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Sustainable Language Training for Engineering Students: Integrating Resource-Efficiency into the Course Content through the Educational Process

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Abstract: The sustainable use of the Earth's resources is recognized as increasingly important on a global scale, especially in relation to natural resource management, and is effectively addressed under the auspices of resource efficiency within engineering education. This has led to an increased demand for engineers able to carry out professional activities whilst considering sustainable issues, as well as adopting state-of-the-art technologies, and applying the best domestic and foreign practices. The study of resource efficiency encompasses a range of aspects, from natural resources, through information management, technological tools, time, and other resources. Effective engineering education should include resource efficiency, whilst enabling students to become autonomous lifelong learners, and to develop as potential researchers and professionals, able to take account of emerging issues and approaches for resource efficiency. This paper begins by analyzing the concept of resource efficiency and key research in this area. It goes on to provide a framework to demonstrate how resource-efficiency can be delivered as part of the teaching of year one engineering students, with a theoretical and methodological scaffolding. The paper presents a case study which utilizes resource efficiency within language training. The paper defines the notion of language training resources and their classification. The case study demonstrates the feasibility of the proposed approach and includes a formal assessment to show its effectiveness.

Keywords: sustainability; resource-efficiency; personal engagement; professionalization; autonomization

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1. Introduction

1.1. Resource-Efficiency and Sustainability: Motivation and Background

Sustainable Development and the associated Sustainable Development Resource-efficiency (RE) can have an impact on almost any sphere of human life and work, enabling a sustainable approach for human activities that is recognized as increasingly important [1].

Sustainability was recognized internationally in late 1960s and early 1970s, with Sustainable Development as a concept being the focus in 1972 of a Stockholm UN conference.

This was a key focus for the Brundtland Commission report in 1987 on "Our Common Future", and a major part of a United National summit in 1992 in Rio de Janeiro, which developed a response to Brundtland. In 2002, an international summit on SD developed initiatives to support SD globally, including "Education for Sustainable Development" (ESD). In 2012, this developed into the Sustainable Development Goals (SDG), and in 2015, all of the UN member states adopted the "2030 agenda for Sustainable Development" with the goals at the heart of the action. Whilst this context is helpful, it also highlights the challenges, as economic and global pressures mean that the commitments to SD are under threat as countries prioritize other policy issues. The recognition of SD within countries also varies, and resource efficiency can have a higher standing in some contexts as it provides material benefits as well as the broader ethical ones that SD itself seeks to create.

The efficiency of an activity depends on the professional and intellectual characteristics of the practitioner, in particular their outlook and thinking. Following from this, professional education should develop the relevant skills and understanding of the world—their noospheric mentality. This should develop alongside an appreciation of the impact of humankind on the environment, and the need to ensure safety and sustainable/smart resource management of this technosphere [2]. Some employers report that engineering graduates have a low level of understanding of the fundamental concepts of resource efficiency, lacking hands-on experience and awareness of the concepts, relevant international standards, and best practices [3]. The broader subject of sustainable development can be utilized to contextualize and motivate professional behaviors and values, and this encompasses RE as a key aspect for software engineers [4].

Nowadays, there is a high demand for world-class engineers able to demonstrate and apply their competences in accordance with international requirements, considering good practice and approaches to tackle RE problems. Given the international context of this, a high level of academic and professional English is an essential attribute for such specialists. That is why teaching English to future engineers is of particular importance. Even though RE technologies are flourishing and gaining significance worldwide, curricula and teaching materials do not necessarily reflect this. This paper will describe and evaluate a framework for embedding the resource efficiency approach within the language teaching, which has the potential to be applied to other disciplines and teaching.

1.2. A Definition of Resource Efficiency

The term "resource efficiency" originated and is predominantly used in the fields of energy engineering and natural resource management. The etymology of the word "resource" stems from the Old French ressourse, traced back to the Latin resurgere meaning "assistance". The usage of the word "resource" in Modern English varies from the description of a creative competent person to means and conditions increasing productive capacity of an activity [5]. RE can be considered as a measure of human activity, namely the degree of the efficiency of an activity to affect the maximum possible result with minimum expenses measured as a smart and creative use of a wide range of resources. In terms of management, RE provides a means to manage physical, financial, timing, information, human, and other resources in an effective and responsible manner [6]. It does not mean doing more with less resources and eliminating wastes as lean philosophy suggests [7]. Efficiency is turning wastes into resources [8]. Resource efficiency is directly linked to Sustainable Development, with similar themes and with specific application to several of the Sustainable Development Goals. Thus, RE should be considered in all branches of human activity, and especially in the field of professional education and training of engineers to enable a sustainable economy. RE teaching and learning implies applying a state-of-the-art educational approach to enhance language training, maximizing its quality and efficiency due to the effective use of various resources available in an academic environment [9].

The term "resources" as applied to FLT (foreign language teaching/training) denotes teaching and learning resources in a general sense, with objects (teaching materials, facilities, and devices) and intellectual tools (strategies and ways of learning and communicating). These mechanisms can be divided into primary and secondary, technical, and nontechnical. Some authors interpret educational methods, content, and process as didactic means for goals realization. Indeed, a foreign language represents not only the goal but also the means of learning [10–12].

There are various ways to teach resource efficiency, and to attempt to integrate it within different modules. These should outline the engineering profession; the basics of resource efficiency; types of resources; and effective technical communication [13–15].

2. Materials and Methods

2.1. Methodology

The approach to this paper is based on a literature review and analysis, to develop a framework to teach resource efficiency. This framework is presented and described in the following section. Having established the framework, the paper presents a case study of its use (Section 3), which provides data to analyze the effectiveness of the framework in practice. The implementation was carried out as action research, collating a mix of quantitative and qualitative data, with questionnaires used to evaluate the framework when applied in practice.

2.2. Resource-Efficient English Language Training

The development of the proposed effective professional training methodology is based on a mix of psychological and pedagogical concepts, along with a systems analysis approach. This is described in this section and summarized in Figure 1. This paper presents just a theoretical framework and generalized description of the model developed to assess and monitor the process and results of implementing the author's innovative technology in terms of efficiency of using the resource complex in a sustainable way. The application of this model with a detailed description of experimental research work (with the statistical analysis of exact and verified data) will be presented in another (the next) paper to avoid the conflict of authors' interests and rights. The system analysis considered the interconnections of all main components and resource inputs (technical, financial, timing, information, human, etc.) in professional education. One of our main objectives in developing RE language teaching/training (LTT) is to assess the impact of the educational process component on the qualitative and quantitative characteristics of the results. The analysis considered the educational technology, which consists of users (students and instructors), goals and learning objectives, the academic content and organization of the educational process, the methods and means of teaching, the intended results, and their measurement criteria. Such technologies must be effective, manageable, and reproducible. The science-based technologies included the psychological, pedagogical, didactic, and methodical procedures of reciprocity among education members. The technologies are combined with innovative intellectual resources (e.g., multifunctional trainings, heuristic discussions, professional and imitation modeling, etc.) [16,17]. In summary, our approach to teaching resource efficient language learning is based upon the following principal ideas:

- Efficiency of students' self-education and creativity, and their readiness to take responsibility for extracurricular autonomous learning;
- The stage wise transition from an outer instruction of educational process to students' self-management;
- The continuity of monitoring, feedback, and correction, including students' self-control and self-correction;
- Individualization, reciprocal design of personal educational strategies;
- The wide range of educational content and its interpretation;
- Development of academic and professional communication, integration into international educational and professional environments, e.g., teleconferencing, enabling academic mobility, activities such as grant applications and publications;
- Effective use and development of information tools, with intelligent multimedia programs and systems, expert systems, training facilities, and other resources providing high levels of engineering competence and productive efficiency.

There are language, linguo-didactic, and autodidactic means and resources methodized in scientific research works. The language means include lexis and grammar, text and discourse, communication acts, etc. Technical tools, teaching materials, task systems, and methodical instructions are classified as linguo-didactic means. As for autodidactic language learning resources, this category is booming and gaining popularity among learners due to the expansion of information and communication technology. "Resources" are commonly associated with ICT, web content, online education courses, virtual learning environments, etc.

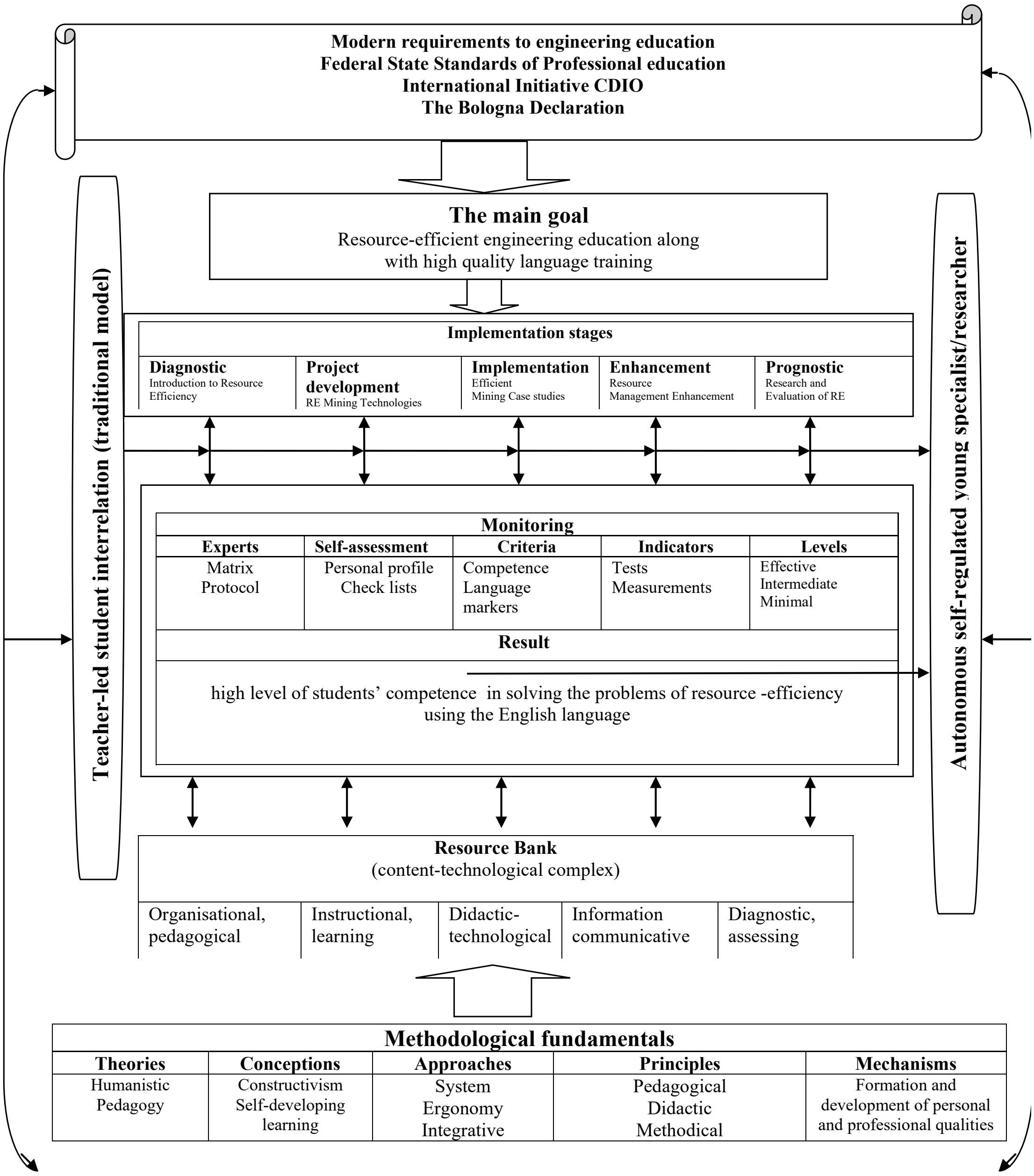

Figure 1. Resource-Efficient second/foreign Language Training (RELT).

Based on the above, we define the term "language training resources" as a specially developed combination of methodical means, materials, and technologies underpinned by the goal and system of developing students as highly effective world-class engineering specialists. The RE technology of language training is based on the principles of engineering pedagogy, the CDIO Initiative, and in accordance with guidelines of international engineering associations, and the International Society for Engineering Education that accredit educational programs at TPU aimed at preparing elite engineering specialists, all of which include our language training course with the framework and technology especially designed and tailored with sustainability and resource efficiency in mind; these two concepts being most in demand for tackling urgent worldwide problems requiring engineers to solve them. The key aim of language training is to form students' experience of successful resource management while solving academic and professional problems. Thereafter, they are gradually involved in creating their own resources (didactical, informational, communicative, technological, etc.) and designing personal learning pathways/environments to provide the quality of language training and competitive performance throughout their engineering career. In fact, it is the efficient use of methodized resources that optimizes the language training and turns it into an innovative technology in its own right. The optimized choice of didactic mechanisms, along with a rational combination of educational formats is the basic principle that allows us to enhance English language training, whilst minimizing the waste of resources.

From a literature review, collating ideas from several approaches [18–20], we have defined a system of interrelated resource groups (along with social, technological, timing, etc.), namely: education-instructional (teaching materials), didactic-technological (methods, strategies), info-communicative (links, discourse types, information channels), control-diagnostic (reports, evaluation sheets, check-papers, measurement protocols and procedures), pedagogical (conditions, processes, management, involvement, design, monitoring, and other procedures).

Resource-efficient language training implies learner autonomization and LTT syllabus professionalization on the basis of an integrative-synergetic approach that allows us to bring together the capacities of more productive up-to-date scientific theories and technologies (competence and personality developing, PBL, heuristic, ergonomics, ICT, reciprocal, etc.). Syllabus professionalization is achieved through the use of specialized work-related materials, tasks, and procedures (cases, projects, reports, meetings, workshops, discussions, conferences, etc.), which help to create a profession-oriented environment [21,22].

Learner autonomization [23] takes place when students gradually (stagewise with the instructor's support and assistance) acquire the skills and qualities of an experienced learner and independent language user capable of using English for solving professional communicative tasks [24]. This is associated with the increase of learners' resourcefulness [25]), i.e., selection and development of various strategies and resources in cooperation with their language instructors, thus, becoming equipped with a personal toolkit and being able to create their own effective instrumentation/environment to implement meaningful complex projects (academic, professional, communicative, etc.). Being a personality attribute, resourcefulness manifests itself in the efficient use and management of inner (self-potential) and outer resources for personal fulfillment and innovative transformation of the surrounding reality/world. A resourceful learner/student is mobile, constructive, organized, self-efficient, and successful in setting and achieving his goals [26,27].

2.3. Assessment and Evaluation of the Framework

RE evaluation procedures must meet the following requirements:

- Application of a variety of diversified assessment methods and procedures, including experts' participation.
- Not only the theoretic knowledge levels of students should be measured, but also their manner of setting and solving tasks as well as the choice of necessary resources.
- Final estimates of RE and FL communicative competence formedness are defined during the experts' discussion and data analysis.

We have considered diverse methods of assessment in human resources based on the best world-leading practices, such as the Delphi method, foresight, strategic session, assessment-center, etc. The definition of qualitative and quantitative criteria for the educational process results and efficiency could be implemented by means of the Pearson method (constructing criterion competence model) and by using Kirkpatrick's model for parametric evaluation of educational process structural components efficiency (methods, materials, stages, etc.).

There are different approaches to the evaluation of educational process efficiency based on separate quality and quantity indicators of teaching methods, didactic materials, results, etc. [28]. Considering various evaluation techniques, we developed a diagnostic approach, allowing us to combine different types of assessment (psychopedagogical, expert, reciprocal and self-control, portfolio, computerized, etc.). The overall value of educational process quality and RE of LTT technology are estimated by means of a generic parameter-oriented arithmetic model.

RE of the above-described technology is evaluated by comparing several measures using our own generalized arithmetic model. The term "measures" refers to the variables and parameters used to describe the model, these are, for example: *Integral measures include the knowledge acquisition volume V and acquired skills level L . . .* using the following parameters: normative educational time period t_{norm}; limitative time expenditures t_{lim}; three pairs of vectors V_0, L_0 . . . measure of a random variable and a mean-square deviation is a dispersion measure, etc. Integral measures include the knowledge acquisition volume V and acquired skills level L. It must be noted that due to the diversity of skills and competencies, the V and L vectors should be analyzed as a whole and by the components. As we have mentioned, there is a variety of resources, but timing t and material m resources have a universal character. Timing and material resources are considered to have an unambiguous correspondence. However, formalization of this correspondence in the context of educational technology could be implemented considering all the studied process components and the resources used.

The efficiency of the technology is estimated through the analysis of the time dependences $V(t)$ and $L(t)$, as well as an acquisition rate/degree $\frac{dV(t)}{dt}$ and skills development rate/degree $\frac{dL(t)}{dt}$.

The arithmetic model for the quality and RE evaluation is defined using the following parameters: normative educational time period t_{norm}; limitative time expenditures t_{lim}; three pairs of vectors V_0, L_0 (vectors of initial knowledge volumes and competence levels), V_{lim}, L_{lim} (vectors of minimally achievable knowledge volumes and competence levels), and V_∞, L_∞ (vectors of minimal remnant knowledge volumes and competence levels). The components of V and L vectors achieved during the time t_{lim} must satisfy the system of inequalities

$$\begin{cases} V_i(t_{\mathrm{lim}}) > V_{\mathrm{lim}\ i}, \quad i = 1 \ldots n; \quad L_j(t_{\mathrm{lim}}) > L_{\mathrm{lim}\ j}, \quad j = 1 \ldots m \\ V_i(t) > V_{\infty\ i}, \quad i = 1 \ldots n; \quad L_j(t) > V_{\infty\ j}, \quad j = 1 \ldots m, \quad t >> t_{\mathrm{lim}}, \end{cases} \tag{1}$$

where n and m represent the number of components in the vectors of knowledge volume and competence levels, respectively. (i) and (j) are indexes corresponding to certain components of the vectors of the knowledge acquisition volume V and acquired skills level L.

Additional limitations for the technology are associated with the prevalence of retention over forgetting.

$$\frac{dV_i(t)}{dt} \geq \alpha_i, \quad i = 1 \ldots n \qquad \frac{dL_j(t)}{dt} \geq \beta_j, \quad j = 1 \ldots m$$

where α_i and β_j are the prevalence coefficients. The technology must ensure the inequalities $\alpha_i > 0$ and $\beta_j > 0$. These inequalities hold for monotonic increasing functions $V_i(t)$, $i = 1 \ldots n$ and $Lj(t)$, $j = 1 \ldots m$. The higher the values of these coefficients, the more efficient the analyzed educational technology.

To illustrate this, the qualitative integral dependences $V(t)$ for different technologies are given in Figure 2. The dependences 1–4 are for the same educational process duration t_{norm} and similar basic levels of knowledge and competences V_0.

A minimum integral index of knowledge volume and competence level t_{lim} is marked on Figure 2, which is determined by the results of pilot tests.

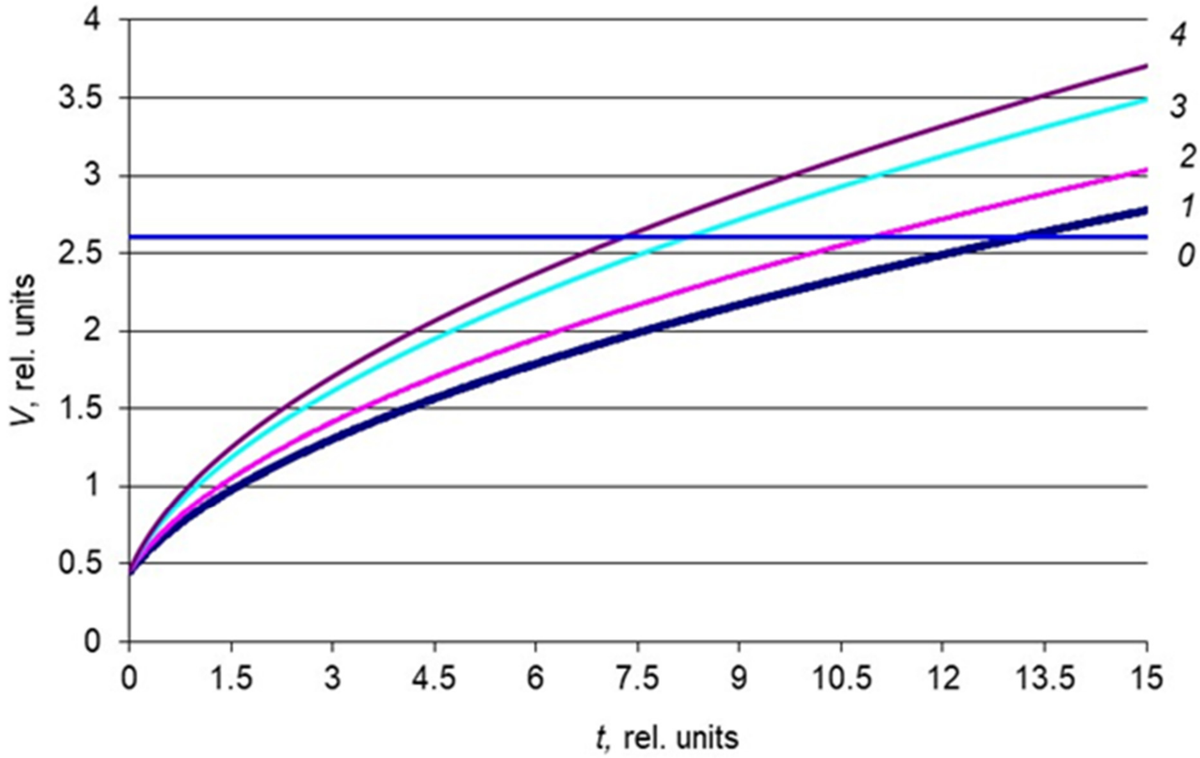

Figure 2. Qualitative integral dependences $V(t)$: 0—required level V_{lim}; 1—low RE level; 2—intermediate RE level; 3—advanced RE level; 4—high RE level.

Remark 1. *The components of the investigated vectors-functions must be continuous but not necessarily smooth. This is since the usage of certain resources might be separated by the time intervals, and, furthermore, the intensity of pedagogical interventions and students' reactions to them are different for these resources. For instance, total language immersion dramatically intensifies the learning process.*

Remark 2. *Students differ by their learning abilities, initial knowledge volumes, and competence levels, so strictly speaking, vectors-functions are random. The vectors and other parameters are random and expressed in letters because this is a generalized description and presentation of our model. However, when it comes to application of this model, we use strictly verified data. This makes it necessary to consider the main parameters of random variable* $\boldsymbol{V_i(t)}$, $\boldsymbol{i = 1 \ldots n}$ *and* $\boldsymbol{L_j(t)}$, $\boldsymbol{j = 1 \ldots m}$ *at an arbitrary point in time. The mean value is the position measure of a random variable, and a mean-square deviation is a dispersion measure. The mean values of integral dependences are given in Figure 3. An absolute continuity of the learning process monitoring is not realistic. However, in order to compare educational technologies, the estimation of mean values and the relevant mean-square deviations* $\overline{V_i(t)}$, $\sigma V_i(t)$, $i = 1 \ldots n$ and $\overline{L_j(t)}$, $\sigma L_j(t)$, $j = 1 \ldots m$ *must be carried out quite often. It is necessary for a timely correction of the pedagogical intervention form and intensity, as well as resources being applied.*

Remark 3. *The two characteristics of the analyzed random variables may not be sufficient. A more complete characteristic feature of a random variable is its frequency distribution. However, a small number of participants in pedagogical experiments does not allow determining random frequency distribution to high precision. Sample distribution functions of the analyzed random values make it possible to implement multifactor monitoring of the educational process with a higher precision.*

To illustrate remark 2, an optimistic scenario and a pessimistic scenario of an educational process development are shown in Figure 3, with the estimation f of a sample relative distribution function/frequency Q_k. The latter is a k-stage assessment, which could be measured on a 100-score scale. The evaluations of all stages characterize the quality of achieving goals against a unified scale along with the sequential tests t_k, $k = 0 \ldots k_0$ connected with the discrete values of $V(t_k)$ parameter. $k = 0$ corresponds to the initial (diagnostic) stage of testing students at the beginning of the course. $k = k_0$ is the final knowledge and competence testing procedure. There's $k_0 = 3$ in the example. Diagnostic testing is aimed at dividing students into groups with relatively similar levels of knowledge.

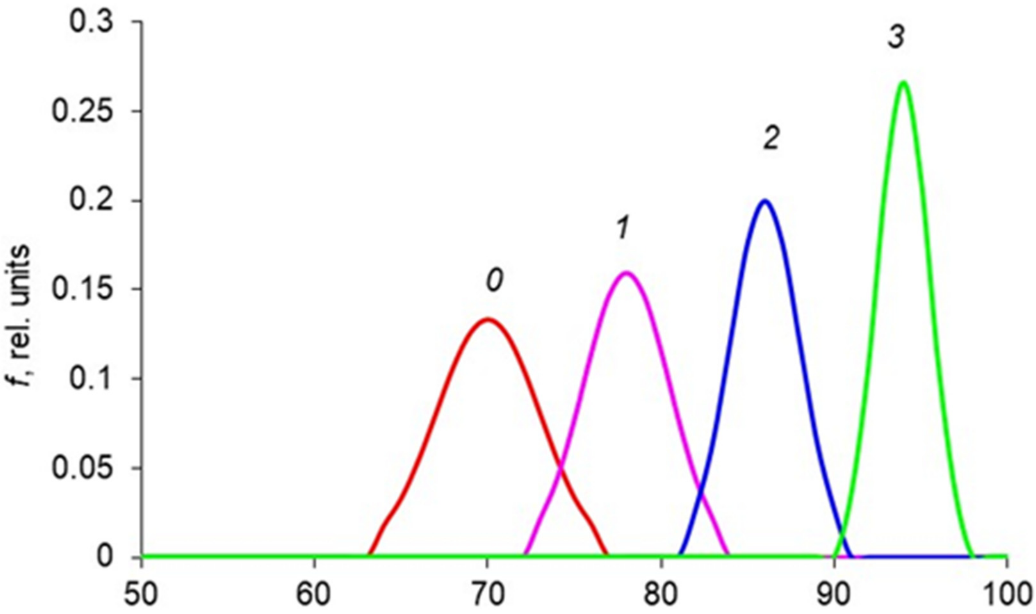

Figure 3. Optimistic modelling of educational process development.

Figures 3 and 4 show the versions of an educational process development: *a*—-optimistic, and *b*—-pessimistic. The shifting of the mean value and the narrowing of distribution density in the optimistic version indicates the increasing knowledge and similarity levels in experimental groups.

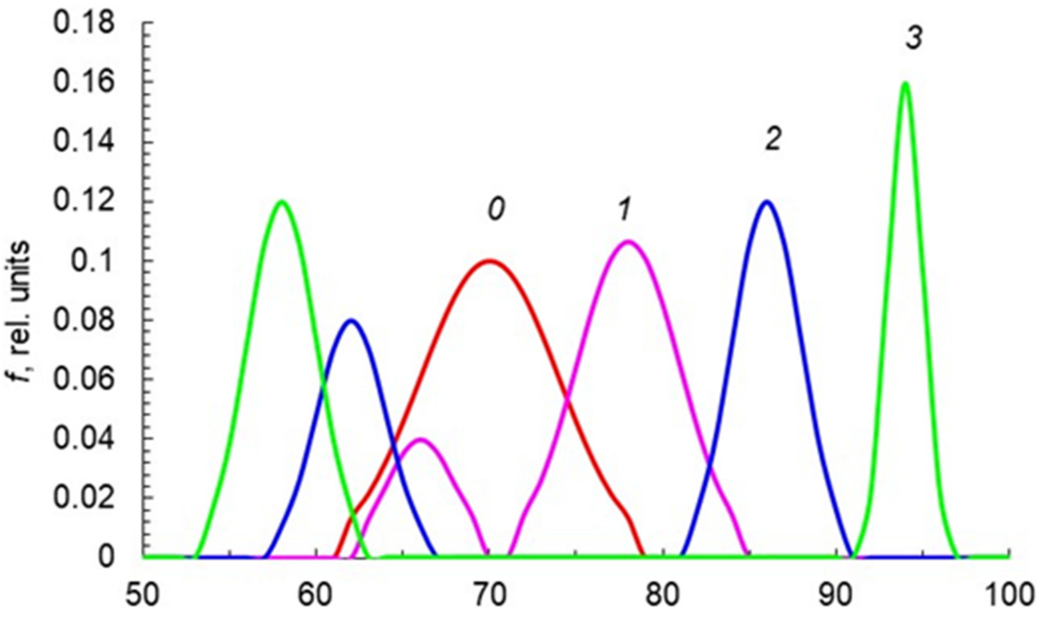

Figure 4. Pessimistic model of educational process development.

Unimodal distribution density is turning into bimodal function with significantly spaced-apart modes in the pessimistic version, which means that the knowledge level is becoming diversified. Q is an essential model parameter for comparing educational technologies at the final stage of the course. If this parameter is lower than a certain limit level Q_{lim} for the student, he/she fails to graduate, and the educational resources spend on his/her training were used inefficiently.

Remark 4. *Additional criteria to compare educational technologies are associated with long-term changes in the knowledge and competence levels. The technology under study will be more efficient if the component means of vectors V_∞, L_∞ exceed those of the conventional education technology. The above-mentioned changes essentially depend on external conditions, with the main one being the presence/absence of motivation for life-long autonomous language studies. An education technology that inspires students to become a life-long language learners is obviously the more efficient one. It should be stressed, here, that a continuous profound monitoring of the educational process allows evaluating the goal adequacy of methods being applied, as well as to consider the individual student's needs and take measures for correction of pedagogical interventions.*

Remark 5. *The above-described approach is considered worthwhile on condition that all material resources are equal in monetary equivalents. It is also necessary to consider the cost of a highly qualified specialist in relation to the real demand for him at the regional and international trade markets.*

3. Case Study

3.1. The Challenge of Teaching Resource Efficiency

Whilst we have identified in Section 1 the importance of RE, in our experience this topic is not always well integrated within the training of engineering students. Given the importance of the topic, our research focusses on developing an approach for RE education within language teaching of engineering students, to help them acquire competence and experience in successful RE problem solving in their academic and professional activities as regards the development of their English language skills. The current work is novel in that it studies RE from multiple perspectives in the context of foreign language training of engineering students. RE is an essential component of the syllabus, i.e., RE and Smart Resource Management represent the content of the language training.

In order to include RE into the content of the language training program, we structured it in the following way. During the first and second terms, students acquire a general understanding of various resource types and learn to appreciate the necessity of using them in a smart way. Students are introduced to a wide range of language learning approaches and tasks, including video presentations, webinars, and workshops on appropriate topics, encompassing: the engineering profession; the basics of resource efficiency; types of resources; and effective technical communication [13–15].

The basic principle of this stage is learning through action and participation in interactive events, which involve students researching different approaches to solve RE problems while using a Foreign Language (FL). Second year students study professionally oriented cases and accomplish scientific projects arranged in the following topics: Engineering Education around the World, Resource Efficient Technologies in Russia and Abroad, Rational Choice of Prospecting and Exploration Techniques, Safety and Effectiveness of Operations, Resource Management Enhancement, Resource Efficiency Research and Evaluation Methods.

The results of students' research project work are presented at conferences to undergo review by experts. Based on their research work, students prepare grant proposals, professional reports, and scientific articles in English, in cooperation with their supervisors. The best articles are chosen to be published in conference proceedings indexed, such as the annual International Scientific Symposium "Problems of Geology and Subsurface Development", the annual Scientific Conference "Youth Energy to Resource Efficient Technology", and Young Engineers Summit, International Conference “Resource Efficient Systems in Management and Control”.

This work took place at the National Research Tomsk Polytechnic University. The pilot experiment was based on a series of interviews and questionnaire surveys with 68 staff and 200 students, utilizing convenience sampling. This followed the ethical procedures and customs and practices of the host institution. In particular, all participation was voluntary. The process included explaining the goal, tasks, and planned procedure, and to invite students/colleagues to join. The results from the sample informed the design of the framework, and the scoring. The case study based on this involved 35 first year students, who were selected and distributed into two control (n = 24) and one experimental (n = 11) groups so that their academic performance and their level of knowledge of RE were similar. As described in Section 3.3, RELT was initially launched in 2012. The current work began with the pilot work in 2018–2019, with the main experimental work conducted in 2019–2020. This paper provides the initial outcomes of that to illustrate the framework, with further details in future work.

Our main objective here was to check if the proposed RELT technology seems to meet the requirements of efficiency and sustainability (along with the technological and methodological criteria) and if it achieves the target results. The traditional LT does not employ the system of all required educational resources and lacks the necessary technology and methodology that satisfy the crucial principles of sustainable and resource-efficient training of modern in-demand engineers who will be competent and experienced in solving urgent worldwide problems in collaboration with their foreign colleagues. Thus, it was also necessary to define the complex of pedagogical conditions facilitating the implementation of the innovative technology and conversion of the traditional process of language training, which failed to provide the proper environment for students to acquire the demanded profession-oriented FL skills and competences.

3.2. Resource-Efficiency at Tomsk Polytechnic University

Tomsk Polytechnic University is among the first universities to approve an RE development program, which includes the following clusters:

- Safe environment;
- Sustainable energy;
- Medical engineering;
- Planet resources;
- Cognitive systems and telecommunication;
- Social and humanitarian technologies of engineering.

A Smart Grids center and an RE Methodology Lab were created to enable and encourage in-depth research of RE phenomenon. Furthermore, RE has been included into the syllabus at Tomsk, for example, with the course “Fundamentals of RE”, aimed at developing the following graduates’ competences [10]:

- System knowledge about the main types of resources;
- Deep understanding of the necessity to enhance the efficiency of natural resource usage;
- Readiness to solve RE problems in professional, social, and personal life;
- Ability to use the methods for evaluation of resource usage efficiency and analysis of resource life cycle;
- Ability to determine the ways of RE enhancement; ability to use the main methods of RE management in line with the ethical and legislative regulations.

One of the most important conditions for RELT technology realization is a stage wise transformation of the traditional teaching framework into a professional businesslike partnership/collaboration. Traditional teaching implies a “teacher–learner” model/relation with the outer absolute pedagogical control of the whole educational process. The professional businesslike partnership/collaboration is a gradual transition to a reciprocal educational environment with an “advisor–trainee/young researcher” collaboration, the latter being more self-governed/autonomous [27]. During such collaboration, students are involved in setting and solving meaningful professional and personal RE problems in communicative research projects while learning and using the English language.

Scientists [29] define the following types of students' engagement:

- Academic/cognitive (learning activity, achievements).
- Social/behavioral (participation in extracurricular university activities).
- Emotional/affective (attitude to the university, institutional culture).

We believe that all types of engagement should enrich students innovative engineering attributes (resource-efficiency, functionality, creativity [30]). The degree of students' involvement is associated with their autonomy level. This level is increasing as students gain their problem-solving experience and adopt personal-subjective functions in the process of professionalization and self-actualization. These functions and strategies include goal setting, prioritizing, decision-making, self-motivation, self-management, etc. We now describe the stages of Resource Efficient Second Language Training (RELT).

3.3. The Stages of Resource Efficient Second Language Training

The course of RELT lasts four semesters, the program is intended to train the first and the second-year students. It was first accepted in 2012 and has undergone five editions since then, but the most profound edition and upgrade began in the 2019–2020 academic session. With the data now collated, we will complete the assessment and evaluation of our innovative technology using the arithmetic model and an advanced expert analysis as described in this paper.

I. **Motivational-diagnostic stage**

The main objectives are:

- Diagnostics and evaluation of students' motives, attitudes, their levels of communicative competence and language proficiency;
- Formation of students' motivational readiness to master professional communicative competences;
- Formation of profession-oriented attitudes, notions, and standards of RE in academic, research, and communicative engineering activities.

During this stage, students are introduced to different types of resources and to the ways of using them efficiently. Didactic-informational resources are display materials, showcases, and models. Diagnostic resources include tests, questionnaires, and assessment sheets. Organizational—self-presentations, interviews, trainings, workshops, etc. Info-communicational—forums, chats, blogs, platforms, mobile and Internet tools and apps, etc. Technological means—didactic, learning, and teaching materials. The main results of this stage are the awareness of students' personal learning styles, personalized resource toolbox, individual competence protocols, high motivation, and interest to achieve success in further project work.

II. **Project development stage**

The main objectives at this stage are:

- Goal setting and specification of individual learners' needs, objectives, language training expectations;
- Preparing individual learning pathways, self-study programs, schedules, completion of documents;
- Development of self-management and project work skills as the basis for RE in profession-oriented FL communication, academic, and research work.

During this stage, all the above-mentioned types of resources are used as well. Students are engaged in formation of their personal resource toolbox/collection, and they start working with their registers, templates, portfolio, and project documentation. The main results achieved at this point are that students become aware of the new academic settings and requirements, and they know their goals and are equipped to reach them within a certain time period.

III. **Implementation stage**

The main objectives are to ensure the attainment and maintenance of high levels of students' motivation and RE, whilst putting into practice their plans and projects (tackling complex problems and tasks, overcoming challenges, etc.). This is done through:

- Formation of a profession-like environment (professionalization);
- Students' autonomization in the process of learning and using English while tackling meaningful problems and tasks;
- Development of FL communicative competence components (discourse, linguistic, strategic, professional, sociocultural).

At this stage, students may use all available resources, but they are encouraged and helped to create their own (individually or in teams, based on the best examples). The main results—students develop their own RE learning and work understanding and techniques through gaining practical experience.

IV. **Enhancement stage**

The main objectives of this stage are to enable:

- Assessment and evaluation, collecting data, analysis of the main outcomes;
- Uncovering mishaps, carrying out correction, improvement of organizational, management and monitoring procedures;
- Adjustment of educational, technological processes in line with the results of RE indicators;
- Development of compensative and regulative mechanisms in communicative competence realization.

The resources used at this stage are mostly diagnostic during the initial phase but in order to implement enhancement measures all other available means and instrumentation are also applicable. The main result—self-efficacy and satisfaction of students with achievements and accomplishments.

V. **Prognostic stage**

The main objective—further planning and setting long-term goals, defining anticipated outcomes. By this stage, students have gained the necessary experience, which allows them to sort out their own resources to identify their needs, meaningful tasks, and overcome challenges effectively and autonomously or with a minimal teacher support. The main result is that students are becoming "teachers" for themselves and peers, sharing their best practices, giving feedback and support, assessing, and commenting on the work of their groupmates. Having completed the full cycle, students acquire "the orientation framework" (P. Galperin) for their future activities, they become self-confident (due to their successful achievement experience) and aware of reachable academic career perspectives.

The stages [31] were defined in accordance with the theory of developmental learning and activity orientation framework (developed by P. Galperin in collaboration with L. Vygotsky), which aims at forming learner autonomy, engagement, creativity, and resourcefulness (crucial RE competence components).

3.4. Empirical Results and Discussion

The following results were obtained from the above implementation (Section 3). The results from the pilot study showed:

- In total, 72% of the respondents (all) stated that the majority of students lack efficiency in their academic and scientific activities;
- In total, 88% of the lecturers claimed that students should be specially trained to make the right use of available resources (create new ones) and apply them to solve meaningful problems, achieve results, and organize their learning in a sustainable way;

- In total, 79% of students pointed out that pedagogical support, control, and regulation provide the effectiveness of the educational process;
- Agency, responsible attitude, and the ability to avoid distractors were marked as the main attributes for a resource-efficient learner;
- In total, 93% of the participants (all) agreed that there should be a more systematic approach to the development of a structured digitalized resource base with clear instructions, engagement features, and functions for customization, information exchange, communication tools, etc.

In order to test the RELT technology, we carried out an educational experiment, which consisted of three phases: ascertaining (preliminary), implementing (realization of RELT technology), and summative. The ascertaining and summative phases lasted for one month each when measurement procedures, data collection, and analysis were accomplished. The implementing phase, when the RELT technology was introduced into the educational process at NR TPU, lasted for three terms in 2019–2020.

Our preliminary assessment showed that of the 35 participants, 27 of them had poor knowledge of RE, they were not aware of the range of available resources and could not choose and apply the right ones to effectively solve meaningful problems (academic, scientific, communicative, profession-oriented, etc.). Only nine students could effectively cope with the suggested tasks at the minimal RE level. The focus of this paper is the framework itself, and future work will expand on the experimental activities and data.

With the help and support of the experts from Academic Results Assessment Centre at TPU who checked and approved the validity and the fairness of measurements, we calculated the RE index before and after the implementing phase of our experiment. The data were obtained and combined from different sources (students' self-evaluation sheets, experts' protocols, teachers' continuous/final assessments) in the course of students' profession-oriented academic project work, which clearly demonstrated their efficiency to choose/create and apply the range of available resources while solving various problems in a sustainable way using/practicing the English language.

Empirical evidence from the authors using the framework indicate that the RELT technology was viable and effective in developing students' competences and that it was necessary in order for them to have the capacity to carry out resource-efficient and sustainable engineering activities globally using English.

4. Conclusions and Contribution

In order to address the global challenges of resource-efficient and sustainable nature management, higher engineering education should provide a corresponding environment for students to become competent professionals who meet the modern international requirements. Such specialists are highly effective at achieving goals and solving professional problems due to their ability to find, create, and sensibly use various resources.

Thus, based on our theoretical investigation, analysis of practical experience, and experimental work, we assert that the developed technology of professionally oriented training (in the course of technical communication) provides the necessary conditions for students to successfully implement resource efficiency in solving complex engineering problems and lifelong self-education with the use of the English language. A key contribution here is the framework in Figure 1, which provides an approach to teach resource efficiency within language teaching.

Furthermore, considering the variability and universal character of its constituents, the presented technology may also be used to train students in higher educational establishments and institutions of different study fields. It should be stressed here that a continuous profound monitoring of the educational process allows evaluating the goal adequacy of methods being applied, as well as to consider individual students' needs and take measures for correcting pedagogical interventions.

There are researchers who argue that RE could be enhanced drastically through total student immersion and involvement through edutainment technology and gamification of the educational process [3]. Others suggest diverse communicative practices and internationalization [3,8,32] in order to improve the professional training in terms of its efficiency. In fact, when it comes to scientific research and practical application of resource efficiency, too many aspects and factors arise that could be rather influential. As for the present study, the limitations include the subject area of the higher professional education (it was not an interdisciplinary research) and the lack of feedback from companies/organizations who are among the stakeholders. We are planning our further research developments and RELT technology improvements, taking into consideration the above-mentioned limitations and welcoming other scientific opinions.

Limitations. This paper considers one case study in which this approach was used, and there is a lack of control study here. However, the qualitative and quantitative data indicate the potential effectiveness. The approach we have described is considered worthwhile on condition that all material resources are equal in monetary equivalents. It is also necessary to take into account the cost of a highly qualified specialist in relation to the real demand for him at the regional and international trade markets. The grouping of factors in the framework, such as the motivational-diagnostic stage, aggregates aspects such as motives, attitudes, and proficiency. Future work will explore how far those aspects are independent and involve further applications of the framework and will analyze its impact on students' understanding of resource efficiency, in both language teaching contexts and other subject areas.

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