

Scale for Assessing University Digital Educational Environment (AUDEE Scale)

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The paper presents results of the development of a scale for assessing university digital educational environment (AUDEE Scale; $N = 406$; 366 (90.1% women; age varies from 19 to 72 years, on average 28.7 ± 9.6 years (median = 24 years)). AUDEE scale provides a comprehensive description of digital educational environment based on the distinguishing of six indicators: satisfaction with the educational process; satisfaction with communicative interaction; stress tension; the need for support; dishonest strategies in knowledge control; and environment accessibility. The results of the confirmatory factor analysis confirm the six subscales model (IFI = 0.87; $\chi^2 / df = 2.6$; RMSEA = 0.06 [0.058; 0.066]; SRMR = 0.06). All subscales have acceptable reliability (Cronbach's alpha = 0.72—0.91, Split-half Guttman alpha = 0.82—0.92) and demonstrate predictable relationships with convergent indicators: experiences during learning (efforts, pleasure, meaning); cognitive motivation, achievement motivation, self-development motivation, introjected and external motivation, amotivation. To standardize the scale, stanines are calculated.

Keywords: digital educational environment of the university, students, assessment scale, reliability, validity.

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Представлены результаты разработки Шкалы оценки цифровой образовательной среды (ЦОС) университета (N = 406; 366 (90,1%) женщин; возраст от 19 до 72 лет, в среднем $28,7 \pm 9,6$ лет (медиана 24 года)), позволяющие дать комплексную характеристику ЦОС на основании выделения шести индикаторов: удовлетворенность учебным процессом; удовлетворенность коммуникативным взаимодействием; стресснапряженность; необходимость поддержки; нечестные стратегии при контроле знаний; доступность. Результаты конфирматорного факторного анализа подтверждают наличие шести субшкал ($IFI = 0,87$; $\chi^2/df = 2,6$; $RMSEA = 0,06$ [0,058; 0,066]; $SRMR = 0,06$). Все субшкалы обладают приемлемой надежностью (альфа Кронбаха = 0,72—0,91, альфа Гутмана = 0,82—0,92) и демонстрируют предсказуемые взаимосвязи с показателями: переживания в учебной деятельности (усилия, удовольствие, смысл), познавательная мотивация, мотивация достижения, мотивация саморазвития, интроецированная мотивация, экстернальная мотивация, амотивация. Рассчитаны станайны.

Ключевые слова: цифровая образовательная среда университета, студенты, шкала оценки, надежность, валидность.

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Introduction

It is impossible to imagine the higher educational environment today without the use of digital technologies. The number of courses delivered online is constantly growing worldwide. Despite risks associated with the rejection of distance learning technologies [25], insufficient digital competence of students and teachers [31], stress [18], lack of motivation and perseverance [20], digital technologies are opening up a new approach to learning based on flexibility [23], interactivity [12], openness [19], expansion of physical space [16] and accessibility [33].

The concept of “digital pedagogy” [11] is understood not only as a tool, but also as a process of expanding pedagogical opportunities for joint activities with students, which are implemented through active, flexible learning strategies based on preparatory principles that privilege the development of intellectual, personal and social resources leading to independent responsibility and involving the provision of intellectual, social and emotional support in learning. The main focus of attention in digital pedagogy is placed on the involvement of students in developing their own responsibility for their education process [11].

In order to achieve maximum efficiency of the digital educational environment (DEE) of the university, it is necessary to ensure its constant improvement. This, in turn, requires a comprehensive assessment of: 1) the information needs of educational subjects to maintain their motivation; 2) conditions for the comprehensive development of students’ individual personality characteristics [8]; 3) students’ psychological security and emotional stability [1]; 4) the conditions under which students feel like equal partners in the educational process [26]; 5) use of honest strategies by students during testing of their academic achievements [9]; 6) DEE accessibility [16; 33].

Thus, the rapid development of a university DEE requires the constant assessment and revision of pedagogical technologies to ensure that they meet the expectations of all participants. In order to ensure the constant improvement of the educational environment, it is important not to underestimate the importance of student experience in the new digital reality.

A number of instruments used internationally for assessing satisfaction with the educational environment are based on a comparison of expectations with experience : 1) the Dundee Ready Education Environment Measure (DREEM) method for studying student perception of learning, teachers, self-perception, atmosphere perception and social perception [27]; 2) the ULEQ methodology for assessing the psychosocial environment of universities, which allows students to identify levels of academic freedom and support for their achievements and opportunities, as well as helping to deal with stress [15]; 3) the Learn methodology, which reflects student learning motivation and perception of the learning environment [21]; 4) the CUCEL methodology for assessing the educational environment of colleges and universities in terms of student and teacher perceptions of differences between the actual and ideal environments [17]; 5) the URP-NEEDS scale for assessing the social, emotional and behavioural support needs of students [14]. Although specifically designed for studying the traditional learning environment, such a diagnostic toolkit at the same time becomes a good reference point for new developments in DEE assessment. Thus, various attempts have been made to determine the effectiveness of teaching in a DEE based on the results of the work of students with test systems [4]; to evaluate the spatial-subject, communicative and technological components of a DEE [5]; as well as define the criteria for assessing a DEE: consistency, mobility, openness, informality, completeness, freedom, accessibility, safety (although the presented technique itself is still under development) [3]. A bipolar scale for assessing digital learning has been proposed [10]. Additional DEE assessment methodologies include those geared towards digital learning self-efficacy and perceived support; the benefits of digital learning and a series of open-ended questions [13]; a scale of assistance and / or barriers associated with the persistence and motivation of online learning students [20]; the Measuring E-Learning Systems Success questionnaire [28], which was created to assess the quality of the e-learning system (teaching, social impact, student anxiety, usefulness, satisfaction with e-learning and the success of the system).

As can be seen, the rapid and large-scale transition of educational institutions to a digital educational environment requires a reliable and valid diagnostic toolkit for its comprehensive assessment based on a selection of indicators as identified in the scientific literature and described above: 1) satisfaction with the educational process in terms of its practical benefits; 2) satisfaction with communicative interaction; 3) security / stress; 4) the need for support; 5) (dis)honest strategies on the part of students when their academic achievements are being tested; 6) accessibility.

The development of the described Scale for Assessing University Digital Educational Environment (AUDEE Scale) occurred over two main stages. The database for the first version (2019), which took the form of a questionnaire [9; 30], is available in the Mendeley Data repository [29]. At the second stage (2020), the methodology was significantly improved on the basis of expert assessments together with a preliminary calculation of individual psychometric characteristics.

Method

Sample description. The study involved 406 students at the Moscow State University of Psychology & Education (MSUPE) who completed online e-courses in mathematical methods in psychology, of which 90.1% (N = 366) were female and 9.9% (N = 40) were male; mean age was 28.7 ± 9.6 years (median — 24 years; mode — 20 years; minimum — 19 years; maximum — 72 years). The database, which was assembled in September-December 2020 when the university was working remotely, is available in the RusPsyDATA repository.

Instruments. The following instruments were used in the study:

Scale for Assessing University Digital Educational Environment (AUDEE Scale).

Activity-Related Experiences Assessment (AREA) technique [6] for studying the subjective representation of the correlation of current learning activity with effort, enjoyment (pleasure), meaningfulness (meaning), emptiness (void).

Academic Motivation Scales questionnaire for studying internal and external motivation to participate in educational activities [2]. The latter two

methods were used to verify the criterion validity of the developed tool.

Statistical analysis of the data was performed in SPSS V.23 and AMOS V.21.

Results and discussion

The original version of AUDEE scale comprised 56 items. Exploratory factor analysis (EFA) using the principal component extraction method and Varimax rotation allowed us to identify 11 factors explaining 59.79% of the total variance. However, the last four factors explained no more than 4% of the variance and contained only individual items of the questionnaire with low loadings.

In order to reduce the number of factors for their better interpretability, 18 items were sequentially removed. Although the removal of one item comprising a factor reduced the number of factors to 10, explaining 58.62% of the total variance, the last 3 factors explained less than 4% of the variance each, while the Cronbach's alpha coefficients for the latter two were about 0.5, indicating a weak correlation with the corresponding scales. Next, first ten, then five and an additional two items were removed with the corresponding EFA, reducing the number of factors first to eight (59.07% of the total variance explained), then to seven (58.44% of the total variance explained) and, finally, to six (56.90% of the total variance explained). The items were removed for the following reasons: either the removed item correlated weakly with the final scale (0.3 or less), had an unclear content, or duplicated other items. The final version of the questionnaire comprised 38 items (see Appendix). The results of checking the reliability and validity of the AUDEE scale are as follows.

Construct validity and internal consistency of subscales

The Kaiser-Meyer-Olkin (KMO = 0.946) and Bartlett sphericity tests ($\chi^2 = 7780.28$, $df = 703$, $p < 0.001$) indicate the adequacy of the sample and factorability of the correlation matrix. The EFA was performed using the method of principal components with Varimax rotation, having eigenvalues greater than 1 as the selection criterion. The extracted six factors explain 56.91% of the total variance: F1 — 16.06%; F2 — 10.89%; F3 —

9.21 %; F4 — 7.49%; F5 — 6.85%; F6 — 6.39%. Although the subscales of the questionnaire for the most part correspond to the extracted factors, six items are assigned to two subscales simultaneously (see Appendix), due to having rather high factor loadings on any two of the six factors and explaining the interpretation of both subscales, respectively. For better interpretability of the subscales, one item with almost the same absolute value of factor loadings on factors F1 (0.52) and F4 (-0.52) was also assigned to subscale 4, while another item with almost equal loadings on factors F2 (0.43) and F3 (0.44) was assigned to subscale 2.

Subscale 1 “DEE Learning Process Satisfaction” includes 12 direct items showing the degree of usefulness of e-courses for preparing for future professional activities and the degree of satisfaction with the educational process (see Appendix), which corresponds to the final scale.

Subscale 2 “DEE Communication Satisfaction and Learning Motivation” includes seven items, three of which are direct, while four are reverse, showing the lack of personal contacts with classmates and teachers, the intensity of classes, assessment of the quality of education and accounting for individual and personal characteristics of students (see Appendix). Since subscale 2 corresponds semantically to the final scale, all direct and inverse items of this subscale retain their “direction” in relation to the final one.

Subscale 3 “DEE Stress Tension” includes eight direct items assessing the practical difficulty of acquiring competencies, deep and lasting knowledge, accessibility of education and support of learning motivation (see Appendix). Since subscale 3 is opposite in meaning to the final one, all questions are inverse to it; this is taken into account when describing the scoring.

Subscale 4 “Need for support in DEE learning activity” consists of six items (five direct and one reverse), reflecting the complexity of time management for classes, an assessment of technical difficulties and unfamiliarity with the training format (see Appendix). Since this subscale is opposite in meaning to the final scale, all questions “change sign” in relation to it; this is taken into account when describing the scoring.

Subscale 5 “DEE Dishonest Strategy Prevalence” consists of six items (five direct and one reverse) reflecting respondents’ opinions on the opportunity and frequency of using dishonest strategies in the DEE (see Appendix). Since subscale five is opposite in meaning to the final scale, all questions “change sign” in relation to it; this is taken into account when describing the scoring.

Subscale 6 “DEE Accessibility” comprises five items (three direct and two reverse), reflecting the availability of educational information for students in the DEE (see Appendix). Since subscale 6 corresponds semantically to the final scale, all direct and reverse items of this subscale retain their “direction” in relation to the final one.

Cronbach’s alpha coefficients for all six subscales vary from 0.73 to 0.91, while Guttman split-half coefficient vary from 0.82 to 0.92; for all subscales, Cronbach’s alpha decreases with the exclusion of any item, indicating good internal reliability (see Table 1). When calculating Cronbach’s alpha coefficients, the scores obtained for the reverse items were preliminarily recoded.

Descriptive statistics for AUDEE scale are presented in Table 1. The Kolmogorov-Smirnov test showing distributions at variance from normal on revealed a lack of normal distribution on the part of all subscales except the Total score ($p = 0.157$). However, due to the mean values not substantially differing from the medians, the distribution symmetry assumption is supported. This assumption is also supported by the skewness values, which do not substantially go beyond the interval from -0.5 to 0.5. If considering either the absolute value of skewness > 2 , or the absolute value of kurtosis > 7 as a criterion for non-normality for large samples (> 400) [32], it can be concluded that the distributions of all subscales, as well as the total score, differ little from normal, with the exception of subscale 6.

The intercorrelations of the subscales and Total score were calculated using the Pearson correlation coefficient (Table 2). As can be seen, subscales 1, 2 and 6 showing positive attitude towards learning in the DEE, and subscales 3, 4 and 5 showing negative attitude, correlate well with each other and with the total score. For example, subscale 1 has strong and mod-

Table 1

Descriptive statistics and indicators of internal reliability for total score and subscales of the AUDEE Scale

Subscale	M±SD	Me	Skewness	Kurtosis	Cronbach's alpha	Guttman split-half coefficient
			Value ± standard error			
1. DEE Learning Process Satisfaction	45.7±8.5	46.0	-0.52±0.12	0.17±0.24	0.91	0.92
2. DEE Communication satisfaction and Learning Motivation	19.4±6.2	19.5	0.10±0.12	-0.61±0.24	0.86	0.88
3. DEE Stress Tension	20.5±6.6	20.0	0.30±0.12	-0.34±0.24	0.87	0.86
4. Need for support in DEE learning activity	14.2±4.6	14.0	0.52±0.12	-0.28±0.24	0.79	0.83
5. DEE Dishonest Strategy Prevalence	16.7±3.8	16.0	0.36±0.12	0.44±0.24	0.73	0.85
6. DEE Accessibility	21.4±3.0	22.0	-0.87±0.12	0.56±0.24	0.73	0.82
Total score	133.1±23.4	134.0	-0.30±0.12	-0.10±0.24		

Notes. *M* — mean; *Me* — median; *SD* — standard deviation.

erate positive correlations with subscales 2 and 6, respectively, while with subscales 4 and 5, it has negative moderate and weak correlations, respectively. The final DEE assessment scale has a pronounced positive correlation with subscales 1, 2, and 6, a strong negative correlation with subscales 3 and 4, and moderate negative correlation with subscale 5.

Confirmatory factor analysis. The complete structure of the AUDEE scale is shown in the figure. On the whole, confirmatory factor analysis (CFA) showed an acceptable agreement of the model with the obtained data. Although the chi-square test shows that the model does not fit the obtained data, with some indices not exceeding 0.90 (GFI = 0.82; AGFI = 0.79;

IFI = 0.87; TLI = 0.86), the relative (or normalised) chi-squared χ^2 / df was 2.6, which indicates a good fit ($\chi^2 / df < 3$ for a good fit [22]). The root mean square error of approximation (RMSEA) was 0.06 with a confidence interval of 0.058 to 0.066, which also indicates good agreement [24]. This is supported by the standardised root mean squared residual (SRMR) indicator = 0.06, which turned out to be less than 0.08 [24]. Thus, the CFA fit indices indicate a good fit of the model to the obtained data. The standardized weight coefficients reproduce the factor loadings of the EFA and are consistent with the questionnaire scoring. Relationships between factors in CFA also satisfactorily reproduce the AUDEE scales correlation matrix (Table 2).

Table 2

AUDEE scales correlation matrix (Pearson correlation coefficients between the original scales / correlations reproduced in the CFA)

Subscale	Subscale					
	1	2	3	4	5	6
2	0.79 / 0.85					
3	-0.76 / -0.86	-0.74 / -0.87				
4	-0.64 / -0.73	-0.63 / -0.77	0.73 / 0.78			
5	-0.37 / -0.38	-0.40 / -0.42	0.52 / 0.46	0.38 / 0.38		
6	0.69 / 0.65	0.53 / 0.46	-0.70 / -0.62	-0.68 / -0.56	-0.24 / -0.15	
Total score	0.91	0.88	-0.91	-0.81	-0.57	0.74

Note. All correlation coefficients are statistically significant at $p < 0.001$.

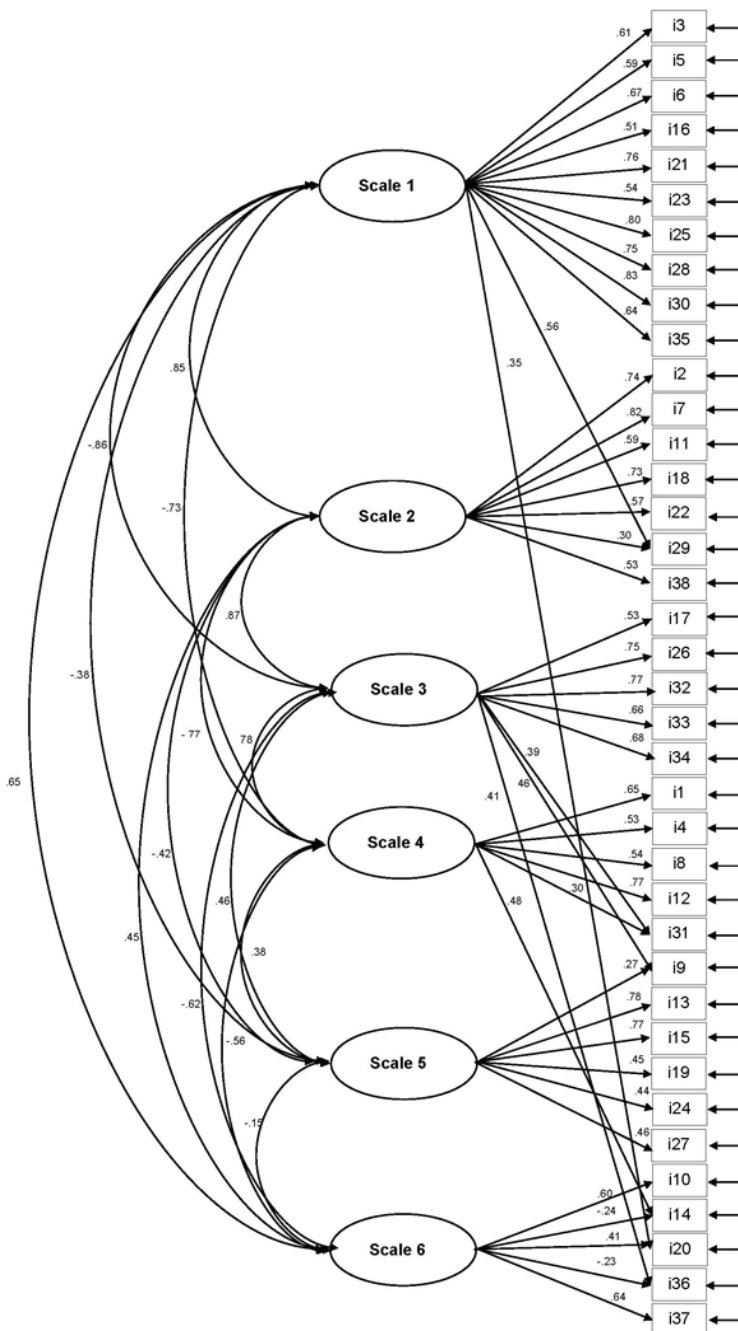


Fig. Structure of the AUDEE Scale with CFA standardized weight coefficients

Criterion validity, stanines. In order to check the criterion validity of the instrument, the correlations of its subscales with the following indicators were calculated: study-related experiences (effort, pleasure, meaning, void); internal motivation (intrinsic cognition, achievement, personal growth), and external motivation (self-respect, amotivation) (Table 3).

The Table 3 supports the criterion validity of the AUDEE scale. The data show that satisfaction with the educational process, communicative interaction and high motivation in the DEE are positively interrelated with a feeling of enjoyment in educational activities and inclusion in a meaningful context. In turn, stressfulness, the need for support and the use of dishonest strategies in the DEE are negatively associated with learning enjoyment and meaningfulness. Satisfaction with the educational process in the DEE is positively associated with cognitive motivation, motivation for achievement, self-development and self-esteem, but negatively associated with a lack of motivation. Due to their consistency with the content of the DEE scales, the findings indicate the sufficient criterion validity of the instrument.

Since no sex differences were found either on subscales or on the total score scale of the

questionnaire, percentiles of ranks 4, 11, 23, 40, 60, 77, 89, and 96 were counted for calculating stanines for the subscales and the final scale for the entire sample. Indicators related to the 4th–6th stanines, which refer to the average level, make up 54% of the standardisation sample. The indicators related to the 2nd–3rd and 7th–8th stanines refer to the levels below the average and above the average, respectively, while to the 1st and 9th stanines, they related to very low and very high levels (Table 4).

Conclusion

Along with other objective DEE characteristics, i.e., completeness of the provided educational information in academic subjects, number of video recordings, availability of competency control and test tools, students’ educational achievements, etc., the developed scale shows an important component of a DEE comprehensive assessment. The developed AUDEE scale possesses statistically proven reliability, as well as internal and criterion validity and can be used for a comprehensive assessment of DEE based on a number of indicators such as satisfaction and practical use; satisfaction with communicative interaction; stress tension; need for support; dishonest strategies; accessibility.

Table 3

Pearson correlation coefficients between AUDEE scales, study-related experiences and scales of academic motivation

Scales	AUDEE subscales						
	1	2	3	4	5	6	Total score
Activity-Related Experiences Assessment technique (AREA)							
Effort	0.02	-0.03	0.08	0.23	0.05	-0.07	-0.07
Pleasure	0.74	0.62	-0.63	-0.52	-0.36	0.45	0.71
Meaning	0.50	0.40	-0.52	-0.38	-0.28	0.35	0.51
Void	-0.49	-0.40	0.54	0.43	0.28	-0.41	-0.53
“Academic Motivation Scales” questionnaire: intrinsic motivation							
Intrinsic cognition	0.38	0.19	-0.33	-0.27	-0.17	0.32	0.34
Achievement	0.28	0.09	-0.26	-0.25	-0.11	0.25	0.25
Personal growth	0.38	0.16	-0.28	-0.23	-0.10	0.28	0.31
“Academic Motivation Scales” questionnaire: external motivation							
Self-respect	0.26	0.18	-0.11	-0.03	0.04	0.11	0.17
Amotivation	-0.26	-0.17	0.36	0.30	0.12	-0.31	-0.30

Note. Statistically significant correlation coefficients at $p < 0.01$ are highlighted in bold.

Table 4

Stanines and norms for subscales of the AUDEE Scale

Subscale	Stanines and norms								
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th
	Very low	Below average		Average level			Above average		Very high
1	12—28	29—34	35—39	40—43	44—47	48—52	53—55	56—58	59—60
2	7—8	9—10	11—13	14—17	18—20	21—23	24—26	27—29	30—35
3	8—9	10—11	12—14	15—18	19—21	22—25	26—28	29—32	33—40
4	6	7—8	9	10—11	12—14	15—17	18—20	21—22	23—30
5	6—9	10—11	12—13	14	15—16	17—18	19—20	23—23	24—30
6	5—14	15—16	17—18	19—20	21—22	23	24	25	25
Total score	38—88	89—104	105—113	114—127	128—140	141—151	152—160	161—172	173—190

The AUDEE Scale is an appropriate tool for studying factors affecting the success of implementing e-learning in higher education institutions. It can help to ensure e-learning quality and the satisfaction of all participants of educational processes taking place in a digital environment. The AUDEE Scale can be applied to partially resolve contradictions in assessments of the effectiveness of distance technologies used across different learning models during periods of intensive development of educational innovations [7]. By using

the AUDEE Scale to assess the satisfaction with digital learning of students studying according to different program majors and tracks in various universities delivered through participation in various e-courses, it will be possible to use the obtained information to improve digital education technology. The AUDEE Scale can also be adapted to secondary educational institutions and colleges. Thus, the AUDEE Scale comprises a valid and reliable tool for solving pure research problems as well as those applied in the field of higher education.

Appendix

Scale for assessing university digital educational environment (AUDEE Scale)

Instructions: Please rate how much you agree with the following statements on a scale from 1 to 5:

- 1 – strongly disagree
- 2 – disagree
- 3 – neither agree nor disagree
- 4 – agree
- 5 – strongly agree

1. It is convenient to prepare for classes using e-courses
2. Learning by means of e-courses is more interesting than by classic face-to-face mode
3. Learning by means of e-courses helps me to exercise independence
4. It is difficult to study by means of e-courses without the help of a teacher
5. The use of e-courses is a requirement of modern life
6. It is convenient to not attend lectures in person, but access them instead via audio or video recordings
7. The use of e-learning reduces the quality of education
8. It is difficult to effectively manage time and complete the assignments for the e-course punctually
9. Tests as a form of control in e-courses focus students exclusively on achieving grades, and not on building competencies
10. It is easy to return to what was not at first clear in the e-course
11. In e-courses in online classes with a teacher, I work much more intensively than in traditional full-time education
12. It is hard to get used to the new learning mode in e-course format
13. Students often use dishonest strategies when their academic achievements being tested

14. The e-course format presents me with difficult technical challenges
15. Online test results are often falsified due to a lack of control over the person being tested
16. In the e-course, I can always quickly find out the class topic and the task
17. E-courses are useless for the development of my professional competencies
18. In the e-course medium, I lack personal contact with a teacher
19. To prevent students from using dishonest strategies in educational assessments, stricter monitoring of students is needed
20. The e-course format makes it easier to make up for missed information
21. E-courses are useful for helping me to prepare well for future professional activities
22. In the e-course medium, I lack personal contact with classmates
23. E-learning contributes to the development of digital competencies
24. There will still be students who use dishonest strategies when their academic achievements being tested
25. Learning via e-courses is a pleasure for me
26. E-learning inhibits the acquisition of deep and lasting knowledge
27. Most (more than half) of my classmates cope with control tasks independently
28. I learn a lot of new and useful things from the e-course
29. I want to study other subjects in the e-course format
30. Mastering the e-course gives me a feeling of satisfaction with the educational process
31. The possibility to use online resources when competency checking reduces the motivation for independent preparation for classes
32. I feel uncomfortable in a digital educational environment
33. The use of e-learning interferes with the development of practical competencies
34. The digital educational environment raises stress level
35. Online learning develops the ability to quickly and effectively navigate information flows
36. E-learning and online learning make education less accessible
37. E-courses are a good solution for those students who cannot attend classes
38. The digital educational environment does not take into account the individual and personal characteristics of students

Scoring

Scale 1. DEE Learning Process Satisfaction: items 3+, 5+, 6+, 16+, 20+, 21+, 23+, 25+, 28+, 29+, 30+, 35+

Scale 2. DEE Communication Satisfaction and Learning Motivation: items 2+, 7-, 11+, 18-, 22-, 29+, 38-

Scale 3. DEE Stress Tension: items 9+, 17+, 26+, 31+, 32+, 33+, 34+, 36+

Scale 4. Need for Support in DEE Learning Activity: items 1-, 4+, 8+, 12+, 14+, 31+

Scale 5. DEE Dishonest Strategies Prevalence: items 9+, 13+, 15+, 19+, 24+, 27-

Scale 6. DEE Accessibility: items 10+, 14-, 20+, 36-, 37+

Total score: items 1+, 2+, 3+, 4-, 5+, 6+, 7-, 8-, 9-, 10+, 11+, 12-, 13-, 14-, 15-, 16+, 17-, 18-, 19-, 20+, 21+, 22-, 23+, 24-, 25+, 26-, 27+, 28+, 29+, 30+, 31-, 32-, 33-, 34-, 35+, 36-, 37+, 38-.

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