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E-LEARNING EVALUATION, INFECTION CONTROL EDUCATION

RESEARCH ARTICLE

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Corresponding author:
Nuray Turan
nkaraman@istanbul.edu.tr

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Quality evaluation of e-learning materials for infection control: a multicenter study of healthcare colleges

Ljudmila Linnik[a], Nuray Turan[b], Cansu Polat Dünya[c], Kati Lahtinen[d], Teija Franck[d], Maija Valta[d], Tuluha Ayoğlu[e], Nuray Akyüz[e], Verónica Coutinho[f], Luis Paiva[f], Irma Brito[f], Natura Colomer-Pérez[g], María del Carmen Giménez-Espert[g], Cristina Buigues[g] and Omar Cauli[g]

[a] Department of Nursing, Tallinn Health University of Applied Sciences, 13418 Tallinn, Estonia

[b] Department of Fundamentals of Nursing, Faculty of Nursing, Istanbul University, 34116 Istanbul, Turkey

[c] Department of Medical Nursing, Faculty of Nursing, Istanbul University, 34116 Istanbul, Turkey

[d] Faculty of Health and Well-Being, Turku University of Applied Science, 20520 Turku, Finland

[e] Department of Surgical Nursing, Florence Nightingale Faculty of Nursing, Istanbul University – Cerrahpasa, 34381 Istanbul, Turkey

[f] Nursing School of Coimbra (ESEnfC), Health Sciences Research Unit: Nursing (UICISA:E), 3046-851 Coimbra, Portugal

[g] Department of Nursing, University of Valencia, 46010 Valencia, Spain

ABSTRACT

Advances in web-based education and technology-mediated learning environments offer opportunities to enhance knowledge access and active learning, particularly in infection control, a critical public health issue. This study aims to assess the quality and reliability of e-learning materials used in infection control education for nursing students by evaluating materials related to hand hygiene, personal protective equipment, isolation measures, and standard precautions in healthcare colleges across Estonia, Finland, Portugal, Spain, and Turkey. The materials were assessed by ten experts from each country (only six experts from Finland) via the Learning Object Review Instrument (LORI). In our study, the Cronbach's alpha coefficient for e-learning materials ranged from 0.736 to 0.932. In terms of the mean LORI total score, the highest mean score was for personal protective equipment (3.983 ± 0.619), whereas the lowest was for standard precautions (3.850 ± 0.550). When comparing the quality of materials related to infection control measures among the countries, materials related to hand hygiene, personal protective equipment, isolation measures, and standard precautions from Spain had the highest LORI total scores. In contrast, materials from Portugal had the lowest mean scores (with the exception of isolation measures). The interobserver agreement coefficients were calculated as 0.516–0.805 for Spain, 0.614–0.729 for Estonia, 0.511–0.711 for Turkey, 0.749–0.938 for Finland, and 0.566–0.882 for Portugal. As the first study to evaluate the quality and reliability of infection control materials via LORIs, the findings contribute valuable insights to the literature and provide a foundation for future research on improving e-learning in nursing education.

Introduction

In the era of rapid technological advancements, the integration of web-based education and technology-mediated learning environments has become increasingly prevalent across various fields (Mhlongo et al. 2023). It has become clear that technology is not merely a supplemental tool but an integral part of the learning ecosystem (Noroozi and Sahin 2023). Since the publication of the Lancet Commission, which addresses global health challenges and emphasizes reforms in health professionals' education, several transformative developments have occurred, including competency-based education, interprofessional education, and the large-scale application of information technology to education (Haakenstad et al. 2022).

In recent years, the landscape of healthcare education and public health outcomes has undergone a profound transformation owing to the advent of e-learning platforms. Infection control as a critical component of public health stands to benefit immensely from these developments (Udoudom et al. 2023).

E-learning has transformed healthcare education by providing healthcare professionals with training and development opportunities, regardless of location (Mahdavi Ardestani et al. 2023). E-learning platforms offer numerous advantages, including flexibility, accessibility, and the potential for individualized learning experiences (Mukamana et al. 2024). These platforms enable healthcare professionals and the general public to access essential information on infection control measures anytime and anywhere, fostering continuous education and awareness. However, the effectiveness of e-learning in achieving its educational objectives hinges on the quality and reliability of the materials provided, the availability of which is rapidly increasing through search engines and repositories (Byungura et al. 2022; Al-Yazidi et al. 2024).

The quality of infection control e-learning materials used in healthcare higher education institutions varies significantly. There is insufficient information regarding the engagement, clarity, and effectiveness of these materials in teaching infection control (Alhumaid et al. 2021; Alrubaiee et al. 2021). It is necessary to assess the quality and reliability of electronic learning objects related to infection control to analyze and compare existing materials, identify their strengths and weaknesses, and develop new, high-quality learning materials (Alrubaiee et al. 2021). The results will help improve infection control education resources and support better healthcare outcomes and public health practices. This study aims to assess the quality and reliability of e-learning materials for nursing students in infection control education.

Materials and methods

Study aim

This study aims to assess the quality and reliability of e-learning materials for nursing students in infection control education. It focuses on the methodology for assessing these materials and selecting the appropriate instructional strategies to ensure effective outcomes.

The Learning Object Review Instrument (LORI), version 1.4, developed by Belfer et al. (2002), was chosen for this study because of its established reliability and comprehensive framework for evaluating e-learning materials. LORIs are used extensively in educational research to assess key quality dimensions, including content accuracy, learning goal alignment, feedback and adaptation, presentation design, and accessibility. Its standardized evaluation framework ensures consistency and comparability of results across institutions.

Research questions

1. Are there differences in the quality levels of infection control e-learning materials assessed via LORIs in different countries?
2. What is the interrater reliability in the quality assessment of infection control e-learning materials?

The evaluation of the quality and reliability of the electronic learning objects used in infection control materials aims to inform educators about critical considerations in their design. Examining the evaluation process and the instruments used can provide valuable insights into methods for peer-reviewing learning objects.

Study design

This study aims to assess the quality and reliability of e-learning materials used in infection control education for nursing students by evaluating materials related to hand hygiene, personal protective equipment, isolation measures, and standard precautions in healthcare colleges across Estonia, Finland, Portugal, Spain, and Turkey. It was conducted between September and December 2023 and provides a comparative analysis of e-learning materials in the five participating countries of the international Erasmus+ project.

E-learning materials

The e-learning materials evaluated in this study varied across institutions and included a diverse range of instructional formats to support different learning needs. These materials consisted of videos, interactive modules, reading materials, self-paced exercises, case-based learning activities, and quizzes. Some institutions have incorporated collaborative learning approaches, such as group discussions, peer-reviewed assignments, and interactive case studies, whereas others have focused on independent learning resources, allowing learners to progress at their own pace. Additionally, certain organizations have integrated virtual simulations and real-world case scenarios to enhance practical applications. These differences in instructional design and learning methodologies were considered during the evaluation process. To ensure a standardized assessment, all faculty members were provided with clear guidelines on how to evaluate different types of materials via the LORI.

Measurements

Study data were collected using the LORI. The LORI is a well-established tool designed to assess the quality of multimedia learning objects by eliciting evaluators' ratings and comments. It can be used for individual or panel reviews, ensuring a structured evaluation process. Reviewers provide assessments on the basis of nine key dimensions: content quality, alignment of learning goals, feedback and adaptation, motivation, presentation design, interaction usability, accessibility, reusability, and compliance with standards (BenSassi and Ben Ghezala 2024). Each criterion is rated on a five-point scale, with an option to mark items as "not applicable" if they are deemed irrelevant to the specific learning object or if the reviewer lacks sufficient expertise to evaluate that dimension.

The LORI supports the evaluation of multimedia learning resources rather than entire educational programs, making it suitable for assessing infection control e-learning materials. This study employed LORIs to systematically evaluate the quality and reliability of infection control e-learning materials

used in healthcare education. The results were aggregated and summarized as an overall quality score for each e-learning object, incorporating reviewer comments to identify strengths and areas for improvement.

Additionally, interrater reliability was examined to ensure consistency across evaluations. As interrater reliability is critical in validating assessment outcomes, this study assessed the degree of agreement among multiple evaluators via the LORI. Prior research has demonstrated the reliability of LORIs in evaluating digital learning materials, with studies by Vargo et al. (2003) confirming their effectiveness as standardized assessment tools. The findings from the present evaluation provide valuable insights into the strengths and weaknesses of current infection control e-learning materials, guiding future improvements in digital healthcare education.

Data collection

The LORI was used to collect faculty members' assessments of the quality of the infection control e-learning materials and ensure that all participants utilized consistent evaluation criteria. Faculty members who met the criteria of having taught infection control for at least 10 years and possessing practical hospital experience were involved in the study, as suggested by Massaroli et al. (2018), who noted that expertise generally begins after 10 years of experience. The faculty members were asked to assess the learning object in the following areas: content quality, learning goal alignment, feedback and adaptation, motivation, presentation design, interaction usability, accessibility, and reusability. They used a five-point rating scale ranging from low to high and were also asked to provide a rationale for their score. All the experts from each country (with only six experts from Finland compared to 10 experts from the other countries) assessed the materials via the LORI. Then, for each country, the faculty members recorded their scores in the LORI Excel sheet created by the researchers to identify the categories in which the infection control e-learning materials received the highest and lowest scores. Each faculty member's evaluation was conducted independently. Two researchers who did not participate in the assessments analyzed the data.

Statistical analysis

Statistical data analysis was performed using SPSS 26.0 (IBM Corp.) and Microsoft Excel 2016. The internal consistency and reliability of the responses given by the experts from Turkey, Portugal, Estonia, Spain, and Finland to the LORI were examined via the Cronbach's alpha coefficient. The Kolmogorov–Smirnov test was performed to determine whether the data conformed to a normal distribution. The data were found to be reliable and normally distributed. To determine whether the responses obtained from the experts in the five countries differed in the dimensions of hand hygiene, personal protective equipment, isolation measures, and standard measures, a one-way analysis of variance (ANOVA) was used. The intraclass correlation coefficient (ICC) was used to assess the agreement between expert opinions. The results were evaluated at a 95% confidence interval (CI) and a significance level of $p < 0.05$ (Özdemir 2005; Kalaycı 2010; Kılıç 2016).

Since this study involved five different countries and languages, careful attention was given to linguistic consistency to ensure the validity of the findings. The instrument was translated into all relevant languages via a rigorous forward and backward translation process conducted by bilingual experts. This ensured conceptual equivalence across different versions of the instrument. The results confirmed an acceptable level of agreement, indicating that the translation process did not introduce significant bias.

Ethical approval

Approval was obtained from the Social and Humanities Research Ethics Committee of Istanbul University (approval No. 2024/2887811; date 09.23.2024).

Results

Characteristics of e-learning materials

The study included 77 e-learning materials. Of these, 29 were related to hand hygiene, 21 to personal protective equipment, 13 to isolation measures, and 14 to standard measures (Fig. 1).

The LORI scores of e-learning materials

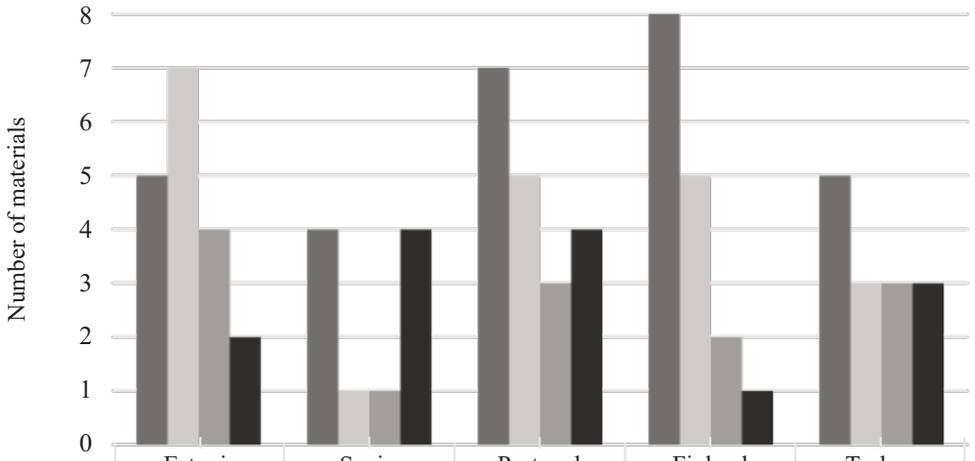
The average LORI scores for the e-learning materials on infection control topics are shown in Table 1. Personal protective equipment received the highest score (3.983 ± 0.619), whereas standard precautions had the lowest score (3.850 ± 0.550). Among countries, Spain had the highest total LORI score, whereas Portugal had the lowest, except for isolation measures. These findings show variations in the quality of e-learning materials across topics and countries.

Interrater reliability of the LORI scale

Table 2 shows the Cronbach's alpha and the ICC values for the e-learning materials related to hand hygiene, personal protective equipment, isolation measures, and standard measures for the five countries. Finland showed the highest reliability and interrater agreement across all materials. Portugal and Estonia showed strong reliability, especially in hand hygiene and personal protective equipment materials. Turkey and Spain demonstrated moderate reliability and interrater agreement overall.

Discussion

Evaluating the quality of e-learning materials related to infection control measures is essential for delivering safer and more effective healthcare services for all healthcare practitioners, patients, and the community (Suppan et al. 2020; Najafi Ghezeljeh et al. 2021). This study aims to assess the quality and reliability of e-learning materials used in infection control education for nursing students by evaluating materials related to hand hygiene, personal protective equipment, isolation measures, and standard precautions in healthcare colleges across Estonia, Finland, Portugal, Spain, and Turkey. This multinational study is the first to evaluate e-learning materials related to infection control. By revealing the



	Estonia	Spain	Portugal	Finland	Turkey
Hand hygiene	5	4	7	8	5
Personal protective equipment	7	1	5	5	3
Isolation measures	4	1	3	2	3
Standard measures	2	4	4	1	3

Fig. 1. Distribution of e-learning materials.

Table 1. The LORI scores of e-learning materials

Scale / type of IC	Country	n	Mean	SD	F	p*	Difference**
LORI – total	Turkey	10	4.094	0.419	**8.256**	**<0.001**	**T > P, F**
	Portugal	10	3.392	0.123			**E > P, F**
	Estonia	10	3.903	0.137			
	Spain	10	4.161	0.609			**S > P**
	Finland	6	3.551	0.076			
Hand hygiene	Turkey	10	4.145	0.319	**9.639**	**<0.001**	**T > P, F**
	Portugal	10	3.500	0.160			**E > P, F**
	Estonia	10	3.945	0.241			
	Spain	10	4.200	0.477			**S > P, F**
	Finland	6	3.630	0.115			
Personal protective equipment	Turkey	10	4.078	0.521	**5.081**	**0.002**	**T > P**
	Portugal	10	3.467	0.208			
	Estonia	10	4.444	0.148			**E > P, F**
	Spain	10	4.133	0.961			
	Finland	6	3.667	0.186			
Isolation measures	Turkey	10	4.033	0.624	**6.698**	**<0.001**	**T > P, F**
	Portugal	10	3.167	0.302			
	Estonia	10	3.667	0.234			**E > P, F**
	Spain	10	4.089	0.946			
	Finland	6	2.945	0.304			**S > F**
Standard measures	Turkey	10	4.122	0.525	**5.584**	**<0.001**	**T > P, E**
	Portugal	10	3.433	0.206			**S > P, E**
	Estonia	10	3.556	0.251			
	Spain	10	4.222	0.741			**F > P**
	Finland	6	3.963	0.303			

* ANOVA, ** Tamhane's T2 test; IC – infection control, SD – standard deviation, F – ANOVA test statistic; **T** – Turkey, **P** – Portugal, **E** – Estonia, **S** – Spain, **F** – Finland

quality and reliability of existing e-learning materials, our study will significantly contribute to the development of more quality and reliable e-learning materials.

E-learning materials play an essential role in education related to infection control measures. These materials help prevent the spread of infections by providing healthcare workers with up-to-date information and practice opportunities (Sikkens et al. 2018; Wolfensberger et al. 2019). Additionally, they offer access independent of time and location, reaching broad audiences and providing content suitable for

Table 2. Interrater reliability of the LORI scale

Country	Scale / type of IC	Number of experts	Cronbach's α	ICC (95% CI)	SEM	MDC
Turkey	LORI	10	0.617	0.524 (0.293–0.712)	0.289	0.801
	Hand hygiene	10	0.755	0.711 (0.365–0.920)	0.171	0.475
	Personal protective equipment	10	0.630	0.511 (0.071–0.850)	0.364	1.010
	Isolation measures	10	0.706	0.531 (0.144–0.850)	0.428	1.185
	Standard measures	10	0.726	0.547 (0.167–0.856)	0.353	0.979
Portugal	LORI	10	0.804	0.801 (0.688–0.885)	0.055	0.152
	Hand hygiene	10	0.879	0.882 (0.721–0.969)	0.055	0.152
	Personal protective equipment	10	0.824	0.824 (0.586–0.953)	0.087	0.242
	Isolation measures	10	0.606	0.566 (0.061–0.879)	0.199	0.551
	Standard measures	10	0.715	0.697 (0.310–0.918)	0.113	0.314
Estonia	LORI	10	0.825	0.823 (0.723–0.898)	0.058	0.160
	Hand hygiene	10	0.683	0.679 (0.251–0.914)	0.137	0.379
	Personal protective equipment	10	0.720	0.729 (0.350–0.929)	0.077	0.214
	Isolation measures	10	0.613	0.614 (0.088–0.897)	0.146	0.404
	Standard measures	10	0.699	0.692 (0.285–0.917)	0.140	0.387
Spain	LORI	10	0.617	0.532 (0.305–0.717)	0.431	1.196
	Hand hygiene	10	0.872	0.805 (0.563–0.946)	0.211	0.584
	Personal protective equipment	10	0.774	0.527 (0.172–0.842)	0.661	1.833
	Isolation measures	10	0.768	0.516 (0.162–0.836)	0.867	2.402
	Standard measures	10	0.805	0.577 (0.225–0.864)	0.482	1.335
Finland	LORI	6	0.909	0.910 (0.855–0.949)	0.023	0.063
	Hand hygiene	6	0.913	0.915 (0.787–0.978)	0.034	0.093
	Personal protective equipment	6	0.846	0.848 (0.620–0.960)	0.073	0.201
	Isolation measures	6	0.787	0.749 (0.409–0.932)	0.152	0.422
	Standard measures	6	0.954	0.938 (0.841–0.984)	0.076	0.209

SEM – standard error of measurement, MDC – minimally detectable change, CI – confidence interval

individual learning speeds. Thus, they offer practical and widespread education opportunities in infection control (Huang et al. 2021; Sayıner and Ergönül 2021). This study revealed that the highest average LORI total score among the e-learning materials was for those related to personal protective equipment (3.98 ± 0.62), whereas the lowest average score was for the materials related to isolation measures (3.63 ± 0.70). A similar result was reported by Suppan et al. (2020), who reported that participants showed improved performance in using personal protective equipment after e-learning. This suggests that e-learning materials for using personal protective equipment are better designed and of higher quality, whereas materials for isolation measures need improvement. Intercountry evaluations revealed differences in the average LORI total scores for e-learning materials related to hand hygiene, personal protective equipment, isolation measures, and standard measures. Spain had the highest quality e-learning materials about infection control measures (with the exception of personal protective equipment). In contrast, Portugal had the lowest quality e-learning materials (with the exception of isolation measures). Estonia had the highest quality e-learning materials related to personal protective equipment. The quality level of Spain's e-learning materials was higher than that of Portugal's, and the quality levels of Turkey's and Estonia's e-learning materials were higher than those of Portugal's and Finland's e-learning materials. These differences may stem from the diversity of educational infrastructures, healthcare systems, and infection control policies among the countries. Therefore, updating the content in the countries with lower-quality materials is recommended. Additionally, organizing training programs for faculty members can help improve e-learning materials pedagogically and technically (Halvoník and Kapusta 2020). In this way, more effective e-learning materials can be used to control infection.

The Cronbach's alpha coefficient is used to assess reliability when Likert-type scales are used. For a test to be considered reliable, the internal consistency coefficient should be greater than 0.60 (Bujang et al. 2018). In our study, the Cronbach's alpha value for the LORI was observed to be between 0.617 and 0.909. These values indicate that the LORI is a reliable tool for evaluating e-learning materials related to infection control measures across the five countries.

In this study, the quality of e-learning materials was evaluated by 10 observers from each country, except for Finland, which had six observers. The ICC reliability threshold, used to assess agreement among the observers, was set at 0.50. An ICC of 0.50–0.75 is considered moderately reliable, 0.75–0.90 is considered good, and an ICC above 0.90 is considered

excellent (Landis and Koch 1977). In our study, the interobserver agreement coefficient ranged from 0.524–0.910. While good and excellent agreement was found among the observers in Finland, moderate and good agreement was observed among the observers in the other countries. As Žmuk et al. (2023) highlighted, Finland is one of the European countries most extensively using e-learning. This may be attributed to Finland's more consistent and systematic educational programs and professional development standards. Differences in interobserver agreements in the other countries may stem from variations in educational infrastructures, the development processes of e-learning materials, and the diversity in the observers' academic levels. Therefore, it is recommended that educators receive training related to digital materials and increase international collaboration. This approach can help reduce differences in agreement and improve the quality of e-learning materials.

To improve the quality and effectiveness of e-learning materials in infection control education, educators and policymakers should consider integrating standardized instructional design frameworks that enhance interactivity and engagement (Leacock and Nesbit 2007). The development of faculty training programs focused on digital pedagogy and evidence-based content creation can further ensure the pedagogical soundness of e-learning materials (Noroozi and Sahin 2023). Additionally, fostering international collaboration in the development and evaluation of e-learning resources can contribute to establishing consistent quality standards across different healthcare education systems (Byungura et al. 2022). Implementing competency-based learning modules guided by evidence-based guidelines can also ensure that infection control education aligns with best practices in nursing education and meets the evolving needs of healthcare professionals (Mahdavi Ardestani et al. 2023).

This study has several limitations. First, the educational infrastructure and cultural differences between the countries may affect the agreement among the observers, making it difficult to compare the results directly. Additionally, the diversity of the evaluated e-learning materials and the differences in technological infrastructures are factors that could influence the observers' assessment results. Furthermore, the results may lose validity over time, given the need for e-learning materials to be continuously updated with rapidly changing health information.

Another limitation is that the LORI has not been validated in all languages, which may have influenced how the evaluators interpreted and applied the assessment criteria across the different linguistic and cultural contexts.

Conclusion

This study is the first multinational study to evaluate the quality of e-learning materials related to infection control measures. The Learning Object Review Instrument (LORI) is a reliable tool for assessing e-learning materials related to infection control. There were differences in the quality levels of e-learning materials related to infection control among the countries. Our study suggests that differences in educational infrastructures, healthcare systems, and infection control policies among countries may influence the quality of e-learning materials. The high observer agreement in Finland may indicate consistent and systematic educational programs. These findings are essential for improving standards and ensuring international consistency in the development of future e-learning materials. Enhancing the quality of e-learning materials will contribute to patient safety and public health by improving the knowledge and skills of healthcare professionals. As a next step, within the framework of the Erasmus+ project, a joint guideline for e-learning materials on infection control is planned. This guideline will be the foundation for a standardized infection control course across participating healthcare colleges. By establishing common educational standards and best practices, this initiative aims to increase the quality and consistency of infection control education, foster a more unified approach to training healthcare professionals, and ultimately improve global healthcare outcomes.

Data availability statement

The datasets used and/or analyzed during the current study are available from the corresponding author at reasonable request.

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Infektsioonikontrolli e-õppematerjalide kvaliteedi hindamine: mitmekeskuseline uuring tervishoiukõrgkoolides

Ljudmila Linnik, Nuray Turan, Cansu Polat Dünya, Kati Lahtinen, Teija Franck, Maija Valta, Tuluha Ayoğlu, Nuray Akyüz, Verónica Coutinho, Luis Paiva, Irma Brito, Natura Colomer-Pérez, María del Carmen Giménez-Espert, Cristina Buigues ja Omar Cauli

Veebipõhine haridus ja tehnoloogiatoega õpikeskkonnad võimaldavad teadmiste paremat kättesaadavust ja aktiivõpet, eriti nakkuste ennetamise valdkonnas, mis on rahvatervise seisukohalt oluline teema. Uuringu eesmärk oli hinnata nakkuste ennetamise õpetamisel kasutatavate e-õppematerjalide kvaliteeti ja usaldusväärsust, keskendudes kätehügieenile, isikukaitsevahenditele, isolatsioonimeetmetele ja standardsetele ettevaatusabinõudele Eestis, Soomes, Portugalis, Hispaanias ja Türgis asuvates tervishoiukõrgkoolides.

Igas riigis hindas materjale kümme eksperti (Soomes kuus), kasutades õpiobjektide hindamisvahendit LORI. Meie uuringus olid Cronbachi alfa koefitsiendid vahemikus 0,736–0,932, viidates materjalide heale kuni suurepärasele usaldusväärsusele. LORI keskmiste koguskooride põhjal said isikukaitsevahenditega seotud materjalid kõrgeima keskmise hinde (3,983 ± 0,619), standardsete ettevaatusabinõude materjalid aga madalaima keskmise hinde (3,850 ± 0,550). Riikidevahelises võrdluses said Hispaaniast pärit materjalid nakkuste ennetamise meetmete osas kõrgeimad LORI koguskoorid, samas kui Portugali materjalid said madalaimad tulemused (v.a isolatsioonimeetmed).

Vaatlejatevahelise kokkuleppe koefitsiendid varieerusid järgmiselt: Hispaanias 0,516–0,805, Eestis 0,614–0,729, Türgis 0,511–0,711, Soomes 0,749–0,938 ja Portugalis 0,566–0,882. Kuna see on esimene uuring, mis hindab nakkuste ennetamise e-õppematerjalide kvaliteeti ja usaldusväärsust LORI abil, pakuvad tulemused väärtuslikku teaduslikku ülevaadet ning loovad aluse edasistele uurimistöödele e-õppe arendamiseks õendushariduses.