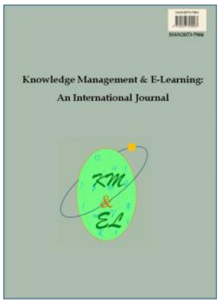
Effectiveness and key success factors of massive open online courses (MOOCs) for smart city workforce development

Theodor Panagiotakopoulos
University of Patras, Patras, Greece
University of Nicosia, Nicosia, Cyprus
Fotis Lazarinis
Hellenic Open University, Patras, Greece
Omiros Iatrellis
Paraskevi Tsoutsa
Panagiotis Fitsilis
University of Thessaly, Larissa, Greece
Achilles Kameas
Hellenic Open University, Patras, Greece



Knowledge Management & E-Learning: An International Journal (KM&EL)
ISSN 2073-7904

Recommended citation:
Panagiotakopoulos, T., Lazarinis, F., Iatrellis, O., Tsoutsa, P., Fitsilis, P., & Kameas, A. (2026). Effectiveness and key success factors of massive open online courses (MOOCs) for smart city workforce development. *Knowledge Management & E-Learning, 18*(2), 190–215. https://doi.org/10.34105/j.kmel.2026.18.009

Knowledge Management & E-Learning, 18(2), 190–215

Effectiveness and key success factors of massive open online courses (MOOCs) for smart city workforce development

Theodor Panagiotakopoulos

Department of Management Science and Technology
University of Patras, Patras, Greece
Business School
University of Nicosia, Nicosia, Cyprus
E-mail: tpanagiotakop@upatras.gr

Fotis Lazarinis*

School of Science and Technology
Hellenic Open University, Patras, Greece
E-mail: fotis.lazarinis@ac.eap.gr

Omiros Iatrellis

Department of Digital Systems
University of Thessaly, Larissa, Greece
E-mail: iatrellis@hotmail.com

Paraskevi Tsoutsa

Department of Accounting and Finance
University of Thessaly, Larissa, Greece
E-mail: ptsoutsa@uth.gr

Panagiotis Fitsilis

Department of Business Administration
University of Thessaly, Larissa, Greece
E-mail: fitsilis@uth.gr

Achilles Kameas

School of Science and Technology
Hellenic Open University, Patras, Greece
E-mail: kameas@eap.gr

*Corresponding author

Abstract: While the role of human capital is central in realizing smart cities, a skilled workforce is significantly lagging behind demand, hindering the incorporation of technological advancements in urban management. To curb this gap, upskilling and training will be a critical investment in future cities. While various educational means and types are suggested in the literature, the actual training offered remains inadequate. This paper assessed the use of massive open online courses (MOOCs) as a continuing training approach for the smart city workforce by examining the learners' perceived relevance, quality and usefulness and acquisition of knowledge and skills. Results showed that MOOCs can be an effective approach for continuing professional development of the smart city workforce, as the vast majority of the participants considered the MOOC engaging, offering them useful and relevant skills, while reporting a significant improvement in their skills. A competency-based structure, multidisciplinary training modules, multiple smart city stakeholder engagement, certification, and updated content of good quality have been identified as key factors for developing effective MOOCs for this professional sector. Our findings contribute to understanding how continuing education programs for smart city workers should be designed and developed, offering critical guidance to various stakeholders, such as educational providers, municipal authorities and current and prospective smart city professionals.

Keywords: Smart cities; Workforce development; Massive open online courses (MOOCs); Professional development; Lifelong learning; Education

Biographical notes: Theodor Panagiotakopoulos is an Assistant Professor in the Department of Management Science and Technology at the University of Patras, Greece. His research interests include pervasive systems, cloud platforms, machine learning and Internet of Things systems, technologies, and applications, with a focus on smart cities, energy and healthcare. Additionally, his research activities target continuous professional training in key emerging digital technologies through e-learning frameworks.

Fotis Lazarinis holds a Ph.D. in educational technology. He works as an adjunct lecturer and senior researcher at the Hellenic Open University. He participates in various research and development projects with a focus on educational technology. He has co-authored more than 50 papers in international journals and conferences.

Omiros Iatrellis is an Assistant Professor in the Department of Digital Systems, University of Thessaly, Greece. His research interests include modeling of educational and business processes, personalized learning, learning analytics, machine learning, semantic web technologies.

Paraskevi Tsoutsa is an Assistant Professor in the Department of Accounting and Finance, University of Thessaly, Greece. Her research interests include Internet Services, Accounting Information Systems, the Semantic Web, and Smart Cities.

Panagiotis Fitsilis is a full Professor at Business Administration Department of the University of Thessaly, Greece, and academic coordinator of the module "*Software Design*" at Hellenic Open University. He has extensive project management experience with the development and deployment of large IT systems and extensive management experience in various senior management positions. His research interests include Smart Cities, Smart Factories, Business Information Systems, Social, Educational Technology and Software Project Management.

Achilles Kameas is a Professor and Dean of the School of Science and Technology, Hellenic Open University, Patras, Greece. He is the director of the postgraduate study program Mobile and Pervasive Systems and his research interests include Pervasive computing, Internet of Things, Ambient Intelligence, competence frameworks, e-learning, MOOCs and STE(A)M education.

1. Introduction

Smart cities comprise a flourishing, fast-evolving and vibrant sector that has drawn significant attention amongst governments, businesses and academia worldwide, in the quest to find sustainable responses to current and looming internal and external urban challenges. Although smart city concepts and tools are implemented in different ways by different cities (Yigitcanlar et al., 2022), the concept is intertwined with tackling meta-issues of climate change, urbanization, citizen engagement and resource efficiency (Antwi-Afari et al., 2021; Buck & While, 2017). While the effects of urbanization unfold gradually, often with subtle social ramifications, the very worrying climate change implications have exacerbated the need for sustainable management of urban infrastructures and resources, paving the ground for the rapid growth of smart city technologies. Smart technologies are radically altering urban planning and governance models with the primary goals of environmental sustainability, economic growth and improved quality of life (Abu-Rayash & Dincer, 2021; Jebaraj et al., 2023).

Nevertheless, while Information and Communication Technologies (ICTs) are increasingly considered to offer unparalleled solutions to contemporary urban management challenges (Kontokosta, 2021), moving away from a techno-centric discourse to an interpretation of smart cities that emphasizes the human and social capital is essential to translate smart city aspirations into effective, tangible interventions (Neirotti et al., 2014; Tan & Taeihagh, 2020). In fact, Hollands (2020) recognizes the central role of human capital, where people's skills and knowledge comprise the driving force of smart city developments. Indeed, in the 21st century, growth, collaboration, creativity and urban innovation of cities will increasingly be obtained from skilled and knowledgeable people (Fredericks, 2020).

Thus, besides putting technologies into effect, a fruitful balance between urban innovation pace and society's ability to capitalize on it can only thrive when people who will staff key positions to plan, develop and manage smart city projects possess the right skills. However, the digital transformation of cities and the diffusion of technologies to all aspects of our personal and professional lives have disrupted the skills that workers should possess to remain competitive. As a result, a scarcity of qualified personnel is currently experienced in the majority of smart city domains (Ahad et al., 2020; Khan et al, 2020). For instance, the skills of smart city managers and planners in Poland (Baran et al., 2022), in the North-American region (Sanchez-Ortiz et al., 2020) and in India (Rana et al., 2019) were found to be insufficient, hindering local smart city developments. In this context, education is considered vitally important for the adoption of emerging technologies in the public sector (Myeong et al., 2020; Ubaldi et al., 2019), constituting a 'focal point in a city's journey to becoming a smart city' (Zhuhadar et al., 2017).

Technological evolution and business competition are constantly changing labor market demands requiring frequent skill renewal (Iatrellis et al., 2021), while a large percentage of future cities' workforce consists of people who have already completed their basic studies and acquired their degrees and diplomas (David & McNutt, 2019). Therefore, it is crucial to maintain a focus on lifelong learning and enactment of professional development strategies to keep the educational offer aligned with skill demands of smart cities. Towards this direction, various professional development approaches have been explored by the public sector, including work-based learning (Markow et al., 2019), distance education (Kumar et al., 2020) and e-learning (Adiego & Martín-Cruz, 2021; Garg et al., 2017) with a particular emphasis on Massive Open Online Courses (MOOCs) (Panagiotakopoulos et al., 2025; Sanchez-Ortiz et al., 2020; Tryfonas & Crick, 2015).

However, while the need along with specific means and types of education are highlighted by many researchers, actual professional development programs are fairly scarce and current initiatives to develop internal talents in the public sector are largely inadequate (OECD, 2020). In addition, most of these educational efforts are sectoral (e.g., addressing smart energy), or subject-based (e.g., engineering) (Flores et al., 2020), failing to develop the multidisciplinary skills that emerging smart city job roles require (Michelucci et al., 2016). In response to these challenges, this study examines the use of a MOOC to address the smart city employees' skill readiness challenge, named the Smart DevOps MOOC.

Lifelong e-learning solutions are considered suitable for up- and re-skilling of adults, especially in aspects related to employability (Friedman, 2023). MOOCs could be an effective learning tool as they are open and offer more equitable learning opportunities without prohibitive constraints for learners with lower skills and qualifications (Patino & Naffi, 2023), as is the case with smart city workers (Curşeu et al., 2021). Moreover, based on their design, MOOCs can support personalized learning paces, host a large number of learners with diverse backgrounds, and have the potential to upskill in-service personnel (Hsu, 2021). Their usage for professional development is rising as it is observed that they can improve job retention (Castaño-Muñoz & Rodrigues, 2021). Whilst, however, MOOCs have been employed for upskilling of workers in a range of professional sectors, limited evidence exists for their role and specific design guidelines in the case of smart cities employees.

Building upon the previously mentioned research works, this paper aims to assess the role of a competence-based MOOC within continuing training approaches, in creating the required skill set of the smart city workforce. To this end, it further develops a method for evaluating learners' perceptions of MOOCs' effectiveness, utilizing various types of quantitative and qualitative data and applies it to the Smart DevOps MOOC. Moreover, it explores the key design principles that should be taken into consideration when developing similar online courses. Specifically, our study seeks to answer two research questions.

RQ1: Can MOOCs help a smart city workforce effectively acquire relevant and useful knowledge and skills?

RQ2: Which are the key factors for developing effective MOOCs for a smart city workforce?

2. Method

2.1. Research model and procedure

This study employed an explanatory mixed-methods research model using both quantitative and qualitative data. Recent studies indicate that mixed methods provide a comprehensive understanding of learning by exploring learners' perceptions and preferences (Ouyang et al., 2020), provide more reliable research findings and allow the acquisition of a more holistic view of the observed topic (de Moura et al., 2021).

An online survey was administered to the Smart DevOps MOOC learners at the end of the course, while a mini questionnaire was provided to learners after the completion of each training module. The survey and the mini questionnaires were anonymous and included a notification that all data would be acquired and used according to the General Data Protection Regulation Data protection (EU) 2016/679 and the Regulation (EU) No. 2018/1725 to evaluate the quality of the Smart DevOps MOOC. Participants were asked to consent to the analysis of data; otherwise, they could not proceed with filling them. Additional quantitative data (e.g., completion of assessment tests, submissions of assignments, etc.) were extracted from the MOOC throughout its delivery to support the investigation of the research questions.

2.2. Research context

Our study was conducted in the context of the Smart DevOps MOOC, an online course that was delivered from mid-October 2020 to mid-January 2021 using a Moodle-based platform. The Smart DevOps MOOC followed a modular, competence-based structure, where each skill/competence formed a training module (following the approach of the classification of European Skills, Competencies, Qualifications and Occupations (ESCO) we consider the terms skills and competencies to be used interchangeably). It consisted of 15 competencies/training modules, each lasting 11 weeks (refer to Appendix I for the schedule). These competencies are part of a group of 42 competencies classified in four categories (transversal, digital, DevOps, smart city-specific), which were ranked as the most important emerging smart city competencies. (Fitsilis & Kokkinaki, 2021; Panagiotakopoulos et al., 2022).

Each week contained 1 to 2 modules requiring 8-10 hours of study in total. The required study effort of the first three weeks was held in half to allow learners to familiarize themselves with the e-learning platform and establish their learning pace. The seventh and eleventh weeks of the course were used for reflection in order to assist learners in completing modules they may have missed. Every module required 4-6 hours of study and consisted of 2 to 5 learning units. Each learning unit included a combination of core learning objects (e.g. presentations), additional learning material (e.g., videos), collaboration objects (i.e., forums) and assessment objects (i.e., multiple-choice question tests). One assessment test was foreseen per learning unit. A practical assignment was also foreseen for each training module to help learners assimilate theoretical concepts through real-world problems and examples.

The Smart DevOps MOOC focused on a learner-centered approach, where learning objects and practical assignments were developed based on distinct learning outcomes that the learners should achieve. Assessment objects explored whether learners achieved these learning outcomes. To successfully complete it, a minimum average assessment test score of 60% or more was required. Forum participation was not graded, although it was strongly encouraged. Likewise, practical assignments did not contribute to the final grade but were qualitatively evaluated by course tutors. One online session was realized for each training module, usually on Mondays, where a tutor provided learners with an overview of the learning objectives and content to support their weekly study efforts.

A group of four European universities, two city associations, a VET provider, a standardization organization, and an IT company in the field of smart cities collaborated in the course design. Non-educational partners led the practical assignments' design, while educational partners led the design of learning and assessment content. The involvement of academics, educators, and practitioners enabled the collaboration of various smart city stakeholders through a transdisciplinary process.

A total number of 961 people enrolled in the course from 34 countries worldwide, albeit the vast majority were from Europe ($N = 895$). Interesting insights into the correlation between demographic information provided during registration and starting the MOOC or not can be found in Panagiotakopoulos et al. (2021a). The registrations that were accepted were for people considered as part of the smart city professionals target group of the Smart DevOps MOOC, which includes civil servants, employees of companies (e.g. IT, construction, etc.) involved in smart city projects, individuals working as subcontractors for smart city municipalities (e.g. engineers, software developers, etc.) and people able to work in the aforementioned positions based on their academic and professional degrees.

Out of the 961 registrants, 428 (approximately 44%) logged into the course and completed at least one assessment test; these were considered active learners. Approximately 48% of those 434 possessed an MSc, 29% had a BSc/BA, and 21.88% were high school graduates. The rest, approximately 1%, were either PhD holders or high school graduates with a professional degree. 64.5% were male, and 34.5% were female. 38.25% were students or unemployed.

2.3. Data collection

Data were collected from two main sources: a) an online survey delivered via the e-learning platform at the end of the MOOC (see Appendix II), and b) the e-learning platform. The first research question of this study concerns the assessment of the effectiveness of the Smart DevOps MOOC addressed to smart city professionals, with a special emphasis on its learning impact in terms of acquired skills. To this end, the following dimensions were considered: i. perceived relevance and quality of the MOOC, ii. perceived usefulness of the MOOC, and iii. learning acquisition of the participants (Chen et al., 2025; Daneji et al., 2019). We adapted these factors and their metrics from Pérez-Foguet et al. (2018) methodology.

Assessing the perceived relevance and quality of the Smart DevOps MOOC includes two sets of indicators: a) registrations to the course and completion rate, and b) replies to an online survey addressed to learners. The items of perceived relevance and quality were adapted from de Moura et al. (2021) and Ucha (2023). The perceived usefulness was assessed through a) engagement in practical assignments and b) replies to the online survey addressed to learners. The items of perceived usefulness were adapted from (Yang & Lee, 2021) and (Tselios et al., 2011). To explicitly rate the learning acquisition with respect to the specific competencies covered in the course, we further asked the participants to rate their competence level for the competencies supported by the MOOC after course completion. Competence level prior to the MOOC was self-evaluated after the first login into the MOOC.

The second research question was examined by asking participants to select factors that contributed to completing the course among ten options. These factors aimed to augment those previously examined by including various course-specific parameters such as online sessions, workload, learner interactions, recognition, and others. Moreover, qualitative data were collected from two open-ended questions at the end of the online survey. Additionally, a mini questionnaire was provided to learners after the completion of each module consisting of two open-ended questions asking them what they liked the least and most in every module. Our goal was to capture small pieces of feedback in order to synthesize them and draw generalized insights on the MOOC's strengths and weaknesses, complementing data obtained through the online survey. An average of 83.5 responses were given to each question.

The online survey was structured in four sections (see Appendix II for the full set of questions). The first section included questions concerning perceived relevance and quality of the MOOC, while the second section contained questions to measure its perceived usefulness. The third section covered self-evaluation of the competence level of the participants with respect to the competencies covered by the course. It has to be noted that after their first login, all learners were requested to self-evaluate their level in the same competences before starting the MOOC. The fourth section mainly focused on collecting information for RQ2 and included a question focusing on the course retention factors and the two open-ended questions, which asked participants to provide feedback for what they enjoyed the most (128 responses) and what they liked the least (122 responses) in the MOOC.

The survey was developed and validated following the procedures suggested by the literature for validating questionnaires in various domains (D'Amour et al., 2008; Fernandez-Rio et al., 2018). A preliminary version was written by the primary author based on the purposes of the evaluation and the experiences gained from the literature review. This survey was then validated by the remaining authors, who ensured that the questions were easy to understand regardless of the background of the participants and that there were no other irregularities. Then the survey was reviewed by the panel of the 5 educational experts who supported us in defining the evaluation methodology. The second version was piloted with the aid of 5 randomly selected trainees who had to report any problems or inconsistencies. Participants were asked to rate the survey items using a 5-point Likert scale, where each point of the scale stands for a specific level of agreement with the statements ranging from "*strongly disagree*" to "*strongly agree*". The Likert scale's points of questions measuring the learning acquisition ranged from Beginner to Expert.

2.4. Respondents

The survey was answered by 250 people, whose demographic data are shown in Table 1. A considerable number of participants were women (77.31%), with the rest being men. Concerning education, almost half of the sample had an advanced educational background, either holding a Master's or a Doctorate degree. A third of the sample owned a Bachelor's degree, while about 20% of the sample were high school graduates. It is worth noting that 32 out of 47 high school graduates (68%) were students pursuing management studies, mainly in public administration, comprising prospective municipal/regional employees.

Looking at the employment status, the data show a balanced distribution between employees in the private and public sectors, with the latter being mainly employed in municipalities and regions. A noticeable percentage of the sample were unemployed, while slightly lower numbers were observed among the self-employed (with business activities in either the private or public sector) and students. In terms of age, almost 70% of the participants were between 18 and 39 years old, with 23.2% of the sample between 40 and

49 years old and very few above 50. This rather young sample is reflected in the professional experience, where 60% of the sample were non- or less experienced (5 or fewer years of experience). Almost 15% had 6-10 years of experience, 11.2% 11-15 years of experience, and only 14% ($N = 35$) had more than 16 years of experience, which aligns with the sizes of the age groups of the sample.

Table 1
Demographics of survey participants

Category	Value	Occurrences	Percentage (%)
Education	High school	47	18.8
	Professional degree	7	2.8
	Bachelor's degree	73	29.2
	Master's degree	112	44.8
	Doctorate degree	11	3.18
Employment status	Public sector employees	77	30.8
	Private sector employees	69	27.6
	Employers	9	3.6
	Self-employed without employees	31	12.4
	Unemployed/job seekers	38	15.2
	Students, in training	26	10.4
Age	18-29	100	40
	30-39	73	29.2
	40-49	58	23.2
	50-59	16	6.4
	> 60	3	1.2
Sex	Male	173	69
	Female	77	31
Years of experience	≤ 5	150	60
	6-10	37	14.8
	11-15	28	11.2
	> 16	36	14

2.5. Data analysis

Information obtained from the surveys underwent pre-processing, coding, and entry into a CSV file. The SPSS statistical analysis software was utilized for the analysis. We initially assessed the quality of the survey instrument by computing its reliability and validity. We first examined the factor loadings of the construct variables to determine the degree of correlation between each item of the questionnaire (or variable) and the associated factor (or construct). Furthermore, the questionnaires' and individual constructs' reliability was assessed using the Cronbach alpha, as well as the Composite Reliabilities (CRs). The latter assesses the internal consistency of a group of questionnaire items, which together measure a specific construct. Finally, the Average Variance Extracted (AVE) was calculated to assess the convergent validity of the questionnaire.

Various techniques of statistical analysis have been employed for the purpose of descriptive statistical analysis and for making statistical inferences through hypothesis testing. More precisely, boxplots and bar charts have been employed for both nominal and ordinal values. We used the non-parametric Wilcoxon Signed-Rank test to compare the means of two related samples with no normal data distributions, and the *t*-test to compare the means of two separate samples.

Participant responses to all open-ended questions were coded to identify key themes. The first author performed an initial definition of coding categories and coded responses for each item in these categories. After a detailed discussion about the coding categories, the second author coded 15% of responses for each open-ended item. Inter-rater reliability between coders amounted to over 88% for each item. Unresolved cases were settled through a concluding discussion between the two coders.

3. Results

3.1. Assessment of measurement model

With regard to factor loadings (see Appendix III), most items had values higher than 0.70. Some items produced lower values, but greater than 0.50 and can be considered acceptable (Chin, 1998), while the majority of them tend towards 0.7.

The results of the reliability assessment of the constructs through Cronbach's alpha, CR and AVE are shown in Table 2. Cronbach's alpha values for the whole questionnaire, as well as for all of its constructs, are greater than 0.70, indicating high internal consistency (Hair Jr et al., 2017). The total survey exhibits a Cronbach's alpha of 0.91. Likewise, all constructs produced satisfactory CR values above 0.70. The AVE values of all constructs were greater than 0.5, showing convergent validity (Hair et al., 2019), apart from perceived usefulness (0.46). Overall, the internal reliability and convergent validity assessment of the survey instrument demonstrated satisfactory results.

Table 2
Reliability and convergent validity of the questionnaire

Construct	Cronbach's alpha	CR	AVE
Perceived relevance and quality (PRQ)	0.86	0.88	0.55
Perceived usability (PU)	0.82	0.83	0.46
Competence level (CL) – before MOOC	0.94	0.94	0.51
Competence level (CL) – after MOOC	0.95	0.95	0.57

3.2. Perceived relevance and quality of the training

252 learners successfully completed the course. Calculating the completion figures based on the registration results in a 26.22% completion rate. However, active learners have been suggested to act as the basis of the calculations for dropout rates (Ho et al., 2015; Huin et al., 2016; Lazarinis et al., 2019, 2022; Panagiotakopoulos et al., 2021b). If we base the calculations on the 428 learners who actually engaged in the course, the completion rate climbs to 58.87%.

Looking at the second set of indicators, as shown in Fig. 1, the average rating for most items highlights the high level of quality of the course. Participants found the course's structure ($M = 4.09$) and level of difficulty ($M = 4.06$) to be very satisfactory. They strongly agreed that the content was contemporary and up-to-date (M = 4. 20), aligned with the course's learning outcomes ($M = 4.06$). The majority of the participants also agreed that the course was relevant to smart cities ($M = 3.60$). The lower mean rating in the responses of this question can be attributed to the structure of the course, which included several educational modules representing transversal skills and only a few modules that focused purely on skills related to smart cities. The former modules were specialized to the smart cities' context in only about 20-30% of their overall content. Additionally, 70% of the participants agreed or strongly agreed that the course was engaging ($M = 3.87$).

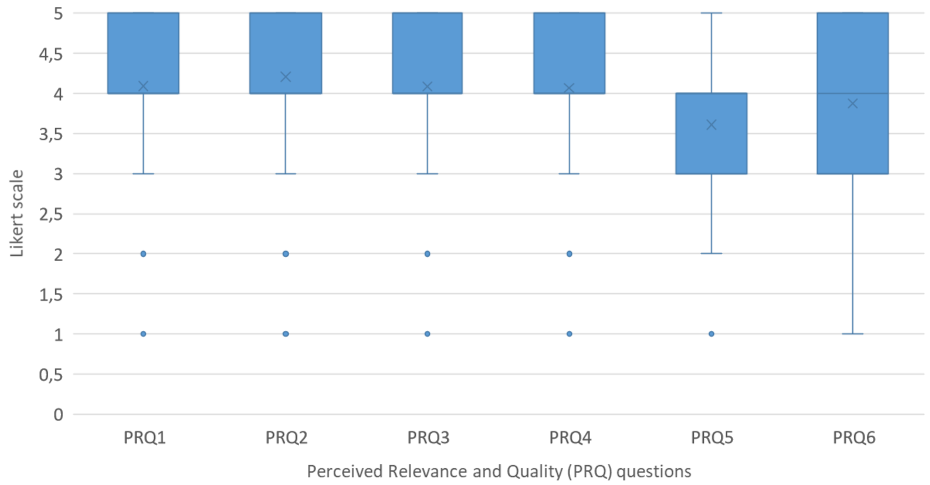


Fig. 1. Responses to questions of perceived relevance and quality

Aiming to identify statistically significant effects of the demographic data on the perceived relevance and quality, we used the *t*-test and the results are shown in Table 3. It is obvious that there are no statistically significant differences ($p > 0.05$) between different groups of participants in terms of sex, education, age, and working experience. It should be noted that we implemented several additional tests with different demographic groups, such as between participants with a bachelor's degree and those with more advanced studies, and the results did not reveal any statistically significant differences.

Table 3
Effect of demographics on perceived relevance and quality

Category	Type	Mean	SD	*t*	*p*
Sex	Male	3.99	0.66	0.36	0.713
	Female	3.96	0.67		
Education	Higher education	3.93	0.83	−0.62	0.531
	Basic education	4.00	0.61		
Age	< 40	3.93	0.70	−1.79	0.073
	≥ 40	4.1	0.56		
Work experience	< 10	3.94	0.67	−1.37	0.169
	≥ 10	4.07	0.64		

Note. *** $p < .001$; ** $p < .01$; * $p < .05$ (2-tailed)

3.3. Perceived usefulness

As shown in Fig. 2, the perceived usefulness of the course was also high. Specifically, the majority of participants stated that they could immediately apply the acquired skills in their jobs (*M* = 3.55), believed that the course would help them perform their work duties more quickly (*M* = 3.61), and felt that it would improve their effectiveness at work (*M* = 3.95). Moreover, they agreed that the course provided them with the necessary skills for their jobs (*M* = 3.60). As a result, participants were inclined to recommend the course to a colleague or friend (*M* = 4.14) and felt confident that they would revisit the course materials in the future (*M* = 4.28).

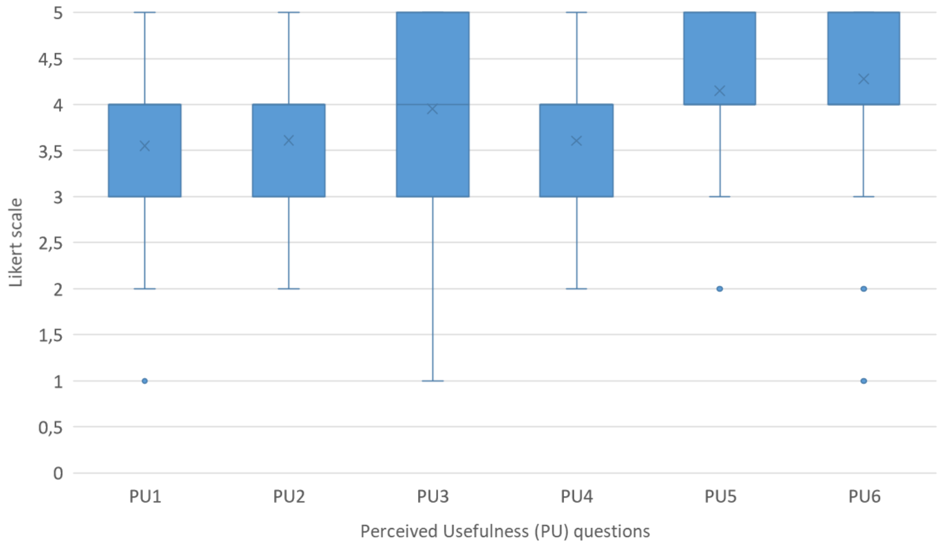


Fig. 2. Responses to questions associated with the perceived usefulness

As with the perceived quality and relevance, we examined the effect of different demographic groups of participants on the findings related to perceived usability. The results showed that there were no statistically significant differences between any of the groups we tested based on education, age, work experience, and sex.

Fig. 3 shows the percentage of learners (from those that successfully finished the MOOC) that carried out the practical assignments. 141 trainees out of 252 (55.95%) handed over all the practical assignments, with this number increasing as the number of practical assignments decreased.

3.4. Acquisition of knowledge and skills

The participants' acquisition of knowledge and skills is a critical component of the assessment methodology, as it represents the added value of our educational intervention. Fig. 4 depicts the participants' responses regarding their perceived competence levels before and after the course. A noticeable improvement can be observed in the level of all competencies taught in the Smart DevOps MOOC. Notably, the average competence level of learners before the MOOC was intermediate for 80% of the taught competencies, while after the MOOC, learners on average rated their level as advanced in all fifteen competencies. Descriptive statistics confirm this improvement, with the mean scores for all individual competencies, as well as the overall competence level, showing an increase after the MOOC.

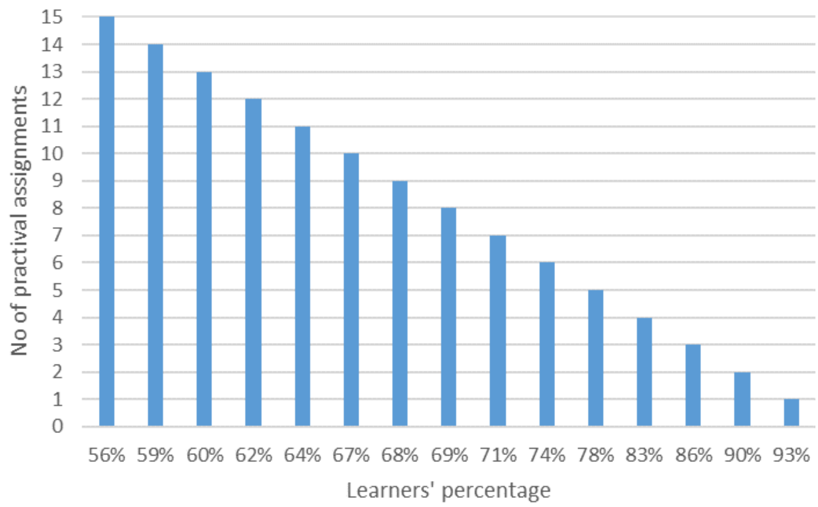


Fig. 3. Implementation of practical assignments

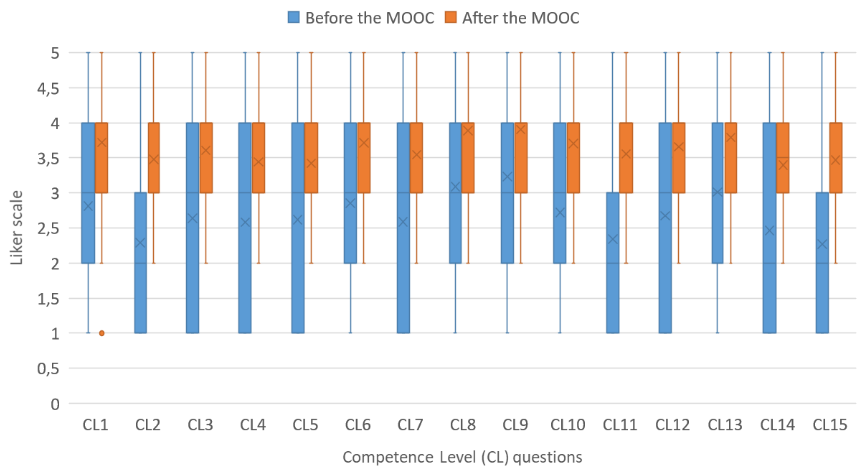


Fig. 4. Self-reported competence level before and after the MOOC

The next step was to use statistical inference to see if this improvement was statistically significant. To this end, since we had to compare paired variables (i.e. individual competencies and overall competence level before and after the MOOC), we initially ran the Kolmogorov-Smirnov test for each pair of variables to examine whether they followed a normal distribution or not. We found that the variables in all 16 pairs did not follow a normal distribution (Kolmogorov-Smirnov, $p < 0.001$) and, thus, we used the Wilcoxon test instead of the paired t-test. The results revealed a statistically significant improvement in all individual competencies (detailed in Appendix IV), as well as in the overall knowledge gained in the course ($p < 0.001$, see Table 4). The findings comprise a very promising outcome of our work, as the improvement of participants' competence level is the primary aim of the Smart DevOps MOOC.

Table 4
Overall competence level before and after the MOOC

Time of measurement	Mean	SD	Statistic	*p*
Before MOOC	2.67	0.27		
After MOOC	3.62	0.16		
Statistical test			$W = 832$	< .001***

Note. *** $p < .001$; ** $p < .01$; * $p < .05$ (2-tailed)

The potential relationship of learning acquisition with the perceived quality, relevance, and usefulness was examined through the Pearson correlation coefficients. They demonstrate a strong positive statistically significant ($p < 0.001$) correlation between the learning gain and the perceived quality and relevance ($r = 0.36$), as well as the perceived usefulness ($r = 0.39$). This means that learning gain is strongly affected by perceived quality, relevance, and usefulness and increases as these elements are perceived to a higher degree.

3.5. Retention factors and open-ended questions

According to the responses of the survey participants (see Fig. 5), the most important reasons that motivated them to complete the course were to learn something new and receive a certificate of successful completion. The course content and the fact that it covered contemporary topics were closely followed. Slightly lower was the relevance of the course to their professional demands, while at the bottom of the list was the support from instructors and collaboration with other learners. Most of the findings align with what was discussed earlier (such as the quality of the educational materials). However, this question highlighted an additional key factor for attending and completing this course: obtaining a certificate of successful completion. It is important to note that the fact that certain options did not receive a high number of preferences does not necessarily indicate that they were negative aspects of the course, but rather that they were not considered as important as the others.

The analysis of the qualitative data collected via the open-ended questions verified and elaborated the findings of the quantitative analysis while revealing specific improvement perspectives. The responses to the question asking learners to describe what they enjoyed most in the course highlighted several elements, with the most frequent being the new things they learned, the knowledge they gained, the course's structure and the blending of theory and practice, the alignment of learning objectives and content, and the content's quality (see Fig. 6). Specifically, for the educational content, the alternative types of material (i.e. videos, tutorials, presentations, and documents) and practical assignments facilitated a smooth and enjoyable learning experience. The majority of the learners found the learning content contemporary, providing them with new knowledge, which would enhance their career prospects (a fundamental objective of the Smart DevOps MOOC), even in cases where the participants claimed they were experts in the field:

> *"I am really glad that I decided to take part in it because now I've learned so many new things that will be helpful in my future jobs/career."*

"Being an expert in the Smart cities area, this course is an eye-opener in various concepts and theories, which helped me understand the complexity and the depth of the subjects. This is really helpful for establishing myself in my future career."

"I learned more about contemporary topics that hopefully will help boost my career opportunities."

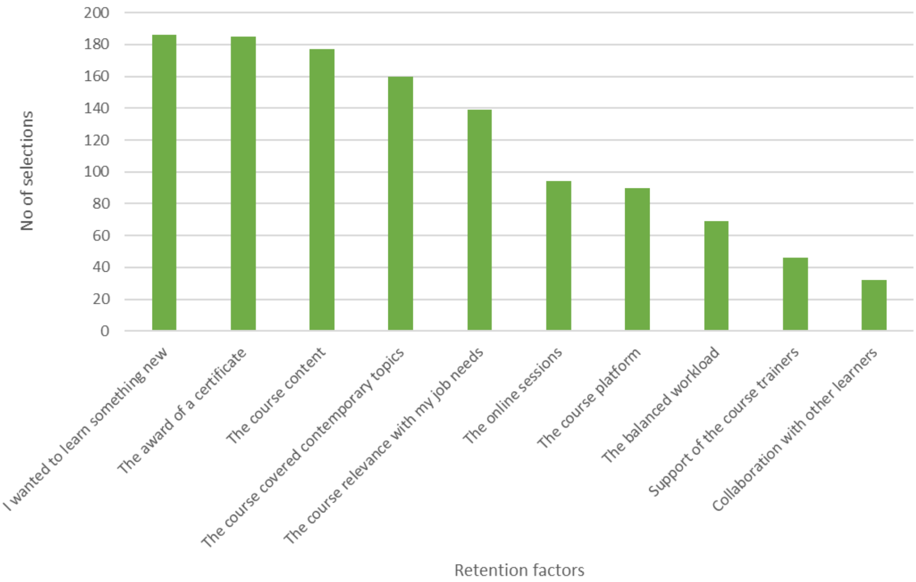


Fig. 5. Motivational factors for course completion

Fig. 6. Word cloud for things learners enjoyed the most

The respondents also praised the variety and multidisciplinary nature of the topics addressed, which covered different aspects of smart cities and the skill coverage for different occupational fields. Several learners stated that they enjoyed the topics of the course and that they found the subjects interesting and relevant to obtaining knowledge about smart cities.

“The variety of information that was provided to people who want to expand their knowledge and learn something new.”

Furthermore, several participants reported the relevance of the training modules to their everyday work, as well as the positive impact of the MOOC on their skill sets and level of understanding of important smart city concepts and technologies. A high number of responses stated that practical assignments were very beneficial for putting acquired knowledge into practice and stimulated learners to further elaborate on the provided content. Some participants also felt that they could somehow offer to the community through the knowledge gained from the MOOC.

The responses to the question asking learners to suggest improvements for the course were mainly centered around four topics: training content, interaction with peers, trainers’ support, and workload. In terms of training content, apart from suggestions for correcting language errors, some participants mentioned the need for deeper exploration of more technical issues, while others stated that they found them difficult to understand – something that is evidently due to differences in the educational background of the learners. In addition, many participants recommended adding more videos and real-world case studies, particularly with regard to technical content. Other comments included suggestions for reduced duration, minor fixes in assessment tests’ reply options, as well as platform layout improvements.

Regarding peer interaction, responses focused on the lack of participation in the forums and suggested the enforcement of collaborative work in practical assignments. Recommendations for group chats and external projects were also made to enhance tutor support and tutor-learner interaction. Several participants also mentioned the need for more online sessions and a richer variety of interaction tools with peers and tutors. Lastly, various participants deemed the workload high and the deadlines for submitting assessment tests and assignments short.

4. Discussion

The first research question of the research discussed in this paper sought to measure the effectiveness of a MOOC as a means of continuing training for a smart city workforce. According to the evaluation results, the majority of the learners enjoyed their participation in the Smart DevOps MOOC, which successfully supported skills and knowledge acquisition in the field of smart cities. Most of the learners agreed with the survey statements concerning the perceived relevance and quality of the course, reporting that the content was well-structured, up-to-date, clear, and aligned with the learning outcomes while being engaging and relevant to smart cities. This is also reflected in its completion rate, which, either calculating it based on registrations or on active learners, is significantly higher than the average MOOC completion rates being below 10%. Even with the provision of a certificate, the completion rates in MOOCs have been reported to be below 14% (Gil-Jaurena et al., 2017). A factor that also increased the propensity to complete the MOOC was the award of a certificate.

With regard to the perceived usefulness, the majority of the participants reported high levels of agreement with the respective survey statements. Considering that our approach in developing training modules was centered around smart city competencies, and thus directly linked to the relevant labor market demands, this outcome is consistent with other studies reporting job relevance as a significant factor for a MOOC’s perceived usefulness (Xu, 2015). The high completion rates achieved by the Smart DevOps MOOC may also be linked to this, as course relevance to jobs is a professional motive that affects learners' MOOC retention (Badali et al., 2022). Apart from its positive impact on perceived usefulness and dropout rates, the modular competence-based structure of the MOOC enables the curriculum to be easily adapted to meet emerging professional needs at different levels. Combined with the segmentation that the learning outcome-based approach brings in educational content, they render the Smart DevOps MOOC a highly flexible training program, a key feature in enhancing its transferability capacity in different urban contexts.

In terms of the knowledge gain, we observed a significant increase in the perceived expertise of the participants as a result of their participation in the course. We found that the learning acquisition was positively and strongly related to the reported levels of quality, relevance and usefulness. This aligns with studies that revealed a significant relationship between usefulness and depth of learning (Lu et al., 2017). It can also be attributed to the quality of the educational content, the course structuring, and the applied methodologies (e.g. student-centered learning and project-based learning through practical assignments), which created an impactful learning experience for the learners, fostering knowledge acquisition. The observed increase in knowledge gain also supports recent research works that recognize the positive impact of e-learning approaches on learning outcomes (Ayu, 2020; Logan et al., 2021). Simultaneously, it can be derived that the collaboration of different smart cities' stakeholders such as academics, municipal employees and officials, IT companies' representatives, and vocational training providers, has the potential to develop an enhanced training program and learning content reflecting the complex dynamics of smart city ecosystems.

The effect of multi-stakeholder collaboration is also reflected in the high level of engagement with the practical assignments, despite their non-participation in the criteria for successful completion of the MOOC and the additional study effort they required on top of an already demanding schedule. This can be associated with the high level of perceived quality, usefulness, and relevance (Pérez-Foguet et al., 2018), as previously highlighted by the other indicators as well. The above findings are in line with recent research studies that reveal the positive impact of practical activities on knowledge gain (Gallego-Romero et al., 2020; Panagiotakopoulos et al., 2024) and a strong correlation between engagement and retention (Paton et al., 2018). This finding was also supported by the qualitative data analysis, where practical assignments were considered as a key factor for assimilating smart city concepts, engaging with the course, and eventually increasing learning acquisition.

As more and more smart cities are emerging, the need for new types of professionals who possess a multidisciplinary skill set, viewing the smart city as a system of systems and acting horizontally across the vertical boundaries of smart city domains, is rising (David & McNutt, 2019; Sanchez-Ortiz et al., 2020). This tendency, however, sits uneasily with the current training offer that mostly focuses on specific smart city domains, disciplines, or technological fields. Thus, multidisciplinary was a primary characteristic of the Smart DevOps MOOC and its most frequently cited positive aspect in the open-ended questions, where many participants expressed their enthusiasm and contentment for the competence transversality. Course structure, diversity of learning material (especially videos), and learning outcomes supported by educational material were also reported as things learners found important and enjoyable. The learning outcome-based content development was also praised by non-educational content developers.

Regarding the issues on which learners expressed their criticisms, lack of practical examples or case studies, and additional learning material in the form of videos, articles, etc., to link the described concepts with smart cities was the most common complaint, especially wherever such material was missing. What is interesting, however, is that these comments mainly stem from learners with higher qualifications (e.g. MSc and PhD holders) and mostly from studies providing technological knowledge. On the contrary, people with lower qualifications and a lack of technical background mostly complained about technical subjects not being thoroughly analyzed or concepts not being extensively described. What can be inferred is that, due to the specific study time assigned to each training module, we need to strike a balance between theory and case studies/practical examples based on the learners' characteristics. Therefore, an important factor for effective MOOCs in smart cities concerns content adaptation (e.g. through learning outcomes) to meet different learner needs and goals.

The required workload was considered an important obstacle for adequately fulfilling learning requirements by several participants. However, this was due to the MOOC's tight schedule for meeting predefined deadlines, and implementing fully self-paced learning, as is usually the case in MOOCs, would alleviate this difficulty. Inadequate communication was also reported, which could be greatly enhanced either through more online sessions or by promoting forum participation and employing additional social tools. This finding confirms other studies reporting that social support and interaction improve learner engagement and commitment (Sun et al., 2020) and dropout rates (Aldowah et al., 2020). A team-based approach in learning activities was also highlighted by a considerably high number of participants, who reported that collaboration with peers in practical assignments would be much wanted. The above would potentially further improve learners perceived learning gains in the learning environments of the Smart DevOps MOOC (Zhou et al., 2021).

The findings of this study have direct implications for instructional designers and course administrators. The high satisfaction and completion rates of the DevOps MOOC highlight the importance of delivering structured, relevant, and engaging content aligned with clearly defined learning outcomes. Practitioners should emphasize job-relevant material and regularly update course content to reflect evolving sector needs, especially in fast-changing domains like smart cities. The competence-based modular design of the MOOC enabled flexibility and scalability, making it easier to adapt the course to various urban contexts and learner backgrounds. This suggests that adopting a modular and outcomes-based curriculum can significantly improve transferability and learner retention. In terms of pedagogical strategy, incorporating project-based and student-centered learning methods – including practical assignments – proved crucial for deep knowledge acquisition and engagement. Finally, challenges related to workload, communication, and interaction underline the importance of incorporating self-paced options, increasing live sessions, and promoting peer-to-peer learning through forums or collaborative tasks. These improvements could foster greater inclusion, reduce dropout rates, and support diverse learning preferences.

Our work demonstrated that targeted, job-relevant e-learning programs can achieve high completion and satisfaction rates when aligned with labor market needs. The modular design supports adaptability, which is particularly valuable for fostering a multidisciplinary workforce capable of operating across traditional domain silos. Corporate stakeholders should also recognize the strategic value of certification in motivating learners. Moreover, the findings underscore the importance of practical, hands-on training experiences.

Investment in MOOCs that include project-based tasks or team activities could lead to deeper learning and better knowledge retention. Supporting MOOCs with interactive elements such as group work, forums, or mentoring can enhance commitment, foster collaboration, and reduce dropout. This is critical for organizations investing in long-term capability building.

Our study has some limitations. The sample is self-reflecting, resulting in the possibility that it consists of learners with high levels of commitment and strong learning motivation, which could partially explain the increased number of completions. The evaluation methodology could be enriched with semi-structured interviews to allow us to extract richer insights about the effectiveness and impact of the course. In addition, the evaluation sample consisted in its majority of Greeks (65%), and therefore it is likely to represent views arising mostly from developing smart cities. Finally, responses to the open-ended questions ranged at 20% of the sample in both summative and formative questionnaires, representing a small fraction of learners.

5. Conclusion

This study aimed at examining the effectiveness of MOOCs for professional development in the smart cities sector and identifying significant course design principles of MOOCs for professional development, offering a comprehensive method for evaluating learners' perceptions on MOOCs' effectiveness. Evaluation data of all indicators highlight the effectiveness of the developed MOOC for upskilling the workforce of future cities, illustrating very positive results in terms of perceived quality and relevance, usefulness, and learning acquisition. Concrete conclusions regarding key success factors drawn from our study are summarized as follows.

- The shift from topic-driven approaches to competence-based training programs aligns the training offer with labor market demands and has a significant effect on perceived usefulness and completion rates.
- Collaboration among different smart city stakeholders positively affects the quality of learning content and perceived usefulness, both of which have a strong positive effect on learning acquisition.
- Practical activities create efficient links of theoretical and practical smart cities' knowledge that foster learning acquisition.
- Training programs for smart city professionals should be multidisciplinary in order to address horizontal, cross-sectoral requirements for governance and management of smart city initiatives.
- Learning gain is strongly and positively affected by perceived quality, relevance, and usefulness
- Certification, along with the acquisition of relevant and up-to-date knowledge, are the primary factors driving retention in online courses
- Social interaction and collaboration with peers are important factors for an enhanced learning experience.
- Smart cities are a global trend and respective educational programs should have a strong transferability potential. Competence- and learning-outcome-based designs provide two degrees of flexibility on an inter- and intra-learning module

level respectively, boosting the applicability of a continuing training program in diverse urban contexts.

Our work provides evidence that a MOOC has the power and potential to be a useful tool for building a knowledgeable and skilful workforce for smart cities, when appropriate design principles are considered, and should be further explored and exploited. Some of these factors are specific to the smart cities sector, such as the level of required flexibility, multi-disciplinarily and multi stakeholder engagement. Other factors are more generic as social support and interaction, modularity and job relevance (both facilitated by the competence-based approach), and practical activities have also been reported in several other studies. These findings contribute to drawing a generalized framework of horizontal principles that MOOCs focusing on professional development should have to achieve improved learning outcomes. Moreover, collected data confirm other studies reporting that there is not a one-size-fits-all MOOC and specific learner characteristics, such as educational background should always be considered during course design.

Our findings contribute to understanding how continuing education programs for smart cities should be designed and developed and which factors are of significance for effective and impactful implementations. By doing so, critical guidance is offered to various stakeholders. People seeking smart city careers will gain valuable insights for assessing and selecting appropriate training opportunities, while educational providers can set an evidence-based framework for creating and delivering new online courses to address emerging smart cities skills needs. Finally, municipal authorities and businesses will gain an understanding on how to offer tailored training programs to their employees, in order to increase their operational capacity and competitiveness.

Author Statement

The authors declare that there is no conflict of interest.

Acknowledgements

This work was supported by the Erasmus+ KA2 under the project DevOps (Project No.: 601015-EPP-1-2018-1-EL-EPPKA2-SSA).

ORCID

Theodor Panagiotakopoulos https://orcid.org/0000-0003-4044-6018

Fotis Lazarinis https://orcid.org/0000-0002-4653-7212

Omiros Iatrellis https://orcid.org/0000-0003-1224-4144

Paraskevi Tsoutsa https://orcid.org/0000-0003-0019-1145

Panagiotis Fitsilis https://orcid.org/0000-0002-7729-2457

Achilles Kameas https://orcid.org/0000-0002-1004-7860

References

Abu-Rayash, A., & Dincer, I. (2021). Development of integrated sustainability performance indicators for better management of smart cities. *Sustainable Cities and Society, 67*: 102704. https://doi.org/10.1016/j.scs.2020.102704

Adiego, J., & Martín-Cruz, N. (2021). Training competences in smart cities: An online program for higher education students. *International Journal of Sustainability in Higher Education, 22*(7), 1630–1645. https://doi.org/10.1108/IJSHE-08-2020-0307

Ahad, M. A., Paiva, S., Tripathi, G., & Feroz, N. (2020). Enabling technologies and sustainable smart cities. *Sustainable Cities and Society, 61*: 102301. https://doi.org/10.1016/j.scs.2020.102301

Aldowah, H., Al-Samarraie, H., Alzahrani, A. I., & Alalwan, N. (2020). Factors affecting student dropout in MOOCs: A cause and effect decision-making model. *Journal of Computing in Higher Education, 32*, 429–454. https://doi.org/10.1007/s12528-019-09241-y

Antwi-Afari, P., Owusu-Manu, D. G., Ng, S. T., & Asumadu, G. (2021). Modeling the smartness or smart development levels of developing countries' cities. *Journal of Urban Management*, *10*(4), 369–381. https://doi.org/10.1016/j.jum.2021.06.005

Ayu, M. (2020). Online learning: Leading e-learning at higher education. *The Journal of English Literacy and Education*, *7*(1), 47–54.

Badali, M., Hatami, J., Banihashem, S. K., Rahimi, E., Noroozi, O., & Eslami, Z. (2022). The role of motivation in MOOCs' retention rates: A systematic literature review. *Research and Practice in Technology Enhanced Learning, 17*: 5. https://doi.org/10.1186/s41039-022-00181-3

Baran, M., Kłos, M., Chodorek, M., & Marchlewska-Patyk, K. (2022). The resilient smart city model – Proposal for Polish cities. *Energies, 15*(5): 1818. https://doi.org/10.3390/en15051818

Buck, N. T., & While, A. (2017). Competitive urbanism and the limits to smart city innovation: The UK future cities initiative. *Urban studies, 54*(2), 501–519. https://doi.org/10.1177/0042098015597162

Castaño-Muñoz, J., & Rodrigues, M. (2021). Open to MOOCs? Evidence of their impact on labour market outcomes. *Computers & Education, 173*: 104289. https://doi.org/10.1016/j.compedu.2021.104289

Chen, X., Zou, D., Cheng, G., & Xie, H. (2025). Chinese MOOC learners' satisfaction and continuance intention: A mixed-method study. *Knowledge Management & E-Learning, 17*(2), 297–330. https://doi.org/10.34105/j.kmel.2025.17.014

Chin, W. W. (1998). The partial least squares approach to structural equation modeling. In G. A. Marcoulides (Ed.), *Modern Methods for Business Research* (pp. 295–336). Psychology Press.

Curşeu, P. L., Semeijn, J. H., & Nikolova, I. (2021). Career challenges in smart cities: A sociotechnical systems view on sustainable careers. *Human relations, 74*(5), 656–677. https://doi.org/10.1177/0018726720949925

D'Amour, D., Goulet, L., Labadie, J. F., Martín-Rodriguez, L. S., & Pineault, R. (2008). A model and typology of collaboration between professionals in healthcare organizations. *BMC Health Services Research, 8*: 188. https://doi.org/10.1186/1472-6963-8-188

Daneji, A. A., Ayub, A. F. M., & Khambari, M. N. M. (2019). The effects of perceived usefulness, confirmation and satisfaction on continuance intention in using massive open online course (MOOC). *Knowledge Management & E-Learning, 11*(2), 201–214. https://doi.org/10.34105/j.kmel.2019.11.010

David, N., & McNutt, J. (2019). Building a workforce for smart city governance: Challenges and opportunities for the planning and administrative professions. *Informatics, 6*(4): 47. https://doi.org/10.3390/informatics6040047

de Moura, V. F., de Souza, C. A., & Viana, A. B. N. (2021). The use of Massive Open Online Courses (MOOCs) in blended learning courses and the functional value perceived by students. *Computers & Education, 161*: 104077. https://doi.org/10.1016/j.compedu.2020.104077

Fernandez-Rio, J., Cecchini, J. A., Mendez-Gimenez, A., Mendez-Alonso, D., & Prieto, J. A. (2017). Design and validation of a questionnaire to assess cooperative learning in educational contexts. *Annals of Psychology, 33*(3), 680–688. https://doi.org/10.6018/analesps.33.3.251321

Fitsilis, P., & Kokkinaki, A. (2021, November). Smart cities body of knowledge. In *Proceedings of the 25th Pan-Hellenic Conference on Informatics* (pp. 155–159). ACM. https://doi.org/10.1145/3503823.3503853

Flores, E., Xu, X., & Lu, Y. (2020). A reference human-centric architecture model: A skill-based approach for education of future workforce. *Procedia Manufacturing, 48*, 1094–1101. https://doi.org/10.1016/j.promfg.2020.05.150

Fredericks, J. (2020). From smart city to smart engagement: Exploring digital and physical interactions for playful city-making. In A. Nijholt (Ed.), *Making Smart Cities More Playable: Gaming Media and Social Effects* (pp.107–128). Springer. https://doi.org/10.1007/978-981-13-9765-3_6

Friedman, A. L. (2023). Continuing professional development as lifelong learning and education. *International Journal of Lifelong Education, 42*(6), 588–602. https://doi.org/10.1080/02601370.2023.2267770

Gallego-Romero, J. M., Alario-Hoyos, C., Estévez-Ayres, I., & Delgado Kloos, C. (2020). Analyzing learners' engagement and behavior in MOOCs on programming with the Codeboard IDE. *Educational Technology Research and Development, 68*, 2505–2528. https://doi.org/10.1007/s11423-020-09773-6

Garg, S., Mittal, S. K., & Sharma, S. (2017). Role of e-trainings in building smart cities. *Procedia Computer Science, 111*, 24–30. https://doi.org/10.1016/j.procs.2017.06.005

Gil-Jaurena, I., Callejo-Gallego, J., & Agudo, Y. (2017). Evaluation of the UNED MOOCs implementation: Demographics, learners' opinions and completion rates. *The International Review of Research in Open and Distributed Learning, 18*(7), 141–168. https://doi.org/10.19173/irrodl.v18i7.3155

Hair Jr, J. F., Matthews, L. M., Matthews, R. L., & Sarstedt, M. (2017). PLS-SEM or CB-SEM: Updated guidelines on which method to use. *International Journal of Multivariate Data Analysis, 1*(2), 107–123. https://doi.org/10.1504/IJMDA.2017.087624

Hair, J. F., Risher, J. J., Sarstedt, M., & Ringle, C. M. (2019). When to use and how to report the results of PLS-SEM. *European Business Review, 31*(1), 2–24. https://doi.org/10.1108/EBR-11-2018-0203

Ho, A. D., Chuang, I., Reich, J., Coleman, C. A., Whitehill, J., Northcutt, C. G., … Petersen, R. (2015). *HarvardX and MITx: Two years of open online courses fall 2012-summer 2014*. MIT Office of Digital Learning. https://doi.org/10.2139/ssrn.2586847

Hollands, R. G. (2020). Will the real smart city please stand up?: Intelligent, progressive or entrepreneurial? In K. S. Willis, & A. Aurigi (Eds.), *The Routledge Companion to Smart Cities* (pp. 179–199). Routledge. https://doi.org/10.4324/9781315178387-13

Hsu, L. (2021). Learning tourism and hospitality subjects with massive open online courses (MOOCs): A cross-sectional and longitudinal study. *Journal of Hospitality, Leisure, Sport & Tourism Education, 29*: 100276. https://doi.org/10.1016/j.jhlste.2020.100276

Huin, L., Bergheaud, Y., Caron, P. A., Codina, A., & Disson, E. (2016, June). Measuring completion and dropout in MOOCs: A learner-centered model. In *Proceedings of the European MOOC Stakeholder Summit on Experiences and Best Practices in and around MOOCs* (pp. 55–67). Springer. Retrieved from https://hal.science/hal-04141929

Iatrellis, O., Panagiotakopoulos, T., Gerogiannis, V. C., Fitsilis, P., & Kameas, A. (2021). Cloud computing and semantic web technologies for ubiquitous management of smart cities-related competences. *Education and Information Technologies, 26*, 2143–2164. https://doi.org/10.1007/s10639-020-10351-9

Jebaraj, L., Khang, A., Chandrasekar, V., Pravin, A. R., & Sriram, K. (2023). Smart city: Concepts, models, technologies and applications. In A. Khang et al. (Eds.), *Smart Cities* (pp. 1–20). CRC Press.

Khan, H. H., Malik, M. N., Zafar, R., Goni, F. A., Chofreh, A. G., Klemeš, J. J., & Alotaibi, Y. (2020). Challenges for sustainable smart city development: A conceptual framework. *Sustainable Development, 28*(5), 1507–1518. https://doi.org/10.1002/sd.2090

Kontokosta, C. E. (2021). Urban informatics in the science and practice of planning. *Journal of Planning Education and Research, 41*(4), 382–395. https://doi.org/10.1177/0739456X18793716

Kumar, H., Singh, M. K., Gupta, M. P., & Madaan, J. (2020). Moving towards smart cities: Solutions that lead to the smart city transformation framework. *Technological Forecasting and Social Change, 153*: 119281. https://doi.org/10.1016/j.techfore.2018.04.024

Lazarinis, F., Karachristos, C. V., Stavropoulos, E. C., & Verykios, V. S. (2019). A blended learning course for playfully teaching programming concepts to school teachers. *Education and Information Technologies, 24*, 1237–1249. https://doi.org/10.1007/s10639-018-9823-2

Lazarinis, F., Karatrantou, A., Panagiotakopoulos, C., Daloukas, V., & Panagiotakopoulos, T. (2022). Strengthening the coding skills of teachers in a low dropout Python MOOC. *Advances in Mobile Learning Educational Research, 2*(1), 187–200. https://doi.org/10.25082/AMLER.2022.01.003

Logan, R. M., Johnson, C. E., & Worsham, J. W. (2021). Development of an e-learning module to facilitate student learning and outcomes. *Teaching and Learning in Nursing, 16*(2), 139–142. https://doi.org/10.1016/j.teln.2020.10.007

Markow, W., Hughes, D., & Walsh, M. (2019). *Future skills, future cities: New foundational skills in smart cities*. Business-Higher Education Forum. Retrieved from https://files.eric.ed.gov/fulltext/ED596449.pdf

Michelucci, F. V., De Marco, A., & Tanda, A. (2016). Defining the role of the smart-city manager: An analysis of responsibilities and skills. *Journal of Urban Technology, 23*(3), 23–42. https://doi.org/10.1080/10630732.2016.1164439

Myeong, S., Kim, Y., & Ahn, M. J. (2020). Smart city strategies − Technology push or culture pull? A case study exploration of Gimpo and Namyangju, South Korea. *Smart Cities, 4*(1), 41–53. https://doi.org/10.3390/smartcities4010003

Neirotti, P., De Marco, A., Cagliano, C., Mangano, G., & Scorrano, F. (2014). Current trends in smart city initiatives: Some stylised facts. *Cities, 38*, 25–36. https://doi.org/10.1016/j.cities.2013.12.010

OECD. (2020). *Smart cities and inclusive growth: Building on the outcomes of the 1st OECD roundtable on smart cities and inclusive growth*. OECD Publishing. https://doi.org/10.1787/8a4ce475-en

Ouyang, F., Li, X., Sun, D., Jiao, P., & Yao, J. (2020). Learners' discussion patterns, perceptions, and preferences in a Chinese massive open online course (MOOC).

International Review of Research in Open and Distributed Learning, 21(3), 264–284. https://doi.org/10.19173/irrodl.v21i3.4771

Panagiotakopoulos, T., Iatrellis, O., & Kameas, A. (2022). Emerging smart city job roles and skills for smart urban governance. In P. Fitsilis (Ed.), *Building on Smart Cities Skills and Competences* (pp. 3–19). Springer. https://doi.org/10.1007/978-3-030-97818-1_1

Panagiotakopoulos, T., Kotsiantis, S., Borotis, S., Lazarinis, F., & Kameas, A. (2021a, June). Applying machine learning to predict whether learners will start a MOOC after initial registration. In L. Iliadis, I. Maglogiannis, & J. Macintyre (Eds.), *Proceedings of the Artificial Intelligence Applications and Innovations: AIAI 2021 IFIP WG 12.5 International Workshops* (pp. 466–475). Springer. https://doi.org/10.1007/978-3-030-79157-5_38

Panagiotakopoulos, T., Kotsiantis, S., Kostopoulos, G., Iatrellis, O., & Kameas, A. (2021b). Early dropout prediction in MOOCs through supervised learning and hyperparameter optimization. *Electronics, 10*(14): 1701. https://doi.org/10.3390/electronics10141701

Panagiotakopoulos, T., Lazarinis, F., & Kameas, A. (2025, June). Competence development of SMART cities' employees via a suite of educational instruments. In *Proceedings of the 17th International Conference on Education and New Learning Technologies* (pp. 10191–10196). IATED. https://doi.org/10.21125/edulearn.2025.2648

Panagiotakopoulos, T., Lazarinis, F., Iatrellis, O., Stefani, A., & Kameas, A. (2024). A competency-based specialization course for smart city professionals. *Research and Practice in Technology Enhanced Learning, 19*: 13. https://doi.org/10.58459/rptel.2024.19013

Patino, A., & Naffi, N. (2023). Lifelong training approaches for the post-pandemic workforces: A systematic review. *International Journal of Lifelong Education, 42*(3), 249–269. https://doi.org/10.1080/02601370.2023.2214333

Paton, R. M., Fluck, A. E., & Scanlan, J. D. (2018). Engagement and retention in VET MOOCs and online courses: A systematic review of literature from 2013 to 2017. *Computers & Education, 125*, 191–201. https://doi.org/10.1016/j.compedu.2018.06.013

Pérez-Foguet, A., Lazzarini, B., Giné, R., Velo, E., Boni, A., Sierra, M., Zolezzi, G., & Trimingham, R. (2018). Promoting sustainable human development in engineering: Assessment of online courses within continuing professional development strategies. *Journal of Cleaner Production, 172*, 4286–4302. https://doi.org/10.1016/j.jclepro.2017.06.244

Rana, N. P., Luthra, S., Mangla, S. K., Islam, R., Roderick, S., & Dwivedi, Y. K. (2019). Barriers to the development of smart cities in Indian context. *Information Systems Frontiers, 21*, 503–525. https://doi.org/10.1007/s10796-018-9873-4

Sanchez-Ortiz, A., Solar, M., Estevez, E., & Viale-Pereira, G. (2020). Identification of competencies and teaching models for the governance of smart sustainable cities in the South American context. In G. Viale Pereira et al. (Eds.), *Electronic Government* (pp. 400–411). Springer. https://doi.org/10.1007/978-3-030-57599-1_30

Sun, Y., Guo, Y., & Zhao, Y. (2020). Understanding the determinants of learner engagement in MOOCs: An adaptive structuration perspective. *Computers & Education, 157*: 103963. https://doi.org/10.1016/j.compedu.2020.103963

Tan, S. Y., & Taeihagh, A. (2020). Smart city governance in developing countries: A systematic literature review. *Sustainability, 12*(3): 899. https://doi.org/10.3390/su12030899

Tryfonas, T., & Crick, T. (2015). *Smart cities, citizenship skills and the digital agenda:*

The grand challenges of preparing the citizens of the future. Government of the United Kingdom. Retrieved from https://assets.publishing.service.gov.uk/media/5a81566ee5274a2e8ab5371a/future-cities-smart-cities-citizenship.pdf

Tselios, N., Daskalakis, S., & Papadopoulou, M. (2011). Assessing the acceptance of a blended learning university course. *Educational Technology & Society, 14*(2), 224–235.

Ubaldi, B., Le Fevre, E. M., Petrucci, E., Marchionni, P., Biancalana, C., Hiltunen, N., Intravaia, D. M., & Yang, C. (2019). *State of the art in the use of emerging technologies in the public sector*. OECD. https://doi.org/10.1787/932780bc-en

Ucha, C. R. (2023). Role of course relevance and course content quality in MOOCs acceptance and use. *Computers and Education Open, 5*: 100147. https://doi.org/10.1016/j.caeo.2023.100147

Xu, F. (2015, August). Research of the MOOC study behavior influencing factors. In *Proceedings of the 2015 3d International Conference on Advanced Information and Communication Technology for Education* (pp. 18–22). Atlantis. https://doi.org/10.2991/icaicte-15.2015.5

Yang, Q., & Lee, Y. C. (2021). The critical factors of student performance in MOOCs for sustainable education: A case of Chinese universities. *Sustainability, 13*(14): 8089. https://doi.org/10.3390/su13148089

Yigitcanlar, T., Kankanamge, N., & Vella, K. (2022). How are smart city concepts and technologies perceived and utilized? A systematic geo-Twitter analysis of smart cities in Australia. *Journal of Urban Technology, 28*(1/2), 135–154. https://doi.org/10.1080/10630732.2020.1753483

Zhou, X., Chai, C. S., Jong, M. S. Y., & Xiong, X. B. (2021). Does relatedness matter for online self-regulated learning to promote perceived learning gains and satisfaction? *The Asia-Pacific Education Researcher, 30*(3), 205–215. https://doi.org/10.1007/s40299-021-00579-5

Zhuhadar, L., Thrasher, E., Marklin, S., & de Pablos, P. O. (2017). The next wave of innovation – Review of smart cities intelligent operation systems. *Computers in Human Behavior, 66*, 273–281. https://doi.org/10.1016/j.chb.2016.09.030

Appendix I: Smart DevOps MOOC schedule

Table A
Competencies taught and training duration

Week	Code	Skill/Competence	Units	Duration (h)
1	C1	Creativity	5	5
2	C2	DevOps basic concepts, culture and practices	3	4
3	C3	Entrepreneurial thinking	4	6
4	C4	Basic concepts of cloud computing	3	4
	C5	Basic concepts of data analytics	4	4
5	C6	Project and process management	5	5
	C7	Stakeholder management	4	5
6	C8	Motivation to learn	4	5
	C9	Ability to work in teams	4	5
7		Reflection week	–	–
8	C10	Strategic vision	3	4
	C11	Smart cities platforms	5	5
9	C12	Basic concepts of Internet of Things	3	4
	C13	Social skills	3	5
10	C14	System and software architecture	3	4
	C15	Smart cities business models and financial management	4	6
11		Reflection week	–	–

Appendix II: Survey instrument

Table B
Survey questionnaire

	Perceived relevance and quality (PRQ)	
PRQ1	The course content was well structured	Likert scale
PRQ2	The MOOC's content was up to date	Likert scale
PRQ3	The learning outcomes of the course were supported by the respective educational material	Likert scale
PRQ4	The level of difficulty of MOOC's learning content was appropriate	Likert scale
PRQ5	Training modules were relevant to smart cities	Likert scale
PRQ6	The course was engaging	Likert scale
	Perceived usefulness (PU)	
PU1	The acquired competencies are immediately applicable to my everyday work duties	Likert scale
PU2	I find the MOOC useful to accomplish my work duties more quickly	Likert scale
PU3	This MOOC will enhance my effectiveness at work	Likert scale
PU4	This course equipped me with desirable skills for my job	Likert scale
PU5	It is very likely to recommend this course e.g. to a colleague or friend	Likert scale
PU6	It is very likely to revisit the course materials in the future	Likert scale
	Competence level (CL)	
CL1 – 15	Rate your competence level prior and after the MOOC with regard to the competencies taught in the course	Likert scale
Retention factors (RF) and qualitative feedback (QF)		
RF1	Please select the retention factors that apply in your case The support of the course trainers The collaboration with other learners The award of a certificate The relevance of the content to my everyday work duties The clear organization of the course The course workload and the learning objectives were clear from the beginning of the course The course was very interesting The course covered contemporary topics	Checkbox

	The balanced workload	
	I wanted to learn something new	
QF1	What did you enjoy most about taking part in the course?	Open-ended
QF2	What are your suggestions for improving this course?	Open-ended

Appendix III: Factor analysis

Table C
Factor loadings

Item	Value	Item (before MOOC)	Value	Item (after MOOC)	Value
PRQ1	0.81	CL1	0.73	CL1	0.74
PRQ2	0.79	CL2	0.68	CL2	0.74
PRQ3	0.83	CL3	0.78	CL3	0.78
PRQ4	0.83	CL4	0.66	CL4	0.71
PRQ5	0.53	CL5	0.68	CL5	0.75
PRQ6	0.62	CL6	0.73	CL6	0.75
		CL7	0.75	CL7	0.77
PU1	0.66	CL8	0.70	CL8	0.73
PU2	0.51	CL9	0.64	CL9	0.72
PU3	0.66	CL10	0.79	CL10	0.82
PU4	0.67	CL11	0.69	CL11	0.74
PU5	0.86	CL12	0.68	CL12	0.73
PU6	0.71	CL13	0.68	CL13	0.74
		CL14	0.66	CL14	0.73
		CL15	0.77	CL15	0.79

Appendix IV: Wilcoxon signed-rank test results for individual competencies

Table C
Individual competency improvement statistics

Competence level	Mean before MOOC	SD before MOOC	Mean after MOOC	SD after MOOC	Wilcoxon	*p*
CL1	2.81	1.20	3.72	0.84	926	< 0.001
CL2	2.28	1.27	3.48	0.89	669.5	< 0.001
CL3	2.64	1.25	3.60	0.89	803	< 0.001
CL4	2.58	1.31	3.44	1.01	921	< 0.001
CL5	2.61	1.31	3.42	1.04	1339.5	< 0.001
CL6	2.85	1.32	3.71	0.97	833.5	< 0.001
CL7	2.58	1.28	3.54	0.99	1004.5	< 0.001
CL8	3.08	1.21	3.88	0.86	1465.5	< 0.001
CL9	3.23	1.21	3.90	0.85	1263	< 0.001
CL10	2.72	1.24	3.70	0.93	1333	< 0.001
CL11	2.34	1.24	3.55	0.91	404	< 0.001
CL12	2.67	1.32	3.65	0.92	887.5	< 0.001
CL13	3.01	1.22	3.79	0.81	832	< 0.001
CL14	2.46	1.31	3.39	1.03	963	< 0.001
CL15	2.27	1.25	3.46	0.96	794	< 0.001