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Electronic, didactic and innovative platform for learning based on multimedia assets

e-DIPLOMA

Funded by the European Union

D5.5: Social and Educational Impact Report

Version No 2.0

31 October 2025

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V2.0	31.10.2025	UJI	▪ Final version approved by Project Coordinator

(*) According to the section "Review and Submission of Deliverables" of the Project Handbook

1. Technical References

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2. Table of Contents

3. Introduction

3.1 Executive Summary

This deliverable (D5.5 – *Social and Educational Impact Report*) presents part of the results of the evaluation of the piloting sessions carried out within WP3 and using the measurement tools developed in WP2 and WP5 of the e-DIPLOMA project. The main objective of this report is to assess the social and educational impact of the co-designed XR-based learning modules, with a specific focus on ethical perceptions and their relation to employability, self-confidence, collective and environmental awareness, and inclusion.

The analysis is based on pre- and post-questionnaires administered to 428 participants across five European countries (Spain, Italy, Cyprus, Estonia, and Hungary). Participants included students, educators, developers, and social entrepreneurs, thereby ensuring a diverse representation of user profiles. The questionnaires were designed to capture perceptions of 21 ethical values, such as autonomy, accessibility, trust, equity, responsibility, and sustainability, identified as particularly relevant to learning in XR environments.

Briefly, the results indicate that participants approached the XR learning activities with high ethical expectations, especially regarding engagement, trust, and emotional well-being. Post-questionnaire responses revealed that many of these expectations were met, particularly concerning trust and safety. However, slight declines were observed in autonomy, accessibility, and satisfaction, highlighting areas where XR environments need to be improved to foster inclusivity and learner control. Correlation analyses further demonstrated that participants tended to perceive ethical values as interconnected, with effectiveness, satisfaction, flexibility, and sustainability forming coherent clusters in the post-experience evaluation.

From a social and educational perspective, the findings suggest that XR-based modules can contribute to strengthening self-confidence, digital competences, and social awareness, while also supporting environmental consciousness through sustainability-focused design. Nevertheless, challenges related to accessibility and inclusion must be carefully addressed to avoid reinforcing existing barriers for vulnerable groups.

In conclusion, the report highlights the importance of embedding ethical principles into the design and implementation of learning environments using disruptive technologies. Recommendations include enhancing accessibility features, ensuring equitable participation, and providing learners with greater autonomy. These measures are essential to maximize the employability, awareness, and confidence benefits of XR, while fostering inclusive and socially responsible educational innovation across Europe.

3.2 Abbreviation List

This is the list of the acronyms that are used in the present document:

- EP: Ethics Plan
- AR: Augmented Reality
- VR: Virtual Reality
- AI: Artificial Intelligence
- WP: Work Packages
- EU: European Union
- EC: European Commission

- ALLEA: All European Academies
- FAIR: Findability, Accessibility, Interoperability, and Reusability
- GA: Grant Agreement
- EEA: External Ethics Advisor
- DMP: Data Management Plan
- GDPR: General Data Protection Regulation
- XR: Extended Reality
- HMD: Head Mounted Display

3.3 Reference Documents

Sources used for developing this report:

- Artificial Intelligence Act https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021PC0206
- D1.3 Data Management Plan (DMP)
- D2.2 Review of e-learning ecosystems
- D3.1 Guidelines and best practices extracted from Piloting monitorization
- D3.5 Testing and Piloting Conclusion report
- D5.2 Definition of appropriate metrics for the assessment of learning competencies
- D5.3 System usability and validation report and ergonomics of evaluation measures
- D5.4 Specifications Report
- D7.2 Ethics Plan
- D7.4 Report on ethics screening and overall legal compliance
- D7.5 Ethics Documents for Check/Review
- D7.6 AI assessment and risk mitigation plan
- D9.1 H - Requirement No. 1 - Annex 1 Informed Consent Form
- D9.1 H - Requirement No. 1 - Annex 2 Informed Consent Form (Minors)
- D9.1 H - Requirement No. 1 - Annex 3 Virtual Reality side effects information form
- Data transfers outside the EU: International data transfers using model contracts
- Directive 95/46/EC
- Ethical guidelines on the use of artificial intelligence and data in teaching and learning for educators (https://education.ec.europa.eu/news/ethical-guidelines-on-the-use-of-artificial-intelligence-and-data-in-teaching-and-learning-for-educators)
- Ethics and data protection (2021) (https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/horizon/guidance/ethics-and-data-protection_he_en.pdf)
- Ethics Issues Table and Ethics Self-Assessment for Horizon 2020 proposals; Horizon 2020

regulation No 1291/2013

- EU Directive 2016/680 of the European Parliament and of the Council of 27 April 2016
- European Code of Conduct for Research Integrity of ALLEA (All European Academies) http://ec.europa.eu/research/participants/data/ref/h2020/other/hi/h2020-ethics_code-of-conduct_en.pdf
- FAIR Principles: https://www.go-fair.org/fair-principles/
- Grant Agreement (GA)
- Guidelines, Recommendations and Best Practices, European Data Protection Board https://edpb.europa.eu/our-work-tools/general-guidance/guidelines-recommendations-best-practices_en
- Handbook on European data protection law (2018 edition), European Union Agency for Fundamental Rights and Council of Europe, European Court of Human Rights, European Data Protection supervisor https://fra.europa.eu/en/publication/2018/handbook-european-data-protection-law-2018-edition
- Manual for Researchers: Information related to Ethics and Gender Issues (July 2019).
- Manual for Researchers: Interview guidelines (July 2019).
- Manual for Researchers: Work methodology and guidelines for the project (July 2019).
- Meetings with the project officer prior to sign the Grant Agreement.
- Regulation (EU) 2021/695 https://eurlex.europa.eu/legalcontent/EN/ALL/?uri=CELEX:32021R0695

4. e-DIPLOMA Alignment with European Frameworks

The e-DIPLOMA project, and consequently this deliverable, is deeply aligned with the European Union's strategic frameworks that promote the ethical, inclusive, and sustainable digital transformation of education. By analysing the educational and social impacts of XR, this report contributes to the realisation of several key EU policy initiatives shaping the responsible use of immersive and Artificial Intelligent (AI)-driven technologies in learning.

- **Artificial Intelligence Act (Regulation EU 2024/1689)**

  The AI Act sets harmonised rules for trustworthy and transparent AI, requiring systems to respect fundamental rights, privacy, and human oversight. e-DIPLOMA's ethical evaluation framework reflects these principles by assessing perceptions of autonomy, fairness, and safety in AI, and XR-enhanced learning environments, offering empirical insights into how these principles manifest in practice.

- **Digital Education Action Plan (2021–2027)**

  This plan calls for the development of digital readiness, innovative pedagogy, and inclusive access to digital education. Through its co-designed XR prototypes and user-centred evaluation, e-DIPLOMA contributes directly to these goals by showing how immersive technologies can enhance learner engagement, self-confidence, and employability, while maintaining ethical safeguards.

- **European Initiative on Virtual Worlds: a Head Start for the Next Technological Transition (COM(2023) 442 final)**

  This recent initiative seeks to foster open, interoperable, and human-centric virtual environments that reflect European values and standards. e-DIPLOMA's work anticipates these objectives by developing pedagogical XR environments that are accessible, inclusive, and ethically aligned. The findings in this deliverable provide evidence-based insights into how virtual worlds can be designed for learning that is participatory, transparent, and socially responsible.

- **European Strategy for a Better Internet for Kids (BIK+)**

  The project's ethical dimension resonates with the BIK+ strategy, which aims to ensure safe, empowering, and age-appropriate online experiences. By examining trust, emotional well-being, and data privacy in XR learning, e-DIPLOMA contributes to the creation of safer and more respectful digital ecosystems.

- **European Green Deal and GreenComp Framework**

  e-DIPLOMA supports the EU's twin green and digital transition by embedding sustainability and environmental awareness within its educational modules, particularly those focusing on social entrepreneurship and responsible innovation. The results presented here demonstrate how immersive technologies can promote ecological literacy and sustainable digital practices.

- **European Pillar of Social Rights and Inclusion Agenda**

  By evaluating accessibility, equity, and vulnerability, the project supports EU objectives for inclusive education and equal opportunities. The ethical assessment tools used in e-DIPLOMA provide concrete methodologies for measuring inclusion within digital and immersive learning environments.

Therefore, the e-DIPLOMA project stands at the intersection of several major European policy initiatives, embodying the EU's commitment to a digital transformation that is human-centric, ethical, and sustainable. By aligning with frameworks such as the AI Act, the Digital Education Action Plan, the European Initiative on Virtual Worlds, the Green Deal, and the Inclusion Agenda, e-DIPLOMA ensures that its outcomes are not only technologically innovative but also socially meaningful. The project demonstrates how immersive learning can foster employability, self-confidence, and social awareness while promoting fairness, accessibility, and environmental responsibility. This strong coherence with EU priorities guarantees that e-DIPLOMA's results have enduring relevance, contributing to both the educational advancement of learners and the broader societal goals of inclusion, equity, and responsible innovation.

5. Context within e-DIPLOMA Goals

The e-DIPLOMA project was conceived to advance experiential e-learning through the integration of disruptive technologies such as Virtual Reality (VR), Augmented Reality (AR), Artificial Intelligence (AI), and gamification into higher education. Its pedagogical approach is based on David Kolb's *Experiential Learning Theory* (1984), which defines "learning by doing" as the process whereby people make sense of their experiences, particularly those in which they actively engage in making things and exploring the world. Following this framework, e-DIPLOMA applies experiential learning as a core methodological principle, promoting active knowledge construction through immersive, hands-on environments that enable learners to experiment, reflect, and apply their understanding in real or simulated contexts. In this way, the project aims to transform online education into a more engaging, interactive, and equitable experience that equips learners for the digital society and labour market.

From the outset, e-DIPLOMA pursued three overarching dimensions:

- **Educational impact**: by designing XR prototypes that enable learners to "learn by doing," the project sought to strengthen digital competences, problem-solving, and creativity. These skills are critical for enhancing employability and ensuring that learners can successfully navigate technologically mediated environments.
- **Social impact**: the project has emphasised values such as collaboration, environmental responsibility, and collective awareness. Prototypes on social entrepreneurship and sustainable

practices aimed to develop not only knowledge but also the civic and social competences necessary to address 21st-century challenges.

- **Ethical impact**: recognising the transformative yet sensitive nature of XR and AI in education, the project embedded ethical reflection and safeguards throughout its activities. Ethical values such as autonomy, accessibility, equity, trust, and inclusion were systematically studied, both to guide design decisions and to evaluate user perceptions during pilots.

Deliverable 5.5 contributes directly to these goals by presenting the evidence of how the co-designed XR modules have impacted learners and educators at educational, social, and ethical levels. While other Work Packages (WP) and deliverables focused on development and technical validation, this report synthesises the outcomes of large-scale pilots across five countries, assessing whether the modules succeeded in strengthening employability, self-confidence, collective and environmental awareness, and inclusion.

By linking user perceptions of ethical principles with educational and social indicators, this deliverable provides the consortium, policymakers, and the wider educational community with actionable insights. It not only demonstrates the achievements of e-DIPLOMA but also highlights areas requiring further development to ensure that immersive learning environments evolve in a direction that is pedagogically effective, socially beneficial, and ethically aligned with European values.

6. Methodology

6.1 Overview

The methodological approach adopted for Deliverable 5.5 builds upon the evaluation framework defined within WP5. Its purpose was to measure how the learning modules developed within e-DIPLOMA influenced users' ethical perceptions, social attitudes, and educational engagement. The study relied on quantitative and qualitative data collected during the multinational pilot activities, using pre- and post-questionnaires designed to assess 21 ethical values identified as central to responsible and inclusive technology-enhanced learning.

The methodology was conceived to ensure reliability, comparability, and cultural sensitivity across pilot sites in **Spain, Italy, Cyprus, Estonia, and Hungary**, covering diverse educational and social contexts.

6.2 Prototypes and Pedagogical Context

Three prototypes were co-designed and developed during the project, each focusing on distinct learning objectives, technological configurations, and user groups. These prototypes served as the foundation for the pilot studies from which data for this deliverable were collected.

The following table summarizes their main features, aims, and technological foundations.

Table 1. Prototype characteristics

Prototype	Description	Aim	Technological elements
Prototype 1 – Block Programming	Immersive course combining VR/AR to teach block programming and electronics (Arduino, sensors, actuators). Structured in two theory/practice modules	To enhance digital competencies in tertiary education stage students through a "learning by doing" approach in block programming and electronics.	VR, AR. Arduino boards, sensors, actuators. Head-Mounted Displays (HMDs). Edison videos.

	plus a collaborative final project.		
Prototype 2 – Social Entrepreneurship	Dynamic e-learning course with five interactive modules on social entrepreneurship, including VR city exploration, cooperative simulations, AI chatbot interactions, and multiplayer games.	To train students in understanding, designing, and managing social enterprises, fostering creativity, collaboration, and sustainable social impact.	VR, AI chatbots, videoconferencing (MS Teams combined with Edison), 3D shared environments, educational games.
Prototype 3 – VR in Education	Training course for educators on integrating VR into teaching. Six modules paired with practical VR activities, culminating in a final VR scene editor project.	To equip educators with knowledge and hands-on experience in VR use, enhancing adoption of immersive technologies in education.	VR, HMDs.

In total, 428 participants took part in the pilot sessions across the partner countries. Significant effort was made to ensure diversity and inclusiveness within the sample, achieving a balanced representation in terms of gender, economic background, and nationality. The participants included students, teachers, developers, and social entrepreneurs, as well as individuals with different disabilities, guaranteeing a comprehensive mix of educational, professional, and social perspectives.

6.3 Study Design

In order to proceed with the evaluation participants were divided into two groups:

- a **control group**, which followed learning activities without disruptive technologies; and
- an **experimental group**, which participated in the disruptive technology-enhanced modules.

This design enabled comparison between expected and experienced ethical perceptions before and after the intervention, thereby measuring the educational and social impact of XR-mediated learning.

Two questionnaires were used for data collection:

- **Pre-questionnaire**: administered before the pilot sessions to capture participants' initial expectations and ethical attitudes toward XR-based learning.
- **Post-questionnaire**: completed after the piloting sessions completed by the experimental group to measure actual experiences and perceived impacts.

Both questionnaires included **15 core questions** mapped to **21 ethical values**, covering dimensions such as **autonomy, accessibility, fairness, trust, sustainability, and emotional well-being**. Responses were recorded on a **1–5 Likert scale** (1 = strongly disagree, 5 = strongly agree). The questionnaires are included in this report as an annex (Annex 1).

In addition, demographic and background data (age, gender, role, country, and prior technological experience) were collected to contextualize the results.

6.4 Ethical Dimensions and Measurement Framework

The set of 21 ethical values was collaboratively defined by the consortium, drawing on prior academic research, EU ethical guidelines for the use of AI and data in education, and insights generated through the project's participatory design workshops. While Deliverable D2.2 provides a broader catalogue of ethical principles identified during earlier phases, this report focuses on 21 values considered most relevant to the educational use of disruptive technologies. Further theoretical grounding is provided in *Väljataga, T. et al. (2024). Exploring Value and Ethical Dimensions of Disruptive Technologies for Learning and Teaching*, which examines these dimensions in greater depth. Each of the selected values was subsequently mapped to specific questionnaire items to operationalize the measurement of ethical perceptions (Table 2).

Table 2. Ethical values

Ethical Value	Associated Question(s)	Illustrative Dimension
Involvement, Productivity	Q1	Engagement and participation
Autonomy, Control, Coercion	Q2–Q3	Freedom of action, perceived pressure
Confidentiality, Surveillance, Trust	Q4, Q7	Data protection, safety, trust
Accessibility, Equity	Q5–Q6	Inclusion and fairness
Vulnerability, Respect	Q7–Q8	Safety, empathy, dignity
Effectiveness, Satisfaction	Q9–Q10	Learning achievement, enjoyment
Responsibility, Dependability, Flexibility, Agility	Q11–Q12	Accountability and adaptability
Enhancement, Sustainability	Q13–Q14	Learning improvement, environmental awareness
Happiness	Q15	Emotional well-being

This mapping ensured consistency across pilot sites and facilitated the analysis of ethical perceptions in relation to social and educational outcomes.

6.5 Data Analysis

Data analysis combined **descriptive statistics (Table 3)**, **comparative tests (Table 3)**, and **correlation analysis (Figure 1 and Figure 2)**:

- **Descriptive analysis** was used to compute mean values, standard deviations, and mean differences between pre- and post-questionnaires.
- **Inferential analysis** employed *t-tests* and *Wilcoxon signed-rank tests* to assess statistical significance of observed changes.
- **Correlation analysis** was conducted using the **Spearman rank correlation coefficient**, appropriate for ordinal Likert data, to explore relationships between ethical values and to identify clusters of interrelated perceptions.

The combined use of *t*-tests and Wilcoxon signed-rank tests provided a robust assessment of pre–post differences. The *t*-test was applied to evaluate mean changes between paired observations, justified by the large sample size and the approximate normality of aggregated Likert-scale data. In parallel, the Wilcoxon test, a non-parametric alternative that does not assume normal distribution, was used to validate these findings and control for potential skewness or ordinal effects. Employing both methods ensured **statistical reliability and strengthened the validity of the conclusions** derived from the participants' responses.

The analysis was complemented by segmentation across participant profiles (students, teachers, developers, social entrepreneurs), enabling the identification of variations in perceptions depending on professional and educational backgrounds.

Table 3. Descriptive Analysis Pre & Post Questionnaires

Question	Mean_Pre	Mean_Post	Mean_Difference	T-Test p-value	Wilcoxon p-value
Q1	4.223	4.142	-0.081	0.212	0.208
Q2	4.000	3.873	-0.127	0.145	0.151
Q3	4.173	4.086	-0.086	0.333	0.530
Q4	4.274	4.391	0.117	0.103	0.099
Q5	4.310	4.107	-0.203	0.006	0.009
Q6	4.269	4.173	-0.096	0.176	0.104
Q7	4.503	4.452	-0.051	0.385	0.402
Q8	4.447	4.386	-0.061	0.341	0.392
Q9	4.137	3.954	-0.183	0.017	0.025
Q10	4.178	3.919	-0.259	0.001	0.001
Q11	4.036	3.904	-0.132	0.110	0.134
Q12	4.193	3.934	-0.259	0.000	0.000
Q13	4.162	3.909	-0.254	0.000	0.001
Q14	3.975	3.883	-0.091	0.202	0.244
Q15	4.391	4.269	-0.122	0.074	0.075

Pre-questionnaire **results reveal high expectations across all ethical values**, particularly for engagement, satisfaction, and emotional outcomes. Therefore, we can conclude that participants viewed learning environments enhanced by disruptive technologies as potentially equitable, secure, and flexible. However, slightly lower scores for autonomy, accessibility, and equity indicated latent concerns about control and inclusion.

Descriptive comparison with post-questionnaire results shows that while most ethical perceptions remained stable, small decreases were observed in all items except Q4. The most notable decline was in accessibility, where users encountered more barriers than anticipated. Trust and safety expectations were generally met, but autonomy and emotional impact scored slightly lower than predicted.

6.5.1 Correlation Analysis

In addition, a correlation analysis has been conducted with the pre-questionnaire data in order to find relations between answers to the questions. The pre-questionnaire responses were analysed using a Spearman correlation analysis, selected because it is well suited to Likert-scale data. The strongest correlation was found between **Q13 (expectation that the technological environment will enhance learning)** and **Q14 (expectation that it will be sustainable)**, suggesting that participants who anticipated educational benefits also expected the system to provide long-term value. Likewise, **Q5 (expectation that materials will be accessible)** and **Q6 (expectation that the environment will be equitable)** showed a strong link, reflecting the perception that accessibility and fairness are interdependent dimensions of the learning experience. Another relevant association emerged between **Q11 (expectation that the system will allow responsibility for one's actions)** and **Q12 (expectation of flexibility in the technological environment)**, indicating that participants saw empowerment and adaptability as connected features. Overall, correlations were generally positive, and the results show that participants entered the learning activity with relatively coherent expectations across ethical and functional dimensions.

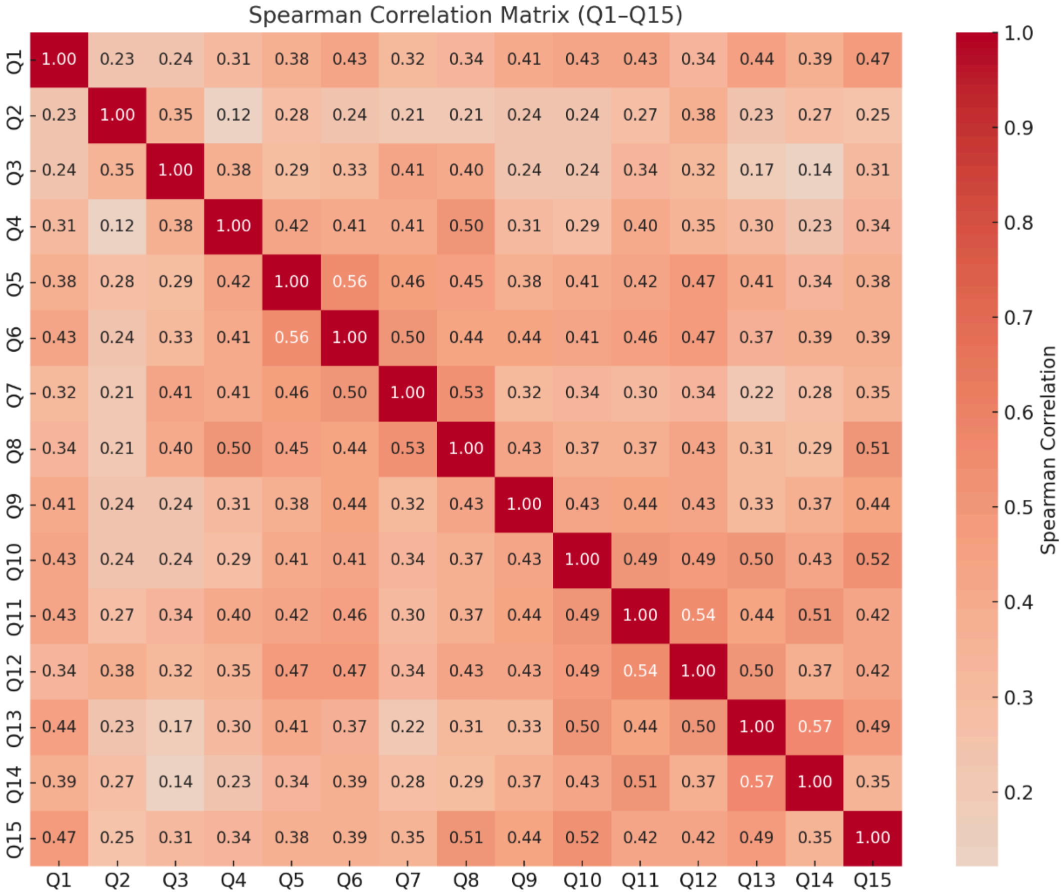

Figure 1. Heatmap – Correlation pre-questionnaire.

In the same way, the answers to the post-questionnaire were analysed. The most robust relationship appears between **Q13 (the belief that the technological environment enhances learning)** and **Q10 (satisfaction with how technologies supported learning)**, showing a very strong positive correlation. This suggests that participants who perceived clear learning benefits from the environment were also highly satisfied with the technological support provided. Similarly, **Q9 (ability to accomplish goals easily)** and Q10 are closely linked, indicating that satisfaction is strongly tied to the perception of effectiveness in achieving learning objectives. Another important cluster connects **Q12 (flexibility of the environment)**, **Q13 (learning enhancement)**, and **Q14 (sustainability of the environment)**, highlighting how adaptability, long-term value, and pedagogical effectiveness were perceived as complementary features. Overall, these findings show that after the learning experience, participants' evaluations converged around a coherent set of dimensions, effectiveness, satisfaction, flexibility, and sustainability, indicating that positive experiences in one area reinforced positive judgments in the others. This convergence contrasts with the pre-questionnaire, where expectations were more diffuse, showing that the actual experience helped crystallize participants' perceptions into a more integrated view of the XR-based learning environment.

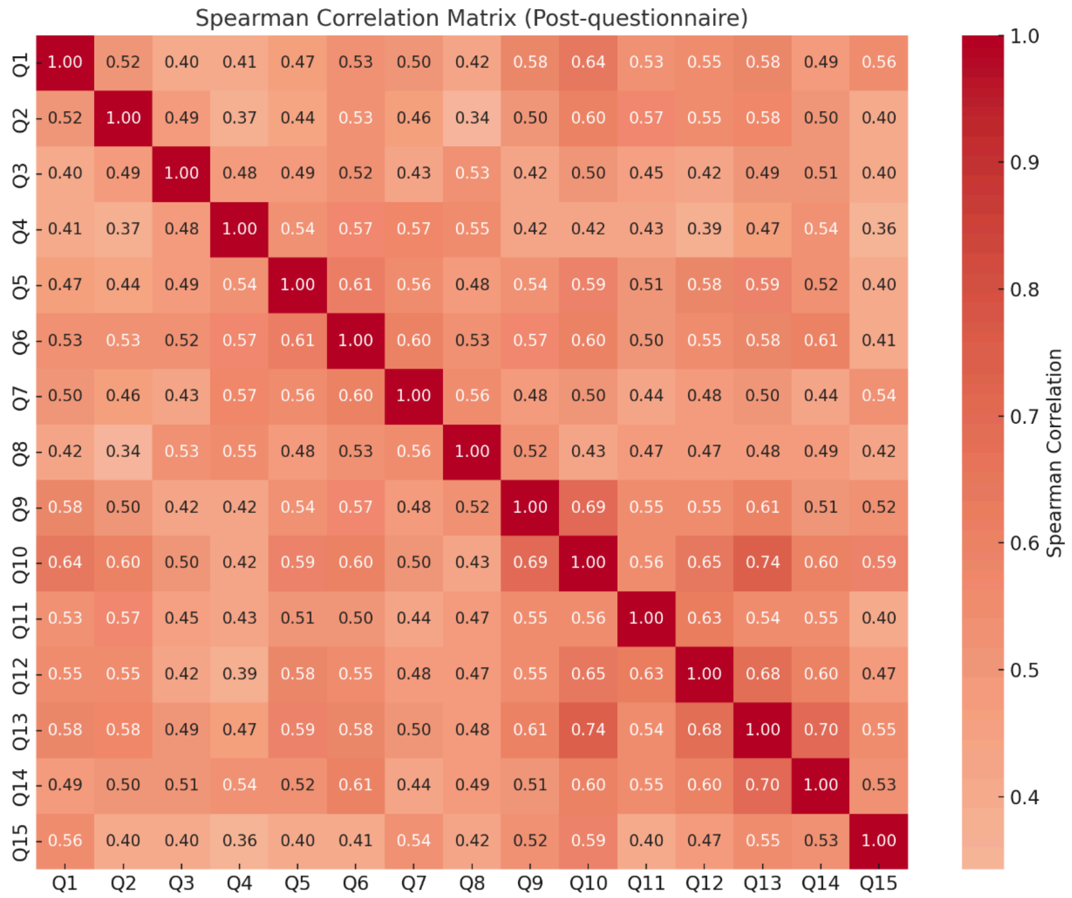

Figure 2. Heatmap – Correlation post-questionnaire.

6.5.2 Profile-Based Differences

To explore how the background and professional role of participants influenced their perceptions of ethical principles in XR-based learning environments, the responses from the pre- and post-questionnaires were analysed according to user profiles. The main categories identified across pilot sites were students, teachers/educators, developers, content creators, and social entrepreneurs or company representatives. This segmentation enabled a comparative understanding of how prior experience, technical expertise, and pedagogical orientation shaped ethical expectations before the intervention and the actual experience after it.

Table 4: Profile □ Content Creator

Question	n_pre	n_post	mean_pre	mean_post	sd_pre	sd_post	mean_diff	t_pvalue_welch	mw_pvalue
Q1	5	5	4	4,2	0,707	0,837	0,2	0,694	0,734
Q2	5	5	4,6	3,8	0,548	0,447	-0,8	0,036	0,056
Q3	5	5	4,4	3,2	0,548	0,837	-1,2	0,032	0,043
Q4	5	5	4	4,4	0,707	0,548	0,4	0,348	0,403
Q5	5	5	4,6	4	0,548	1	-0,6	0,282	0,364

Q6	5	5	4,4	4,2	0,894	0,837	-0,2	0,725	0,734
Q7	5	5	4,2	4	0,837	0,707	-0,2	0,694	0,734
Q8	5	5	4,4	4,2	0,548	0,837	-0,2	0,668	0,817
Q9	5	5	4,4	4,2	0,548	0,837	-0,2	0,668	0,817
Q10	5	5	4,4	4	0,548	0,707	-0,4	0,348	0,403
Q11	5	5	4,4	3,4	0,548	0,894	-1	0,073	0,076
Q12	5	5	4,2	4	1,304	0,707	-0,2	0,773	0,504
Q13	5	5	3,8	4,4	0,837	0,548	0,6	0,222	0,257
Q14	5	5	3,8	4,2	1,095	0,837	0,4	0,536	0,651
Q15	5	5	4	4,6	1	0,548	0,6	0,282	0,364

Table 5: Profile □ Developer

Question	n_pre	n_post	mean_pre	mean_post	sd_pre	sd_post	mean_diff	t_pvalue_welch	mw_pvalue
Q1	15	14	4,2	4	0,775	0,784	-0,2	0,496	0,533
Q2	15	14	4,133	3,714	0,743	1,139	-0,419	0,257	0,385
Q3	15	14	4,2	3,571	0,676	1,505	-0,629	0,169	0,409
Q4	15	14	4,533	4,429	0,834	0,938	-0,105	0,754	0,835
Q5	15	14	4,2	4,071	0,862	0,917	-0,129	0,701	0,745
Q6	15	14	4,333	4,071	0,816	0,475	-0,262	0,298	0,210
Q7	15	14	4,6	4,571	0,632	0,514	-0,029	0,894	0,738
Q8	15	14	4,133	4,357	0,834	0,842	0,224	0,479	0,450
Q9	15	14	4,267	4,214	0,884	0,699	-0,052	0,860	0,668
Q10	15	14	4,267	3,857	0,594	0,949	-0,41	0,181	0,238
Q11	15	14	3,667	3,857	0,976	0,864	0,19	0,582	0,834
Q12	15	14	4,2	3,571	0,676	0,852	-0,629	0,038	0,048
Q13	15	14	4,067	3,643	0,799	0,745	-0,424	0,151	0,187
Q14	15	14	3,867	3,429	0,99	0,852	-0,438	0,212	0,243

Q15	15	14	3,933	4,143	0,594	1,167	0,21	0,554	0,194

Table 6: Profile □ Social Entrepreneur/Social Company

Question	n_pre	n_post	mean_pre	mean_post	sd_pre	sd_post	mean_diff	t_pvalue_welch	mw_pvalue
Q1	6	6	4,667	4,667	0,816	0,516	0	1,000	0,752
Q2	6	6	4,667	4,5	0,816	0,837	-0,167	0,734	0,673
Q3	6	6	4,333	4,667	1,211	0,816	0,333	0,590	0,599
Q4	6	6	5	4,667	0	0,516	-0,333	0,175	0,174
Q5	6	6	4,833	4,5	0,408	0,837	-0,333	0,409	0,527
Q6	6	6	4,833	4,667	0,408	0,816	-0,167	0,668	1,000
Q7	6	6	5	4,833	0	0,408	-0,167	0,363	0,405
Q8	6	6	5	4,667	0	0,516	-0,333	0,175	0,174
Q9	6	6	4,833	4	0,408	0,632	-0,833	0,025	0,033
Q10	6	6	4,667	4,667	0,516	0,516	0	1,000	1,000
Q11	6	6	4,5	4,667	0,837	0,816	0,167	0,734	0,673
Q12	6	6	4,667	4,167	0,516	0,983	-0,5	0,304	0,417
Q13	6	6	4,667	4,5	0,516	0,837	-0,167	0,688	0,923
Q14	6	6	4,5	4,5	0,837	0,837	0	1,000	1,000
Q15	6	6	5	4,833	0	0,408	-0,167	0,363	0,405

Table 7: Profile□ Student

Question	n_pre	n_post	mean_pre	mean_post	sd_pre	sd_post	mean_diff	t_pvalue_welch	mw_pvalue
Q1	103	103	4,262	4,233	0,727	0,819	-0,029	0,787	0,912
Q2	103	103	3,825	3,874	1,014	0,977	0,049	0,727	0,835
Q3	103	103	4,068	4,087	0,783	1,086	0,019	0,883	0,234
Q4	103	103	4,068	4,32	1,165	1,012	0,252	0,098	0,080
Q5	103	103	4,165	4,117	0,755	0,844	-0,049	0,664	0,824
Q6	103	103	4,204	4,194	0,772	0,864	-0,01	0,932	0,825

Q7	103	103	4,408	4,466	0,617	0,683	0,058	0,522	0,331
Q8	103	103	4,369	4,388	0,741	0,77	0,019	0,854	0,688
Q9	103	103	4,126	4,058	0,71	0,884	-0,068	0,544	0,958
Q10	103	103	4,165	3,971	0,793	1,024	-0,194	0,130	0,341
Q11	103	103	3,971	3,932	0,834	0,973	-0,039	0,759	0,998
Q12	103	103	4,194	4,029	0,715	0,934	-0,165	0,156	0,365
Q13	103	103	4,097	4,01	0,823	1,005	-0,087	0,495	0,845
Q14	103	103	3,874	3,932	0,977	0,983	0,058	0,670	0,627
Q15	103	103	4,476	4,388	0,639	0,843	-0,087	0,403	0,859

Table 8: Profile □ Teacher/Lecturer/Educator

Question	n_pre	n_post	mean_pre	mean_post	sd_pre	sd_post	mean_diff	t_pvalue_welch	mw_pvalue
Q1	71	72	4,113	3,931	0,838	1,039	-0,182	0,250	0,410
Q2	71	72	4,127	3,806	0,755	1,194	-0,321	0,057	0,246
Q3	71	72	4,296	4,139	0,725	1,011	-0,157	0,288	0,636
Q4	71	72	4,493	4,403	0,754	0,899	-0,09	0,516	0,670
Q5	71	72	4,451	4,014	0,65	1,081	-0,437	0,004	0,013
Q6	71	72	4,31	4,056	0,709	1,06	-0,254	0,094	0,290
Q7	71	72	4,606	4,333	0,597	0,904	-0,272	0,035	0,075
Q8	71	72	4,592	4,319	0,575	0,932	-0,272	0,037	0,114
Q9	71	72	4,07	3,681	0,799	1,185	-0,39	0,023	0,081
Q10	71	72	4,141	3,736	0,816	1,222	-0,405	0,021	0,073
Q11	71	72	4,127	3,792	0,861	1,1	-0,335	0,044	0,076
Q12	71	72	4,183	3,792	0,85	1,061	-0,391	0,016	0,020
Q13	71	72	4,225	3,681	0,778	1,149	-0,545	0,001	0,004
Q14	71	71	4,056	3,789	0,924	1,145	-0,268	0,128	0,193
Q15	71	72	4,31	4	0,803	1,088	-0,31	0,055	0,122

6.5.2.1 Pre-questionnaire Analysis

The pre-questionnaire results (Tables 4 – 8; columns "xx_pre") reveal that participants entered the XR learning activities with **high expectations across all ethical dimensions**, particularly in engagement, trust, and emotional well-being. However, **statistically significant differences** among profiles were observed for some items according to the Kruskal–Wallis tests. Students and teachers tended to rate autonomy and accessibility lower than developers and entrepreneurs, reflecting limited confidence in managing new technologies or concerns about inclusivity. Conversely, participants with professional experience in technology or innovation, such as **developers** and **social entrepreneurs**, expressed higher optimism regarding autonomy, effectiveness, and sustainability, suggesting a greater familiarity with digital environments and/or self-directed learning processes.

6.5.2.2 Post-questionnaire Analysis

After the completion of the XR learning sessions, profile-based differences became less pronounced (Tables 4 – 8; columns "xx_post"). The **convergence of post-questionnaire results** indicates that the immersive experience fostered a shared understanding of ethical and pedagogical values across all participant groups. Nevertheless, subtle distinctions remained.

- **Students** reported modest declines in perceived autonomy and satisfaction, which may be linked to the novelty of the technology or the structured nature of the learning tasks.
- **Teachers and educators** maintained strong perceptions of trust, respect, and sustainability, consistent with their emphasis on responsible and long-term use of educational tools.
- **Developers and content creators** recorded slightly higher averages in flexibility and control, reflecting their professional familiarity with digital tools and a higher tolerance for technical challenges.
- **Social entrepreneurs** continued to show the most positive evaluations across most ethical values, particularly in engagement, effectiveness, and emotional well-being, aligning with their collaborative and innovation-oriented mindset.

6.5.2.3 Comparative Pre–Post Insights

When comparing pre- and post-questionnaire results per profile, the **mean differences** (Tables 4 – 8; column "mean_dif") were small across most questions, with only a few statistically significant changes identified by the Welch *t*-test and Mann–Whitney tests. Slight declines were observed in accessibility, autonomy, and satisfaction, while trust, safety, and respect remained stable or improved. These trends suggest that, although participants' expectations were initially very high, the real use of XR environments revealed practical barriers that mainly affected less experienced users, such as students or educators with limited technological exposure.

Despite these nuances, the overall convergence of results across profiles indicates that the **co-designed e-DIPLOMA prototypes succeeded in providing a balanced and ethically coherent experience**. The post-intervention reduction in variability between profiles supports the conclusion that immersive and ethically informed design principles can foster inclusivity and shared ethical understanding among diverse user groups.

In summary, the analysis shows that **background differences initially influence ethical expectations**, but **immersive participation mitigates these disparities**, enabling all participants to develop a more unified perception of autonomy, responsibility, and trust in technology-enhanced learning. This finding confirms the value of co-creation and participatory design in producing XR learning environments that are both equitable and pedagogically meaningful.

6.5.2.4 Significant Pre–Post Variations by Participant Profile

A detailed statistical comparison between pre- and post-questionnaire responses confirmed that **teachers/educators** exhibited the highest number of significant changes across ethical dimensions, with eight items showing variation at $p < 0.05$. The most affected dimensions were accessibility (Q5), effectiveness and satisfaction (Q9–Q10), responsibility and flexibility (Q11–Q12), and perceived sustainability (Q13). These findings suggest that educators have become more critical after directly engaging with XR technologies, particularly regarding the practical usability and satisfaction implications of immersive tools. Smaller yet notable changes were observed for **content creators** (Q2–Q3, autonomy and coercion), **developers** (Q12, flexibility), and **social entrepreneurs** (Q9, effectiveness), all of which reflected modest decreases in perceived autonomy or efficiency. Overall, the significance pattern reinforces that professional background shapes the way participants reinterpret ethical values after using XR, with pedagogical profiles showing greater sensitivity to inclusivity, satisfaction, and sustainability issues.

7. Conclusions and Recommendations. Lessons Learned and Guidelines for Future Implementations

7.1 Lessons Learned

The analysis of the e-DIPLOMA pilots confirms that XR can be an effective and ethically grounded tool for education when its design is guided by inclusivity, accessibility, and user empowerment. The project demonstrated that learning environments using disruptive technologies encourage engagement, collaboration, and reflection, supporting both cognitive and socio-emotional development.

A key lesson learned is that ethical alignment is not static but emerges through interaction. Participants across different profiles initially approached XR with high expectations regarding autonomy, trust, and inclusiveness. After experiencing the technology, their evaluations became more nuanced, revealing the practical barriers that can limit inclusiveness and autonomy. This indicates that the ethical quality of XR environments depends as much on usability, context, and facilitation as on technical design.

Another relevant lesson concerns convergence among profiles. Despite initial differences between teachers, students, and professionals, the post-questionnaire data showed a harmonisation of perceptions. Immersive, well-moderated experiences can reduce inequalities in confidence and familiarity with digital tools, helping diverse groups to develop a shared ethical understanding of technology-enhanced learning.

Finally, the project highlighted that emotional and social factors are as important as cognitive gains. Perceived respect, safety, and empathy strongly influenced satisfaction and trust, confirming that XR design should be sensitive to well-being and relational dimensions, not only to performance metrics.

7.2 Guidelines for Future Implementations

Based on these lessons, the following guidelines are proposed to support future XR-based educational initiatives and ensure ethical and sustainable deployment:

1. **Adopt Human-Centred Design Principles**
    a. Start from the needs and contexts of learners and educators rather than from technological capabilities.
    b. Include diverse user groups in the co-design process to anticipate accessibility barriers and equity issues.
2. **Integrate Ethical Reflection into the Design Cycle**

   a. Treat ethics as an iterative process, revisited during design, testing, and evaluation phases.
   b. Use structured tools such as value-sensitive design checklists or ethical impact matrices to ensure that principles such as autonomy, equity, and transparency remain active design drivers.

3. **Ensure Accessibility and Inclusivity**
   a. Provide multimodal access to content (text, audio, tactile, simplified 2D alternatives) and low-cost hardware options.
   b. Follow accessibility standards such as WCAG 2.1 for XR interfaces and continuously evaluate usability with end users.
4. **Promote Learner Autonomy and Agency**
   a. Offer flexible navigation, self-paced learning, and adjustable levels of immersion to accommodate diverse learning preferences.
   b. Include self-assessment and reflection tools that empower users to manage their learning progress responsibly.
5. **Support Educators as Ethical Facilitators**
   a. Train teachers to manage immersive sessions safely, to recognise signs of fatigue or stress, and to moderate collaborative interactions.
   b. Provide them with pedagogical frameworks that connect immersive learning to ethical and social objectives.
6. **Foster Well-Being and Social Connection**
   a. Embed collaborative and empathy-based tasks that strengthen peer relationships and emotional literacy.
   b. Monitor user feedback on comfort and inclusion to adapt the level of immersion and ensure positive affective experiences.
7. **Evaluate Ethical Impact Continuously**
   a. Use mixed methods combining surveys, interviews, and behavioural observations to track changes in perceptions over time.
   b. Include indicators for accessibility, autonomy, satisfaction, and inclusiveness as standard metrics in XR evaluation protocols.

7.3 Outlook

The outcomes of e-DIPLOMA demonstrate that ethical, inclusive, and sustainable approaches to immersive learning are both feasible and effective, providing a strong foundation for the responsible integration of XR technologies in education. The results highlight the importance of aligning pedagogical innovation with ethical awareness, accessibility, and social inclusion, proving that technological advancement and human-centered values can coexist and mutually reinforce each other. The project provides clear evidence that it is necessary to develop practical and context-sensitive guidelines to be integrated into teacher training programmes and digital education strategies, enabling educators to apply XR tools in a critical, safe, and meaningful way. In this sense, immersive learning becomes not only a vehicle for technological innovation but also a pathway to promote **equitable participation, personal empowerment, and long-term social cohesion across Europe**.

8. Annex 1

Table 9. List of questions of the Questionnaires

Question	Pre-questionnaire	Post-Questionnaire
Q1	I believe I will feel engaged and productive in this learning activity.	I felt engaged and productive in this learning activity.
Q2	I expect to feel free to use the technology however I want, without feeling controlled.	I felt free to use the technology however I wanted, without feeling controlled.
Q3	I don't expect to feel pressured to do things I don't want to do.	I didn't feel pressured to do things I didn't want to do.
Q4	I believe the technology and instructors will keep my data private and secure.	I trusted the technology and instructors will keep my data private and secure.
Q5	I believe all learning materials will be accessible.	I felt all learning materials will be accessible.
Q6	I believe the environment will be equitable.	I believe the environment were equitable.
Q7	I expected to feel safe in the learning environment.	I felt safe in the learning environment.
Q8	I believe my values and beliefs will be respected during this learning experience.	I felt my values and beliefs were respected during this learning experience.
Q9	I expect to easily accomplish my goals in the technological learning environment.	I could easily accomplish my goals in the technological learning environment.
Q10	I expect to be satisfied with how technologies will support my learning.	I was satisfied with how technologies supported my learning.
Q11	I believe that the system will allow me to take responsibility for my actions.	My actions were not predefined by the system and allowed me to take responsibility in actions.
Q12	I expect the technological environment to be flexible and allow me to react quickly.	The technological environment was flexible and allowed me to react quickly.
Q13	I believe that the technological environment will enhance my learning.	I felt the technological environment enhanced my learning.
Q14	I believe the technological environment is sustainable.	I felt the technological environment was sustainable.
Q15	I expect to experience positive emotions during the course.	I experienced positive emotions during the course.

e-DIPLOMA

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