SURFACE MODIFICATION USING A GLASS-CERAMIC ENAMEL COATING AS A MEANS OF INNOVATING TECHNICAL EDUCATION

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Abstract

This paper examines the potential for implementing innovative instruction focused on metal enamelling technology within primary and secondary education and investigates teachers' willingness to adopt and apply this innovation in practice. The empirical part of the study is based on a questionnaire survey exploring educators' perceptions of the benefits and potential risks associated with this educational innovation. Three groups of respondents were compared: teachers who had completed theoretical training, teachers who had supplemented the theoretical training with a practical workshop involving hands-on experience with enamelling technology, and teachers without prior knowledge or experience in the field.

Respondents were asked about their willingness to incorporate the topic of metal surface engineering and protective coatings into formal teaching as well as extracurricular activities conducted in schools and leisure-time educational institutions. The overarching objective is to identify effective methods for integrating surface engineering technologies into youth education and to inspire primary and secondary school students to develop an interest in materials science and related fields of study. Educational research methods were applied according to Chráska. [2]

An enamel coating is the final product of physicochemical reactions occurring during the thermal processing of glass with a complex chemical composition combined with other inorganic constituents. The resulting material integrates the properties of glass and ceramics while exhibiting strong adhesion to a metallic substrate. Its primary function is to protect the underlying metal against corrosive environments and elevated temperatures. At the same time, enamel coatings fulfil important aesthetic and decorative functions. They represent an environmentally friendly type of inorganic coating, particularly suitable for applications involving contact with drinking water and food. The enamelling process itself encompasses a broad range of technical and technological knowledge.

Enamelling technology constitutes an interdisciplinary educational tool that connects technical education, art education, and the natural sciences. This paper analyses its didactic potential, identifies key barriers to implementation, and presents research findings concerning teachers' attitudes toward its adoption. The results indicate that the acceptance of this innovation is significantly influenced by the availability of material resources, the level of methodological support, and the perceived safety of instructional implementation. Teachers who completed a pilot enamelling course demonstrated a substantially higher willingness to introduce this innovation into both primary and secondary education. Such implementation may contribute to raising awareness of enamelling technology and its applications in industrial and artistic practice, thereby facilitating the transfer of technical knowledge and cultural heritage to future generations.

Keywords: Glass-Ceramic Enamel Coatings, Technical Education, Environmentally Friendly Technologies

1. INTRODUCTION

Contemporary educational trends emphasize the need to integrate theoretical knowledge with practical experience while fostering both technical and creative competencies among students. Within the framework of polytechnic education, increasing attention is being given to approaches that combine traditional craft techniques with modern pedagogical and technological methods. One promising direction is the incorporation of enamelling technology into education from the primary school level onward. Primary education should include the systematic exploration of material properties and their practical applications.

Enamelling technology, as a method of metal surface treatment, has gradually moved to the periphery of educational and industrial interest, partly due to its relatively high energy demands. However, the growing emphasis on sustainability, product durability, and the safety of materials for human health provides a strong rationale for its reintegration into educational practice.

Compact enamelling kilns may offer lower energy consumption than conventional ceramic kilns due to their smaller chamber volume and shorter firing cycles.

This situation creates favourable material and technical conditions for expanding educational activities to include metal enamelling technology. The introduction of this innovation would enable students to acquire knowledge related to metal surface engineering while simultaneously developing aesthetic awareness through artistic design and creative expression.

As a method of metal surface treatment, enamelling represents a unique intersection of technology, aesthetics, and physical principles. Despite its educational potential, it is not yet a standard component of primary school curricula. A key question therefore remains the extent to which teachers are willing to adopt and implement this innovation in their teaching practice.

To address this question, a pedagogical experiment complemented by a questionnaire survey was conducted to investigate teachers' perceptions of the benefits and risks associated with teaching enamelling technology. Three groups of respondents were compared: teachers who had completed theoretical training, teachers who supplemented this training with a practical workshop involving hands-on application of enamelling technology, and teachers without prior professional knowledge or practical experience in the field. Respondents were asked about their willingness to incorporate the topic of metal surface engineering into both formal teaching and extracurricular activities, while also evaluating the perceived benefits and risks of such implementation.

2. EXPERIMENTAL WORK

Students enrolled in a part-time teacher education program who were already teaching at primary and secondary schools were surveyed regarding their basic knowledge of enamel coatings, including their benefits and potential risks. Three groups of respondents were compared: teachers who had completed theoretical training, teachers who had supplemented this training with a practical workshop focused on the application of enamelling technology, and teachers who had not yet participated in either the training or the workshop.

The respondents were asked about their willingness to incorporate the topic of metal surface engineering and protective coatings into both formal classroom instruction and extracurricular educational activities. Subsequently, all participants attended a theoretical lecture, while a selected group also participated in a practical workshop. The workshop covered the preparation of metal substrates for enamelling, including material preparation, cutting, edge rounding, and degreasing procedures. A base enamel coat (enamel slurry) was then applied to the prepared metal surface. Following firing in a kiln and subsequent cooling, coloured decorative enamel layers were applied.

The practical workshops focused on the production of small pieces of jewellery or decorative ornaments, enabling participants to gain hands-on experience with the technology. After completing the practical workshop, the participants were surveyed again using a questionnaire designed to assess their perceptions of

the benefits, risks, and feasibility of implementing enamelling technology within primary and secondary school education.



Figure 1 Representative Products of the Enamelling Workshop

3. RESULTS AND DISCUSSION

Only the principal factors identified in our research are presented here. The study involved 48 respondents, all of whom were practicing teachers enrolled in a part-time study program. The sample consisted of 45 female teachers and 3 male teachers.

The respondents' initial knowledge of enamelling technology is illustrated in **Figure 2**. The results clearly indicate that the majority of respondents had little or no prior practical experience with enamelling technology. This finding confirms that enamelling is not commonly represented in teacher training or school practice and highlights the need for targeted educational activities aimed at increasing awareness of this technology and its potential applications in teaching.

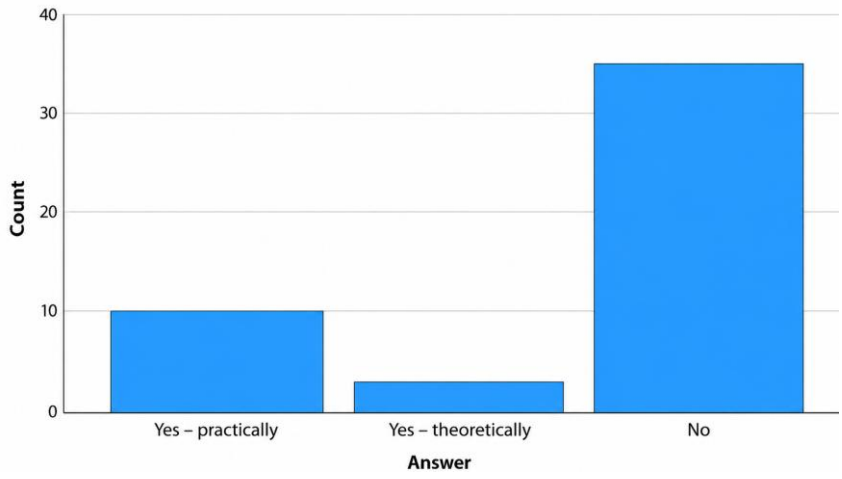

Figure 2 Initial Knowledge of Enamelling Technology Among Teachers. Survey Question: "Have you ever encountered enamelling technology?"

The individual groups were further surveyed regarding the perceived benefits of enamelling technology for students and their willingness to adopt this innovation in educational practice, as illustrated in the graphs (see **Figure 3, Figure 4, Figure 5**). The largest group of respondents consisted of teachers who reported having no prior knowledge of enamelling technology. This finding corresponds with the results presented above and confirms the generally low level of awareness and practical experience with enamelling among the surveyed teachers. Consequently, the evaluation of the technology's educational potential was significantly influenced by the respondents' previous exposure to theoretical training and practical experience.

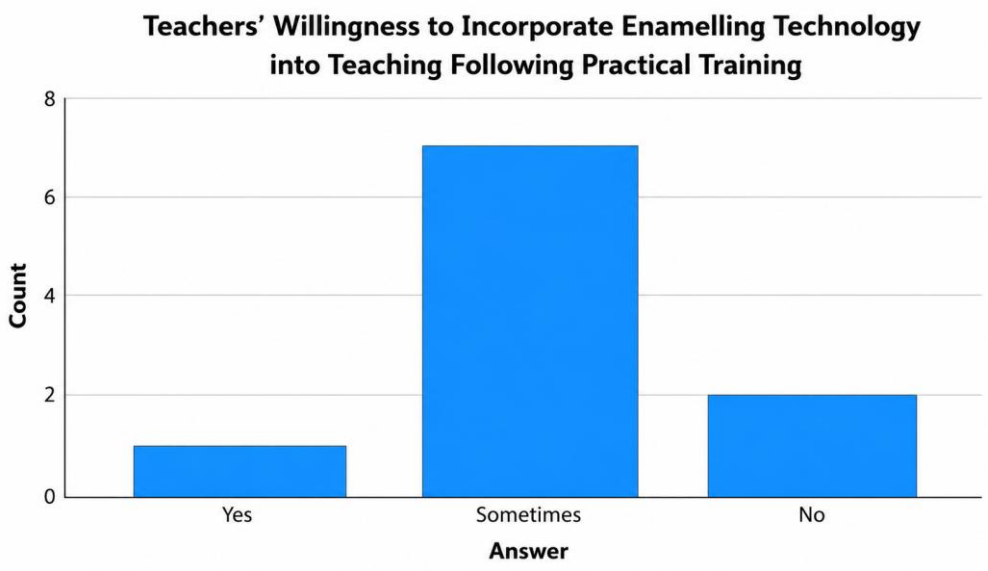

Figure 3 Level of Acceptance of Enamelling Technology Among Teachers After Completing a Practical Workshop

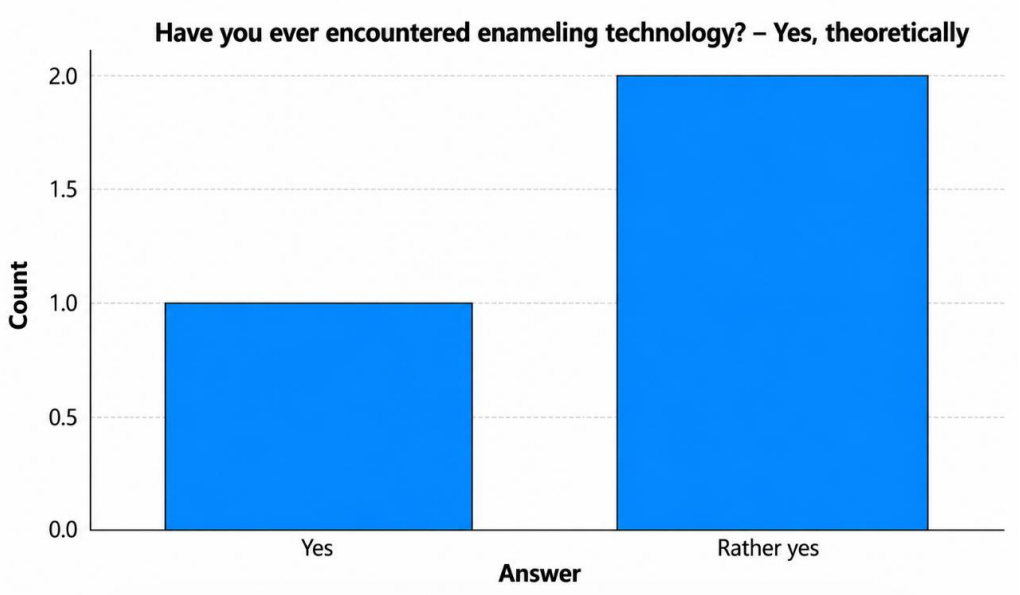

Figure 4 Teachers with Theoretical Knowledge of Enamelling Willing to Incorporate the Topic into Teaching

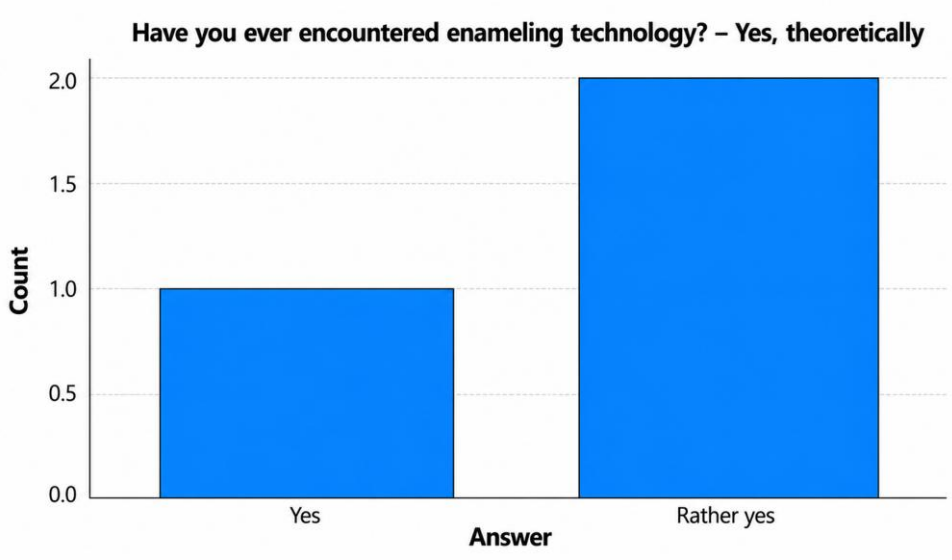

Figure 5 Teachers' Readiness to Introduce Enamelling Technology into the Curriculum Without Prior Training or Experience

After completing the theoretical lecture and practical workshop, all respondents were asked the following question: "How do you evaluate the idea of introducing enamelling technology into teaching?" The results are presented in **Table 1**.

The findings indicate a predominantly positive evaluation of the proposed educational innovation. Based on an analysis of all questionnaire responses, it can be concluded that the neutral evaluations, as well as the single negative response, were primarily influenced by respondents' scepticism regarding the feasibility of purchasing an enamelling kiln and the necessary equipment within the financial constraints of school practice. Another factor contributing to negative attitudes was concern about occupational health and safety risks associated with teaching the technology to children.

Issues related to risk assessment and the implementation of appropriate safety measures were addressed as an integral part of both the theoretical lecture and the practical workshop. The results therefore suggest that, despite certain organizational and safety-related concerns, teachers generally perceive enamelling technology as a valuable and feasible innovation with considerable educational potential.

Table 1 Teachers' Evaluation of the Introduction of Enamelling Technology into Educational Practice

Evaluation	Percent	Responses
Very positive	29 %	14
Rather positive	44 %	21
Neutral	25 %	12
Rather negative	2 %	1
Very negative	0 %	0

Based on the analysis of the collected data, the following conclusions can be drawn:

OVERALL WILLINGNESS TO INNOVATE TEACHING PRACTICE

77 % of respondents indicated that they would probably or definitely incorporate enamelling technology into their teaching. At the same time, 73 % of respondents evaluated the idea of introducing enamelling technology positively. Interpretation: These findings suggest that teachers are generally open to educational innovation, even when it involves a topic that is not commonly represented in current curricula. However, this willingness is not unconditional and depends on several practical factors affecting implementation.

DISCREPANCY BETWEEN INTEREST AND PRACTICAL CONDITIONS

73 % of schools do not possess the necessary equipment for enamelling activities, although existing ceramic kilns could potentially be utilized. 60 % of respondents believe that their schools would be unlikely to invest in the required equipment. 83 % of respondents identified the acquisition of technical equipment as a prerequisite for implementation.

Interpretation: A significant gap exists between teachers' declared interest in introducing enamelling technology and the actual conditions available within schools. Any implementation must also take into account compliance with occupational health and safety regulations and should avoid reliance on provisional or inadequately equipped solutions.

INFLUENCE OF TEACHERS' PREVIOUS EXPERIENCE

50 % of respondents reported previous experience working with metal materials. However, 73 % had never encountered enamelling technology prior to the study. These results indicate that although many teachers possess some background in practical or technical activities, specific knowledge and experience related to enamelling remain limited. This finding highlights the importance of targeted professional development and practical training.

PERCEIVED BENEFITS FOR STUDENTS

The most frequently identified educational benefits were: development of creativity (46 %), improvement of fine motor skills (33 %).

Teachers primarily emphasized aesthetic and motor-skill-related benefits, while technical and scientific aspects were mentioned less frequently. For example, the development of technical thinking was identified by only 4 % of respondents, and the interdisciplinary links to physics and chemistry by only 8 %.

Interpretation: The results suggest that teachers tend to perceive enamelling mainly as an artistic and craft-oriented activity. The broader interdisciplinary potential of the technology, including its connections to materials science, physics, chemistry, and engineering, appears to be insufficiently recognized.

PERCEIVED RISKS AND CONCERNS REGARDING IMPLEMENTATION

The most frequently reported risks were: high-temperature processes (46 %), lack of experience and expertise (21 %), furthermore, 73 % of respondents assessed the overall level of risk as moderate.

Interpretation: Teachers do not generally regard enamelling as an excessively hazardous activity; nevertheless, concerns related to safety and insufficient professional competence remain significant barriers to implementation. These concerns emphasize the importance of methodological guidance, practical training, and clearly defined safety procedures.

4. CONCLUSION

The research findings demonstrate that the overall willingness to introduce enamelling technology into teaching is closely associated with teachers' theoretical knowledge and, in particular, their practical experience. The results indicate that hands-on training significantly increases teachers' readiness to implement this innovation within educational practice.

Compared with the current approach to ceramics instruction, which is often focused primarily on artistic expression, enamelling technology provides greater opportunities for the effective teaching of technical, technological, and physical principles. Through the enamelling process, students can gain practical insights into material properties, thermal processing, surface engineering, and the relationship between science, technology, and artistic design.

Another important factor supporting the implementation of enamelling technology is the growing availability of compact enamelling kilns suitable for educational environments. These kilns generally require less energy than conventional ceramic firing kilns, making their operation both economically and environmentally advantageous. Consequently, the integration of enamelling technology into practical and technical education at the primary school level represents a realistic opportunity for curriculum innovation, particularly in subjects focused on practical activities and technology education.

From this perspective, it appears beneficial to utilize educational development and research projects to support the introduction of enamelling technology through practical training courses for in-service teachers and student teachers. Such initiatives would create valuable opportunities for acquiring knowledge and skills related to surface engineering technologies while strengthening teachers' confidence in implementing these activities safely and effectively.

The introduction of enamelling technology into school education may therefore contribute not only to the diversification of teaching methods but also to increasing students' interest in technical and engineering disciplines. In the context of the Czech Republic, this approach may represent an effective means of supporting the long-term development of technical literacy and encouraging future generations to pursue studies and careers in science, technology, engineering, and materials-related fields.

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