness vary. In Poland it is felt that they lack problem-solving skills and are less able to 'join dots' and see a bigger picture. The Netherlands agree with this, and also see students as less capable of rote learning. Spain sees issues with topics such as trigonometry and fractions, and frustrations as students do not understand mathematics. Irish findings suggest a lack of independent learning skills.
- Suggestions for supports for students in The Netherlands include mentoring, concrete materials. They also suggest that teachers check their own skills. In Ireland it is seen to depend on the students' needs, with inclusion and diversity a key issue.
- Extra challenges that would help include, according to Poland, real life relevant issues; encouragement for collaboration in The Netherlands, along with more research-based and thematic work forms. In Ireland anything that promotes critical thinking and problem solving.
- The ideas for useful items to include in the toolkit was extensive. The links with everyday life is important, and support to help the students see the relevance of mathematics and develop their thinking about problems, and really relate to other disciplines. For the teacher a manual to accompany the toolkit, with tips and guidance. Poland wishes to have something visible and linked to aspects of the real world, and a task to be completed with a lesson [45 mins]. Apps and 30-minute exercises were proposed by The Netherlands, also research-based work as this is a new development there. Problem solving kits, resources, games, creative thinking kits, quizzes were among the items mentioned by Ireland.
- The issue of how STEAM is useful varies. Most state that it needs support, explanation. In Spain research showed that 50% of students asked about STEAM, the usefulness and applicability.

Main Findings

1. National curriculums in mathematics have improved over 20 years but much remains to be done to move from passing examinations to developing continuous learning that focuses on problem-solving, skills and critical competence.
2. Teachers play a critical role in shaping curriculum to meet student needs and develop engagement with mathematics.

3. Activities and methods that go beyond textbooks produce better results.
4. Mathematics projects that connect various disciplines have better results.
5. Project approaches, autonomy, contests, lab resources, robotics and digital media are all examples of initiatives that produce positive outcomes.
6. Learning materials used by teachers are varied but include textbooks as well as valued internet based resources.
7. Direct instruction, interactivity and individual attention facilitate mathematical learning as well as resources such as GeoGebra.
8. While problem based learning approaches are used, less concentration is used in developing STEM or STEAM approaches.
9. While teachers are open to real-life and alternative approaches, a common complaint is the lack of time.
10. Awakening student interest is a common goal – problem solving, use of visual elements, challenges related to other sciences.
11. 21st century skills are essential: learning to solve problems and to think critically. Teachers need competence in this area. Another challenge is to reduce the testing culture. As to science and technology: the challenge is getting these into the curriculum and to supply the teachers with enough knowledge and skills to teach these subjects.
12. Need for mentoring is common
13. Gamification and competition can be positive tools
14. Toolkits are needed which can incorporate various elements:
    a. Strategic framework physical design to locate maths in context
    b. Maths apps and activities cards
    c. Digital tools
    d. Story frameworks and problem-solving kits
    e. Templates for learning exercises
    f. Multidisciplinary tools linking other subjects and maths
    g. Individualized supports within common framework
15. Many challenges remain and the emphasis on rote learning and examination results can impede creative learning approaches in mathematics significantly.