Project-based learning as an approach to enhance ecological component in professional education

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Abstract. 93 undergraduate and graduate students of the Kyiv National University of Technologies and Design were interviewed to assess students' attitudes to using upcycling technologies and changes in this attitude over the years of study. Students receive professional education in the clothing industry, studying technology, design, and vocational education and training. Despite the generally positive attitude, studies have shown a lack of understanding of the benefits arising from the application of waste administration technologies. Both junior and senior students demonstrated similar bimodal distributions concerning perceived benefits. Approximately half of the students (sceptics) disagree with the benefits, and the other half (optimists) express barely noticeable confidence in the benefits. The changes to the curricula of two disciplines for one of the specialities (vocational education and training) included several classes on problem-based and project-based learning and preparation and execution of ecology-related projects. This experiment changed the existing preferences of students significantly, reducing to zero the number of sceptics and forming a one-peak Gaussian of optimists. Understanding the main problems of waste management is essential in enhancing the ecological component of training future clothing industry specialists operating under sustainable development conditions.

Keywords: project-based learning, professional education, upcycling, recycling

1. Introduction

The modern labour market assumes that universities produce ready-to-work engineers. About 70% of surveyed employers are satisfied with the professional and social skills of graduates of Kyiv National University of Technologies and Design (KNUTD). However, some gaps in graduates' competencies still exist; this concerns the ability to independently acquire new knowledge, work independently, work in a team and apply engineering knowledge to solve real production and ecological problems.

Technologies studied in training a future engineer usually relate to specific stages of the product's "life cycle". This technological "life cycle" starts with the product design and engineering stage, which becomes crucial to ensure the sustainability of production. At this stage,

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the possibility of energy [17] and materials [7, 40] savings and recycling of the product after its use [31, 38] is established.

Other technological stages that should be noted are cutting, product manufacturing, transferring the developed technology to production, sales and the stage of product use. The need for time is to design the possibility of reusing or adapting the product to another purpose, i.e. different ways of recycling. However, this stage is still often disregarded in the study of technology. The need or order for specialists familiar with modern recycling technologies comes from employers.

In production, the transition is made from optimising individual stages of technology to fully understanding and optimising the technological chain throughout the product's life cycle. Accordingly, specialists who understand this and can work at all life cycle stages and predict the influence of technological activities on the environment are in need. There is a lack of such specialists, as no targeted training would consider modern ecological requirements. There are no specialists or no production, so modern technologies cannot be implemented.

Therefore, there is already a contradiction between employers' needs and graduates' existing competencies, which encourages changing engineering training content for future professionals. In this context, the university's role is to provide the best training for future engineers. It can be ensured by forming a graduate's adaptive profile that meets the modern requirements of the labour market.

Thus, training specialists who have mastered the necessary competencies is a key factor in industrial development. The novelty of this article lies in the fact that it raises the issue of forming a profile of a graduate adapted for work in the clothing industry in current conditions. In particular, the paper focuses on enhancing the ecological component in engineering education.

The effectiveness and quality of training future engineers depend on many factors. For example, individual learning preferences are essential [14]. The educational preferences of students of technical specialities have been sufficiently studied [10]. The account for learning preferences allows one to optimise teaching methods, forms and means to train typical engineering students that best meet their needs. In current conditions, when the role of academic mobility has significantly increased, another essential aspect of effective learning is the problem of teaching in a foreign language [16].

As shown in a previous study [11, 30], most students in all majors do not understand the benefits of recycling. Therefore, they rarely engage it in practice and are not even interested. There have been no significant changes over the years of study, which is an obvious disadvantage of the existing learning process. This fact shows that the current training programs do not contribute to accumulating the necessary knowledge about processing and forming relevant competencies.

Problem-based learning (PBL) is best suited for training future engineers [13] because it best contributes to forming key competencies of sustainable development specialists. However, this approach has gained limited application in Ukrainian higher education institutions. The PBL method is mainly used when writing courses and diploma projects and has not traditionally been used to teach fundamental or vocationally oriented disciplines.

At the same time, the ability to design and manage projects is one of the most critical competencies of an engineer. This competence involves the ability to participate in various aspects of project development and implementation, including informational, material, financial and personnel support. It also consists of managing the team's strategic growth and correctly using the tools necessary to implement programs to ensure effective positive change management and effective communication. Therefore, activities aimed at designing and managing projects should become a vital component of the training of future engineers.

However, there is a contradiction between the desired and applied teaching methods. Student-centred learning, including learning in teams, is desirable for meeting the needs of students and helpful for forming their competencies but is not always applied. In contrast, traditional teaching methods are much more frequently used in reality. In recent years, the popularity of problem-based approaches to educational activity has been growing significantly [8, 15, 25]. All research in this direction is divided into at least two parts. In the first case, learning is fundamentally problem-solving, and this approach is known as PBL. However, this organisation of the educational process primarily focuses on theoretical and methodological aspects characteristic of works in pedagogy [22, 24]. The second part of the research deals with specific examples of applying the mentioned learning technologies in various subject areas for the organisation of project-based learning. This approach is commonly referred to as project-based learning (PjBL). Researchers are mainly teachers of specialised disciplines in the relevant fields (computer engineering, technologies, design, etc.) [6, 21, 36].

Both approaches, namely PjBL and PBL, are similar in the involvement of students in solving real-world problems; they imply collaboration in teams and simulate the professional environment. However, they are based on two different strategies. In PBL, learning issues are considered problem situations. In PjBL, a student project is viewed as an end product. Such project results from the study of the discipline [18, 27]. PjBL is usually considered a further development of PBL.

The article's purpose was to implement PBL and PjBL methods into operating educational programs of professional disciplines. Appropriate modules of the discipline contents were developed and tested. The impact of new modules incorporated into the existing learning programs on improving the perception and understanding of upcycling technologies as an important ecological component of professional education was investigated by surveying students studying in a modified program compared to students in a traditional study program.

2. Materials and methods

The experiment was conducted at the Faculty of Arts and Fashion at KNUTD. Students of different enrolment years from 2014 to 2017 participated in it. The faculty provides professional education to various specialities in the clothing industry. A total of 93 bachelor's and master's students participated in the study. Among them, 22 students specialised in the design, 36 studied the technology of clothing industry products, and 35 specialised in vocational education and training (VET).

A survey was conducted to determine students' attitudes to the upcycling process. The questionnaire was developed in Great Britain to study the behaviour of people actively involved in upcycling. The materials used in the survey were designed according to the principles of the Theory of Interpersonal Behaviour [35] and the Theory of Planned Behaviour [1]. According to these theories, several factors (a total of 9 factors) shape a person's attitude toward recycling waste. The combined model, united elements of both approaches, was presented in [32, 33]. The questionnaire contained 62 questions. A 7-point Likert scale was used to quantify the responses. A 7-point Likert scale ranges from one extreme to another, from "extremely likely" to "not at all likely." The influence of each factor is estimated based on the answer to the different number of questions. Other details of the questionnaire and the conducted survey, including Cronbach's alpha test for internal consistency, are given in the work [11, 30].

The frequency of application of upcycling techniques assessed the personal experience of each respondent in upcycling behaviour (*UB*). Respondents chose one of eight available answers that best describes their experience: never use upcycling (1 point), less than once a year (2 points), once a year (3 points), once every six months (4 points), once a quarter (5 points), once a month (6 points), once a month week (7 points), and more than once a week (8 points).

The syllabi of the two disciplines for students specialised in VET were supplemented with classes using project activities. The students of this speciality will have the most significant influence on the teaching of future professionals and the development of the industry as a whole in the coming years. Students of all other specialisations (technology and design) studied according to traditional, unchanged educational programs.

The method of problem situation development and the technology of project-based method (PBL) application are described in many papers and usually include three stages [4, 28]. At first, educational material that could be a subject for creating a problem situation is selected. Then, the necessary knowledge, including factual material and information resources, is identified. The third stage focuses on a methodological analysis of the emergence and resolution of contradictions. The general scheme of PjBL application in learning consists of five steps: a problem-target stage, the development of requirements specification, practical work, and preliminary and final defence of the developed project [19, 34].

The practicality of the application of PBL and PjBL was studied in teaching two disciplines. The first discipline was used to practice the skills of working on individual elements of the PBL and PjBL methods under teacher guidance. The second one was used for the independent creation of student projects by PjBL.

The first discipline, named "Creative learning technologies", included 180 hours (6 ECTS credits) and consisted of 54 lecture hours and 76 hours of practical work. The second discipline is "Fundamentals of engineering and pedagogical creativity." Its volume was 270 hours (9 ECTS credits), including lectures (44 hours) and practical work (66 hours). The syllabus of the first discipline was supplemented with three new lectures and three practical classes. Students mastered the PBL and PjBL methods and performed a cycle of works focused on developing creative abilities, thinking, and ecological approaches. Finally, students independently developed webinars using the PjBL method.

Five new lectures and five practical works on project development were introduced into the syllabus of the second discipline to master the primary elements of a project, such as the "tree of problems", "tree of solutions", a logical-structural matrix of the project, etc. After that, the mandatory development of a project for an arbitrary topic was added as an individual research task for eight weeks. Environmental projects devoted to the organisation of waste management in the textile industry occupied a large part of the topics. Teachers played mainly advisory roles in the process of project design and implementation.

In parallel with the project activity, practical classes of the course "Fundamentals of engineering and pedagogical creativity" aimed to improve creative processes. The self-questioning techniques, known as SCAMPER, were used to expand a view of the problem's environment and develop solutions [29]. The method of F. Kunze, improved and renamed to the Method of Focal Objects (MFO), was applied for problem-solving and creative thinking enhancement [39]. Some components of the Theory of Inventive Problem Solving (known as TRIZ) were utilised. They focus on provoking a breakthrough in students' thinking patterns and the way they approach problem-solving [2]. Besides, some elements of the creative training system CARUS [26] were also used in teaching. They focus on stimulating creative thinking and developing skills to solve new problems in engineering activities.

Statistical analysis of the obtained results was carried out using the IBM SPSS version 21 statistical program package [20]. The total sample of respondents was divided into separate groups, depending on the year of study or speciality. In this case, the Mann–Whitney U test (if two groups were compared) or the Kruskal–Wallis H test (if three or more groups were compared) was used to assess the presence or absence of a statistically significant difference between individual groups. The mentioned tests are non-parametric tests for two (or more) independent samples of rank (or ordinal type) variables that allow one to determine if the distributions of both populations are equal.

Fitting experimental distribution curves using nonlinear curves with the fitting parameters, function expression, constraints and determination coefficients R^2 was performed using the software package OriginLab, version 8.

3. Results

3.1. Mastering of PBL and PjBL methods

As already mentioned, the project activity was incorporated into the educational programs of VET students. All changes took place within the credit framework approved by state education standards. Preliminary, the effectiveness of the implemented training modules was determined based on the results of task fulfilment. In addition, students underwent a small survey regarding their impressions of the new modules after their completion.

Survey data showed that most students demonstrated a positive attitude towards projecting. They are more interested in learning using PjBL than in traditional learning. They agree that teaching strategy is an essential factor influencing their interest in learning. About 51% of students agreed that PBL improves their critical thinking. About 49% firmly decided that they became more creative when designing their projects. Such conclusions fit well with literature data [3]. The PjBL aims to involve students in studying real-life events and developing personal creativity. Teachers noted that when creating a project, students often exchanged ideas, discussed ideas within a group and learned to find solutions. PjBL increased students' ability to work in a team.

Nevertheless, the overall result of the PjBL application is not entirely satisfactory, as 23% of the students could not complete all project stages. The success rate was much higher – 93% if they worked on the project entirely under the teacher's guidance. The reason seems to consist of a lack of student knowledge needed to develop a full-fledged project and some teachers' problems they experience using PBL and PjBL methods.

According to the student survey, the most severe difficulties occurred in the following types of activity: formulation of the purpose and identification of project tasks; creation of logical framework (logframe) matrix; and budget calculation. A lack of necessary knowledge in economics caused the latter difficulty. Probably, there is a need to implement interdisciplinary projects in the future. Such a transition will provide an opportunity to involve teachers of economic disciplines as supervisors or project consultants.

3.2. Students' perceived benefits after PBL and PjBL studies

As shown in previous studies [11, 30], the influence of different factors on upcycling behaviour varies significantly. Two elements (perceived habits (*PH*) and perceived facilitating conditions (*FC*)) have a generally small impact on expected upcycling behaviour (*UB*). The other five factors, on the contrary, significantly influence the intention factor (intention *In*), which in turn influences and correlates with *UB*. These influential factors are the following attitude (*At*); perceived behaviour control (*BC*); and social factors, which include subjective norm (*SN*), personal norm (*PN*) and role beliefs (*RB*).

The influence power can be illustrated as follows. Depending on the frequency of upcycling, the respondents can be conditionally divided into three groups. Respondents who occasionally practice upcycling (once a year and less often, corresponding to 1 to 3 points) can tentatively be called sceptics. The group of upcycling optimists includes those who practice upcycling more often than once every three months (5-8 points). Between them is an intermediate subgroup (*UB*=4 upcycling once every six months). It is a small group, and an analysis of their responses shows that they are still undecided about upcycling. Therefore, when comparing the opinions of upcycling optimists and sceptics, those who are undecided will not be considered. The maximum difference in the influence of various factors exists between the respondents' answers of groups 1 and 2. Mann-Whitney statistics were used to compare them. The results of the comparison of average values for all factors are given in table 1.

Table 1
Results of Mann–Whitney U test for *UB*<4 and *UB*>4.

	At	*SN*	*PN*	*RB*	*BC*	*In*	*FC*	*PH*	*PB*
Mann–Whitney U statistics	462.0	523.0	676.5	662.5	516.0	403.5	763.0	763.0	803.5
Z	-3.49	-2.82	-1.36	-1.49	-2.89	-3.95	-0.54	-0.54	-0.16
Significance (2-sided)	0.000	0.005	0.174	0.136	0.004	0.000	0.590	0.590	0.876

There is a significant difference between groups for factors *At*, *In*, *BC* and *SN*. In all these cases, the agreement of active upcyclers with the questionnaire questions (i.e. the calculated ranks) appears to be much more reliable than the agreement of people who do not resort to upcycling in their activities. That is, it is evident that the factors listed above have the most significant influence on the behaviour of respondents.

The perceived benefits (*PB*) factor stands out. According to the used model, this factor does not directly influence upcycling behaviour; however, it owes a lot to shaping attitude (*At*) toward upcycling. At the same time, previous studies have shown that students do not understand the benefits of upcycling. The average *PB* factor for the group as a whole is approximately 3.6. In other words, the answers to the questions about the availability of benefits ranged from neutral "neither agree nor disagree" to "somewhat disagree". Any 15 benefit options (questions in the questionnaire) did not receive at least minimal support among the students.

A lack of understanding of the available benefits of using upcycling technologies forms a generally restrained attitude towards upcycling technologies. It is possible to assume that the highly positive attitude towards upcycling is partially artificial, initiated by modern fashion trends but not supported by thorough knowledge. This assumption is supported by figure 1.

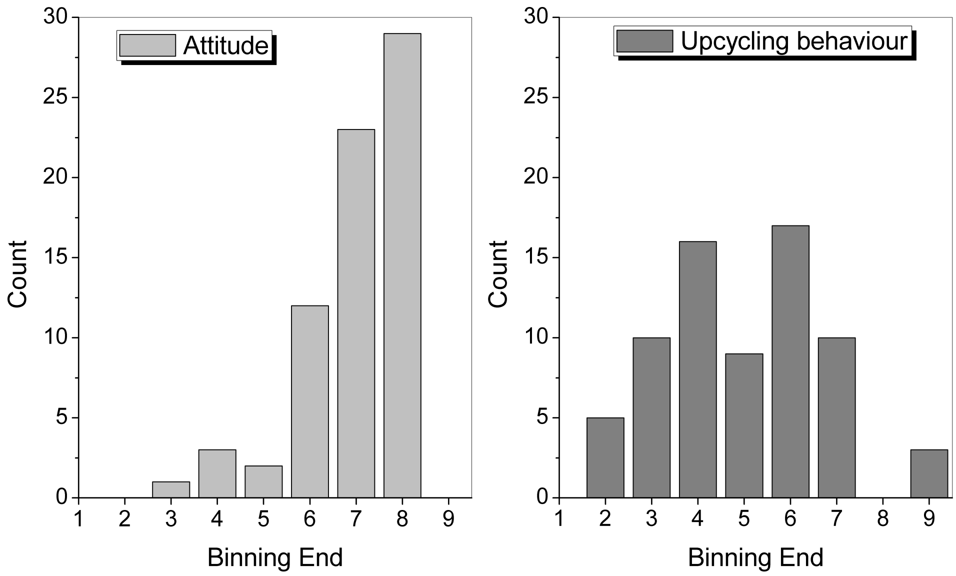

Figure 1: Frequencies of attitude and upcycling behaviour count as a function of the average scores in respondent responses. Only answers of junior students (1st to 3rd year of study) were considered.

The frequencies of factors *At* and *UB* are compared as a strength of their perception. The given data refer only to students of 1-3 study years who have not yet participated in project training. As you can see, the number of respondents is constantly increasing with the increase in loyalty to the *At* factor. In contrast, if the frequency of use of this technology in real life (*UB*) is taken as a positive attitude towards upcycling, then the number of respondents does not increase. Moreover, two peaks are observed at intermediate values of *UB*. The nature of this phenomenon will be discussed further.

In other words, in theory, the respondents have a very positive attitude towards upcycling, but in practice, that is, in real life, they are much more sceptical. The reason for such a discrepancy may lie in misunderstanding the potential advantages and the unformed attitude of society and individuals to the importance of upcycling. At the same time, a careful attitude to materials, energy, and pollution of the surrounding environment is critically important for forming the professional competencies of future engineers. We are discussing the environmental component and several other competencies, such as responsive project management, implementation and integration competencies, creativity. This conclusion, among other things, is evidenced by the demands of the industry. Under the conditions prevailing today in engineering education in Ukraine, the formation of competencies that include a caring attitude in future specialists for the consumption of energy and materials and pollution of the surrounding environment [9, 12, 17] is inhibited.

Also, it follows from the previous results that the assessment of *PB* is weakly dependent on the year of study. That is, the existing educational program does not contribute to developing competencies related to waste processing. As already mentioned, changes were made to the initial program associated with initiating project activities to correct this shortcoming. Much attention was paid to waste processing technologies, particularly upcycling techniques, in the project topic. Therefore, after graduation from project studies, a survey was conducted according to the [32, 33] method. The results are compared for student groups that studied or did not study projecting methods. The primary attention was paid to the perception of the benefits of upcycling. For each of the two groups of students mentioned above, the understanding of available benefits was assessed separately for students of junior years (years 1-3 who did not participate in the project activity yet) and separately for senior years (4th year of bachelor and master students). The distribution by years of education was carried out to ensure the maximum possible equality between sample sizes.

The results illustrating the number of students (technologists and designers – 58 respondents) concerning the perceived benefits are shown in figure 2. The attitude to *PB* is defined as the average score for all 15 questions related to *PB* in the questionnaire. The distribution has a clearly expressed bimodal character for junior and senior students. The positions of the peaks on the curves and the area under these peaks look similar at first glance.

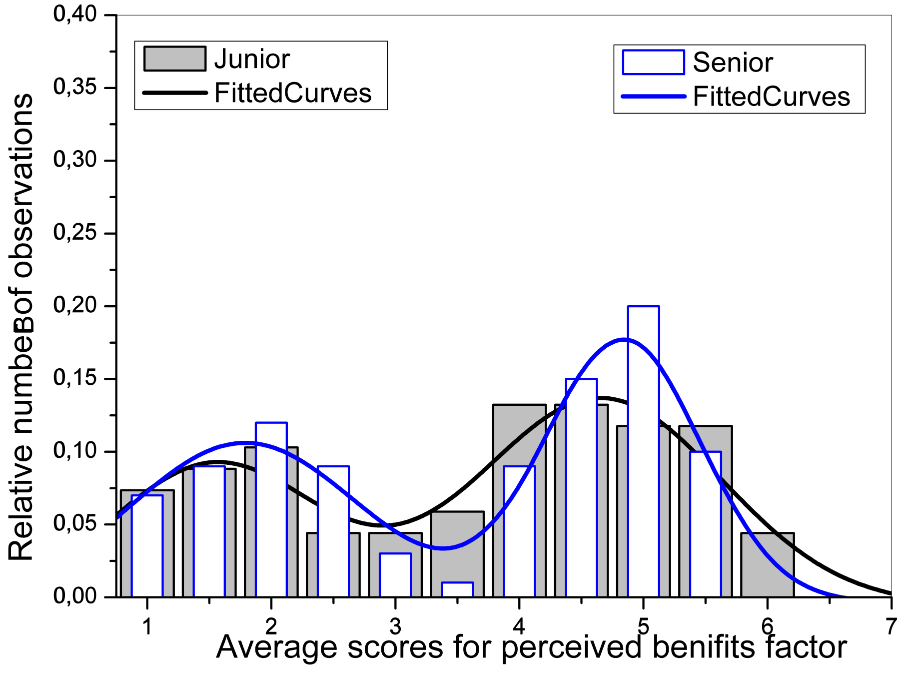

Figure 2: Relative numbers of observations as a function of the scores for the perceived (averaged over all 15 items) benefits for groups of junior and senior students of the specialities technology and design, respectively.

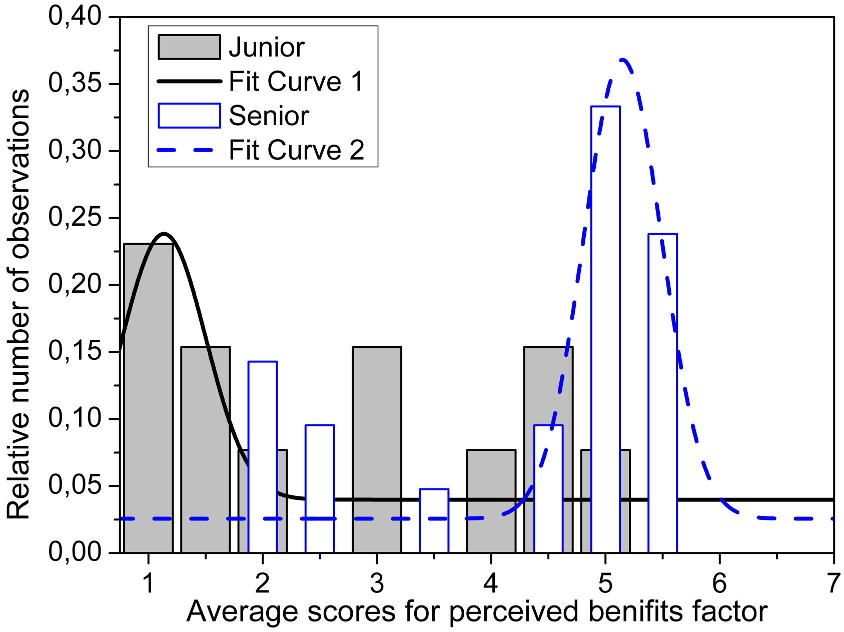

Figure 3: Relative numbers of observations as a function of the scores for the perceived (averaged over all 15 items) benefits for groups of junior and senior students of the VET speciality, respectively.

For VET students (35 respondents), a similar illustration (figure 3) looks somewhat different. First, pronounced bimodality disappeared. Single-peaked Gaussian curves approximate the experimental curves for both junior and senior courses.

In terms of individual items, the difference between juniors and seniors was significant in answering ten questions out of 15. It gave a significant difference between the average values at the p<0.05 level (figure 3). Juniors still pretty strongly disagree with the benefits claim. As seen from the approximation equations, the peak of responses for juniors is near the mark of X_c=1.1357 points, which almost corresponds to the "strongly disagree" option. Among senior students, the opposite opinion prevails with the strength of "somewhat agree" since the peak of the answers is about 5.1484 points. The given illustration only demonstrates the existing difference in the ratio but cannot explain the reasons for its occurrence. On the one hand, the opinion about the available benefits is still rather weakly expressed. On the other hand, the softening of the negative attitude towards this issue with the years of study with the use of appropriate methods (projecting) is undeniable.

4. Discussion

4.1. Formation of a conscious attitude towards waste recycling under project activity

The obtained results, namely changes in the understanding of the benefits of upcycling among junior and senior students of various specialities, indicate the feasibility of introducing PBL and PjBL technologies into educational programs. Undergraduate students of all majors show mild scepticism regarding the possible benefits of engaging in upcycling activities. Accordingly, it is not easy to expect that future teachers and engineers in the clothing industry, who are unaware of the benefits of recycling, will consciously use environmental standards in their professional work. The use of projecting methods leads to significant changes in the attitude to this issue, as shown in figure 2 and figure 3. More conclusions become available if we try to approximate the obtained experimental data.

The multiple peaks were fitted as the accumulation of the Gaussian function. Thus, the approximation curve for the distribution of juniors and seniors according to the average benefit score is generally described by the following equation:

$$y = Y_0 + \frac{A_1}{w_1\sqrt{\frac{\pi}{2}}} \exp\left(-2\frac{(X - X_{c1})^2}{w_1^2}\right) + \frac{A_2}{w_2\sqrt{\frac{\pi}{2}}} \exp\left(-2\frac{(X - X_{c2})^2}{w_2^2}\right) \quad (1)$$

where there is a bimodal curve for students of technologists and designers (figure 2) and a unimodal curve for VET students (figure 3). Numerical parameters obtained in the approximation process are listed in table 2.

Table 2
Fitting parameters for the distribution of student number vs the average *PB* score in junior and senior groups of students of technology, design and VET specialities.

	Technology and Design		VET	
	Junior	Senior	Junior	Senior
R^2	0.9337	0.95826	0.506	0.81904
Y_0	-0.0050±0.0103	-0.0036±0.0082	0.0390±0.0692	0.026±0.0135
X_{c1}	1.550±0.1217	1.7883±0.1032	1.1357±0.1217	
w_1	1.5731±0.2903	1.7544±0.2525	0.7283±0.2903	
A_1	0.2039±0.0408	0.2539±0.0415	0.1824±0.0408	
X_{c2}	4.6549±0.0895	4.8352±0.0463		5.1484±0.0623
w_2	1.8549±0.2374	1.1133±0.1052		0.6823±0.1447
A_2	0.3458±0.0542	0.2840±0.0294		0.2953±0.0527

Table 2 clearly shows that students who did not gain experience in PBL and PjBL do not exhibit a statistically significant change in their attitude to *PB* during their studies. Thus, for both juniors and seniors, this group is characterised by the presence of two subgroups, sceptics and optimists, respectively, in their attitude to *PB* (two maxima on the curve). The coefficients of determination of the approximating curves have high values of R^2>0.93, which indicates a good agreement of the experimental data with fitting curves. The maximum peaks for sceptics are equal to X_{c1}=1.550 and X_{c1}=1.7883, and the difference between their positions is not statistically significant. For both subgroups, sceptics' view lies somewhere between "completely disagree" and " disagree" with the existence of benefits from upcycling.

For optimists, the peaks are located at X_{c2}=4.6549 and X_{c2}=4.8352 for younger and older students, respectively. The difference between them is also relatively small. Such estimates lie between a neutral attitude towards *PB* (4 points) and a rating of "somewhat agree" (5 points). Although for both subgroups, the number of optimists (defined by the value of A_2) is slightly greater than the number of sceptics (A_1), this difference is not statistically significant. We can roughly say that for technology and design students, the number of sceptics and optimists concerning recycling is 50:50, and this ratio practically does not change with the years of study.

Students specialising in VET demonstrate qualitatively different behaviour (table 2). First of all, the experimental data are described by single-peaked Gaussians. Although, the determination coefficients for both subgroups of students are not very high, especially for junior-year students (R^2=0.506). It means that the obtained experimental data are only partially consistent with model ideas about the existence of one maximum on the curve. Also, the number of VET students is twice as low as other specialities, which increases data spread.

The position of the maxima on the *PB* scale is significantly different. Scores of junior-year students accumulate primarily on the left (X_{c1}=1.1357), i.e. sceptics about the benefits of upcycling prevail in this subgroup. On the contrary, most senior students are optimists, and their average assessment of the benefits is X_{c2}=5.1484. The share of optimists is almost twice as large as the share of sceptics. It follows for the comparison of A_1 and A_2 in table 2.

Changes in the mentality of students occur quickly enough with a purposeful provision of training with the necessary content and organisation of students' activities. At the same time, introducing meaningful modules is not enough, and mastering them does not provide an opportunity to look at a complex of problems globally. Therefore, to achieve the desired efficiency, more significant changes in educational programs with the introduction of integral disciplines are necessary. Such disciplines should be interdisciplinary, allowing the formation of relevant skills and knowledge not episodically but constantly. Introducing new disciplines should be accompanied by specific corrections in their teaching.

4.2. Competencies for professional education in conditions of sustainable development

Learning by the PBL and PjBL is one of the pedagogical approaches used to form students' competencies. In Ukraine, it is carried out fragmentarily by introducing special modules of disciplines and implementing research works with students' participation. This situation contrasts with modern European practices, where professional education is based on well-defined competencies. An analysis of existing practices and publications of European universities was carried out [5, 23, 37]. Five key, one general and two professional competencies were identified (table 3 and table 4). Today they are not formulated as separate competencies in educational programs of Ukraine and vice versa are characteristic of European educational practices.

The given list of competencies does not pretend to be universal but is formed to train students in professional education. Thus, learning goals and outcomes will be formulated through competencies in cognitive, socio-emotional and behavioural aspects. Key competencies need to be integrated into the educational program. Among them, systems thinking enables the development of action plans and achieving sustainable development goals if successfully implemented (which requires implementation competence). Interpersonal and intrapersonal competencies enable planning and implementation. Finally, integrative competence provides a coherent mix of joint personal planning and implementation efforts, using established procedures to address sustainability issues.

Professional competencies in clothing production technologies complement the key com-

Table 3
Identified key competencies and their descriptors for professional education in conditions of sustainable development.

Key competencies. Definitions	Most common descriptors from the literature
Systems-Thinking Competence (including Futures-, Values- and Strategies-Thinking). Ability to 1) apply modelling and complex analytical approaches, 2) carry out or construct simulations, forecasts, scenarios, and visions, 3) identify, map, specify, negotiate, and apply sustainability values, principles, and goals, 4) construct and test viable strategies (action plans) for interventions, transitions, and transformations toward sustainability	Understand, identify, describe, and analyse sustainability challenges and problems, complex issues, relationships, impacts, structures, unintended consequences, feedback loops, context, interactions across different domains (environmental, social, economic), scales (local to global), and perspectives (interdisciplinary). Anticipate, foresight, envision, craft, analyse, and evaluate long-term future consequences, scenarios and visions regarding intergenerational equity, future generations, and uncertainty. Identify, assess, negotiate, reconcile, reflect on, map, and apply sustainability principles, morals, norms, ethics, goals, integrity, justice, conflicts, and trade-offs. Design, create, develop, and test transformative, innovative, viable, feasible interventions, transitions, strategies, action plans, solutions, etc., considering barriers, inertia, path dependence
Implementation Competence. Ability to implement sustainability strategies (action plans), including implementation, adaptation, transfer and scaling, in practical and efficient ways.	Implement, enact, adapt, manage, transfer, scale action plans, strategies, change plans, intervention plans, governance initiatives, etc.
Intrapersonal Competence. Ability to avoid personal health challenges and burnout in advancing sustainability transformations through resilience-oriented self-care (awareness and self-regulation)	Enable, motivate, and facilitate interdisciplinary, transdisciplinary, cross-cultural collaboration in teams and among stakeholders through listening, compassionate communication, negotiation, conflict resolution, empathic leadership, etc.
Interpersonal Competence. Ability 1) to collaborate successfully in interdisciplinary and professional teams; and 2) to involve diverse stakeholders, in meaningful and effective ways, in advancing sustainability transformations.	Reflect, motivate, have respect for, be responsible, be empathetic, self-care for identity, commitment, feelings, burnout, personal boundaries, limits of capacity, etc.
Integration Competence. Ability to apply collective problem-solving procedures to complex sustainability problems: 1) to develop viable sustainability strategies (action plans); and 2) successfully implement them in collaborative and self-caring ways	Develop, apply, promote, and make decisions to advance sustainability by using viable, equitable, and inclusive solution processes, procedures, frameworks, schemes, etc.

Table 4
Identified general and professional competencies and their descriptors for professional education in conditions of sustainable development.

Competence. Definitions	Most common descriptors from the literature
General competency	
Creativity. Ability to envision, develop, implement, and assess transformative interventions for sustainability	Reshape, criticise, analyse, take a decision, critically interpret text/information, show initiative, create, synthesise, integrate, change, propagate
Professional competencies	
Compassionate communication. Ability 1) to communicate with others without accusing, to hear criticism, to have constructive dialogue, 2) to communicate to reduce conflicts and improve relationships between people, and 3) to understand the influence of your communications on life for you and others around them.	Communicate, understand the role of communication and social processes in making sustainable decisions, demonstrate strategies for effective interviewing and successful communication of personal and professional statements when it comes to sustainability, respond, explain, understand, help, discuss, discuss, promote, categorise, perform, present, report
Responsive project management. Ability to use the tools necessary to implement organisational projects and programs appropriately and ensure positive change management and effective communication.	Demonstrate leadership skills. Organise teamwork, and perform individually assigned work carefully, efficiently and on time. Know project approaches to increase the sustainability of the organisation/processes, determine project types, plan and initiate, develop, adhere to, use, compare, complete, defend, summarise, integrate

petencies of sustainable development. Compassionate communication and responsive project management are essential for advancing sustainability transformations on a more fundamental level. Following the defined competencies, program learning outcomes were developed using the descriptors listed in table 3 and table 4, which are strictly measurable. Training results will allow for establishing the compliance of the quality of training of specialists with the requirements.

5. Conclusions

1. The attitude to the use of upcycling technologies among students of three specialities majoring in technology, design and professional education in the clothing industry was investigated using the questionnaire method. It is shown that according to most characteristics, students have a positive attitude towards upcycling. At the same time, this positive attitude is more theoretical, often not supported by appropriate actions, but is the result of a popular trend which does not have a firm and reasoned belief. Any change in circumstances will quickly change the situation to the opposite.
2. One significant result is a feeble understanding of the benefits that the use of upcycling technologies can bring. Many students do not understand the benefits of careful

waste management – economic, environmental, or benefits at the level of consciousness development, and it undermines the ecological bases of engineering education.

3. Among students of all specialities and courses who studied according to the traditional program, two subgroups of sceptics and optimists of approximately the same magnitude stand out concerning benefits. Sceptics are characterised by a lack of acceptance of the available benefits of upcycling, and the strength of the lack of acceptance is, on average, between the scores of "strongly disagree" and "disagree" (1.55 and 1.79 points for junior and senior students, respectively). Among optimists, the average strength of perception of upcycling is very moderate – an average score is between a neutral position and "somewhat agree" (4.65 and 4.84 points for junior and senior students). Thus, the attitude toward waste disposal or utilisation practices remains almost unchanged throughout the years of study by traditional programs. This fact means that training according to existing educational programs does not produce an increase in interest in the problem of waste processing.
4. The attitude to the benefits of upcycling was improved by introducing PBL and PjBL methods into the curricula of the two disciplines in VET. Projecting methods gain new competencies and real teamwork experience, increasing their motivation to learn, develop creativity and perceive the benefits of recycling. Students initially experienced problems during the development of problem situations. However, they moved from simple elements of the researched methods to complex ones under teacher guidance. As a result, both PBL and PjBL methods have been successfully mastered by 93% of all students.
5. Using PBL and PjBL methods decreased the number of sceptics among senior VET students to almost zero and simultaneously increased the number of optimists concerning upcycling. Among junior-year students who did not listen to projecting methods, the peak corresponding to non-perception of benefits dominates. So, developing the ways of implementing PjBL to a broader student circle is a promising topic for further research.
6. The central and extensive perspective for further work is the development of training programs in professional education that will ensure the formation of the necessary competencies, which in turn still need their final formulation.

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