Zoja RAUD, Valery VODOVOZOV

Tallinn University of Technology

Innovative Training Practice in Electronics for Enterprises

***Abstract**. An educational practice suitable for planning optimal staff training trajectories is described. Effective instruments are given to build professional thesauri and to find an institution capable of providing training in the frame of such thesauri. Using them, new knowledge and skills can be introduced, the contents of the corresponding disciplines refreshed, and the borders between the disciplines shifted fluently. This promotes designing the teaching modules in highly interdisciplinary areas and in the areas with specific needs.*

Streszczenie.** W artykule opisano praktykę edukacyjną przydatną do optymalizowania formy i zakresu szkolenia personelu. Podano także skuteczne instrumenty do profesjonalnego budowania tezaurusów i sposobów znajdowania instytucji zdolnych do szkolenia w ramach takich tezaurusów. Tezaurusy mogą być uzupełniane o nową wiedzę i umiejętności, może być również odświeżana zawartość odpowiednich dyscyplin, a granice między dyscyplinami przesuwane płynnie. Sprzyja to projektowaniu modułów nauczania w dziedzinach wielodyscyplinarnych oraz na obszarach o szczególnych potrzebach. (**Innowacyjne praktyka szkoleń dla przedsiębiorstw w obszarze elektroniki).

Keywords: electronics, training, thesaurus.
Słowa kluczowe: elektronika, szkolenia, tezaurus.

Introduction

In many sectors, specialists are generally responsible for driving innovation and competition. Contemporary changes in the business sector, responses of enterprises to these changes, as well as available information and communication technologies pose a number of challenges to the engineering staff [1], such as:

- continuous learning of new technologies and methods
- fast promotion of projects in the frame of time scarcity
- maintenance of manufacturing systems based on the online tools and resources
- active personal development and competency improvement

Companies require from their engineers an aptitude for collaborative work, team and task management, concept synthesis, and decision-making, thus stimulating progress in learning environment, which gives all of these job-related skills.

Over the past few years, there has been increasing interest in effective lifelong learning technologies for engineering. To promote staff development, employees usually attend training courses, workshops, seminars, and conferences. With advancements in technology, organizations are engaging the employ different educational media to enhance staff skills and knowledge. In addition, training on the job and situation-based learning are increasingly considered in the modern fast changing knowledge society. However, most research and surveys indicate that enterprises have a limited capacity and participation in continuous education and training. It is confirmed also by the authors' own findings that companies are slow to implement new educational approaches and the staff does not benefit much from training because of their context of work, productivity and time.

To recognize the optimal learning pathways, the definition of the professional profiles has been offered in [2]. Using such profiles, company representatives may choose between different courses and educational institutions to find the most appropriate for their profile specifics and targets. In [3], an overview of educational strategies used in enterprises is also given and a number of attempts to increase their effectiveness are listed. With that end in view, learning in industry is divided between formal training and vocational training. Formal approach is classified as training arranged and packaged to cover a given subject, with clearly defined topics, eventually leading to the delivery of a certification whereas vocational approach relates to training, the costs of which are supported by the company and the topics of which are related to individual jobs. Moreover, it is presented in [4] that apart from the normal working environment, staff training also occurs in social events and in everyday activities. This means that work activity is carried out in various social settings where employees collaborate and interact on specific subjects. Therefore, enterprises have to integrate learning from economic, human and social perspectives.

Following an analysis of the promoted innovative set-ups and practices in world industrial companies, this paper proposes a novel approach to curricula scheduling. The aim is to facilitate and improve the quality and efficiency of in-service training, on-the-job training, and undergoing training provided in a workplace environment. An appropriate educational model is grounded enabling development of optimal training trajectories in the framework of the curricula organization, particularly in the field of electronics. The focus concerns re-evaluation of the syllabi design along with the strengthening of e-learning role using the conceptual approach. Effective instruments are given to find an institution capable of providing training in such environment.

Educational thesaurus

Through experience and education people appreciate the surrounding world obtaining the information, facts, descriptions, and skills. Schooling, study, observation, and practice supply an individual with concepts [5]. Let a *concept* be the elementary unit of knowledge composed of the unique combination of characteristics. All the concepts may be divided into the known and unknown ones. Call the concepts given beyond a training system as *outside concepts*. A learner knows the meaning of the outside concepts at the ongoing stage of a course. During the educational process a learner crosses a succession of knowledge levels (courses) thus obtaining new conceptual understanding of the universe. As he passes from one course to another, a balance of the known and unknown concepts changes gradually. Next, call the concept the meaning of which is described by the current schooling as a *defined concept*. The entries earlier introduced in the course and used to explain a defined concept call as *parents*. The entries produced from the defined concepts call as *kids.*

It is suitable to evaluate the knowledge level by a *thesaurus*. According to [6], the thesaurus represents a compendium of a body of knowledge with the structured controlled relationship of concepts within an application area. Many thesauri types exist, such as encyclopaedic and explanatory dictionaries, professional glossaries, reference books, etc. Part of them belongs to the online tools, the most powerful of which are *Wikipedia.org*, *Thesaurus.com*, *Ask.com*, *Thefreedictionary.com*, *Visualthesaurus.com*, etc. The online glossary *Electropedia.org* [7] covers explanations of the concepts relevant to electrical engineering. The knowledge level of an individual may be estimated by the personal thesaurus presenting the collection of known concepts that concerns some delimited field of the individual's interest.

Every thesaurus entry represents an article devoted to a separate concept, including its *term* and *definition*. All the thesaurus articles are directly and indirectly connected with each other. Generally, the direct links have the alphabetic and thematic nature of the concept terms. The indirect links are implemented throughout the concept definitions which expose a concept by dozens of other terms. A degree of the conceptual appreciation from the thesaurus depends on the learner knowledge of the concepts used in definition. The presence of unknown components impedes progress in learning.

Numerous methods have been developed for the thesaurus presentation [8]. Traditional offline encyclopaedic and explanatory dictionaries have the article structure. To explore them, the theory of syntax [9] is used. Higher effect brings separate processing of the terms and definitions. Numerous database technologies and list handling methods along with matrix approaches are applied to study the separated terms [10]. As well, many treelike algorithms were designed to optimize and enhance the entries [11]. Generally, a modified family tree, called as a pedigree chart [12], may successfully represent conceptual relationships, starting from the root (ancestor) and ending by the leaf (descendant's) concepts. Unlike a conventional family tree structure, the number of incoming branches for a thesaurus tree node is not limited by the couple of parents whereas each node has only one outgoing branch.

This paper focuses on the new tool, namely *educational thesaurus* (ET) [13], [14]. In contrast to other thesaurus types, it is intended primarily for learning. Every course studies the concepts in a specific context, giving them distinctive meanings that may deviate from the meaning the same words have in other contexts and in everyday language. Taking into account this target, the ET structure and the definition part require a unique arrangement.

Assume an ET of a discipline comprises *m* entries. Describe each of *m* concepts CON_i by an *i*-th entry with the following components:

$$CON_i = \{i, Term_i, D_i(T_{i1}...T_{ip})\} \quad (1)$$

where $i = 1...m$, $T_i \neq Term_i$, $p < m$. Here, i is an index, $Term$ is the term which titles the concept, D is the definition of the defined concept, and T are the terms of the parents used in the definition of CON_i.

Shortly, the main principles of ET arrangement important from the educational viewpoint can be formulated as follows:

- from known to unknown
- from simple to complex
- step by step (no recursion, no repetition)
- redefinitions and synonyms are welcome

The strong statement of these principles sounds as follows [5]:

Principle A. In the definitions $D_i(T_{i1}...T_{ip})$, the application focus and/or the main operation principle of the defined ET concepts must be outlined. It is prohibited to explain thesaurus concepts through their parts and opposite concepts. This means the parents are to be introduced into the thesaurus before the defined concept. Mathematically, a properly designed ET should be presented by the left-triangular matrix of terms.

Principle B. The first concept CON_1 is to be the heading of the current course defined through the terms foregoing this course ($p = 0$). This will result in the learners' appreciation of the course goals and requirements before enrolment. If the body of terms is presented by the list, relational database or matrix, the term of the starting concept will be the first ET line or row. If the thesaurus is drawn by the tree, the course heading will occupy the tree root. For instance, for the first entry of the course "Electronics" the following definition of "electronics" meets the proposed principles: "*Electronics* is a field of science, engineering and technology dealing with semiconductors and, rarely, with vacuum tubes". All the parents of this definition are the terms foregoing the course. Neither parts, nor the opposite concepts are used.

Principle C. It is reasonable to restrict the number of parents by two or three ($p < 4$). Multiple studies show that definitions based on the greater number of the parents require much time and effort for understanding.

Principle D. As the synonyms are the usual ET entries, all the synonyms must be referenced to the uniform definition within the thesaurus.

Principle E. ET must be accomplished with the tools that prevent recursion along with the thesaurus filling. At the same time, synonyms are not the same as repetition. Hence, the ET must be accomplished with the tools that prevent repetition during the thesaurus preparation.

Principle F. Redefining of the concepts is the normal situation in education. While the first definition is simple and short, the following ones may be more complex and detailed as they are based on the new concepts introduced throughout the course duration.

Flexible curriculum

To enlarge the above given conception of the ET across the full educational process, assume a thesaurus of the particular speciality comprises M entries represented the sum of entries of K disciplines of the speciality, $M=\sum m$. Let DIS_k be a component of CON_i which corresponds to the k-th discipline of a curriculum as follows:

$$CON_i = \{i, DIS_k, Term_i, D_i(T_{i1}...T_{ip})\} \quad (2)$$

where $k = 1...J$ and $p < M$. Call the number of concepts M a learner should acquire within the full learning period as the *length of an educational trajectory*. Since the thesaurus is ranged, the neighbour concepts may be involved into the groups outlined in Fig. 1.

These groups are effectively associated with the disciplines of a curriculum. From now, a curriculum may be represented by a double-level model which includes

- top curriculum level as an ordered system of disciplines $DIS_1…DIS_K$, $K < M$, which shows an educational trajectory of a learner
- concept matrix, which serves as a source for the top level

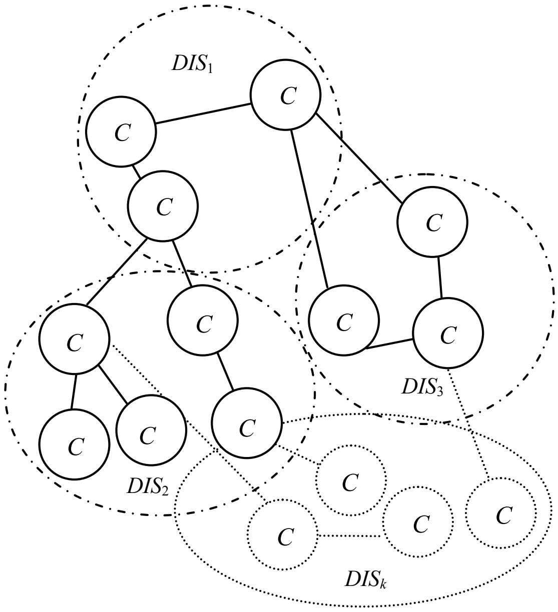

Fig.1. Concept (C) aggregating with disciplines (DIS)

From this viewpoint, the curriculum arrangement poses the process whereby the components are interpreted through the learning experiences [15].

Let i_{DIS} be a given starting instant where a discipline DIS_k begins. In the simplest case, when $p = 0$ (no predetermined concepts), $i = i_{DIS}$, which means that all such concepts CON_i may be introduced starting from the first study of DIS_j. The same concerns the defined concepts described by the components of the earlier passed disciplines. For instance, if $i_{DIS1} < i_{DIS2} < i_{DIS}$ and CON_i is defined by the predetermined concepts of i_{DIS1} or i_{DIS2}, then $i \geq i_{DIS}$.

To support the basic concepts of an application area and to reflect the challenges being an instrument for solving the practical problems of companies, a thesaurus should possess sufficient redundancy. Really, different professional branches of knowledge require the sets of defined concepts, thus an excess capacity of concepts and disciplines is the normal feature of any thesaurus. For example, the known branches of Power Electronics are as follows: Industrial Electronics, On-Board Electronics, Aircraft Electronics, Automotive Electronics, Military Electronics, etc.

As the number of concepts M a student should acquire within the learning period is less than the total number of the professional concepts, the personal educational trajectories may differ depending upon the staff goals and the future degree that a learner approaches. To enhance the engineers' knowledge level for different enterprises, specific educational trajectories are needed therefore different groups of concepts and particular disciplines of the full thesaurus may be selected.

Hence, the offered system of the consolidated disciplines aggregated into a curriculum represents a suitable tool to generate the required educational trajectories. Being connected by means of concepts, the disciplines successfully support the total plan for learning. In Fig. 1, the solid nodes and branches outline the appropriate educational trajectory whereas the remaining concepts deleted from the total thesaurus are given by the dotted lines.

In addition to the concepts and disciplines, a curriculum may include everything that promotes the learners' intellectual, personal, social and physical preferences [16]. It may also involve the studies, extracurricular activities, approaches to teaching, learning and assessment systems, the quality of relationships within an institute, and the values embodied in the way the institute operates.

Unlike the traditional environment, the proposed model of learning has an exclusively dynamic nature; therefore, it may be called as a *flexible curriculum*. Any time when the professional level is raised, the curriculum may be changed simultaneously along with its background conceptual matrix. Thus, the new disciplines are introduced, the contents of the corresponding disciplines refreshed, and the borders between the disciplines shifted fluently. This promotes designing the teaching modules in highly interdisciplinary areas and in the areas with specific needs.

Defining of the optimal educational trajectories

Design and control the personal educational trajectory is a new problem suitable for solution by the developed approach. Consideration of learning paths concerns the sequence of learning objects consumed by the students, which defines a trajectory of navigation to plan the student activities. Finding the correct individual learning paths leads to achieving a flexible platform for all the participants of an educational process. Such self-monitoring system follows the progression of individual learning. It will allow students to have greater flexibility in learning, thus reducing many constraints to progress. By comparing the optimal trajectory with the actual one, the learning quality and the student knowledge level are evaluated to suggest the corrective actions. All this can be considered as a control loop with a fast feedback the response of which to deviations provides the system stability.

Definition of the optimal educational helps

- to evaluate the complexity of the particular disciplines and the full specialty curriculum
- to optimize the order of the disciplines in the curriculum
- to design curricula for an additional education and for the second specialty

The common information problem may be formulated as follows. The previously studied discipline (specialty) is based on a system of concepts A. The new discipline (specialty) is based on a system of concepts B, some of which may be the concepts of A. Find an educational trajectory between the new and previously studied disciplines (specialities).

If among the concepts of B there is at least one defined through the concept of A, the two systems can be described together by a graph T and the solution of the problem is reduced to finding a path between these concepts in T using the known algorithms of the theory of information, for example, Dijkstra's algorithm [17]. Thus, the challenge is to find the terms of B that correspond to the concepts of A. If there are no concepts of A among the concepts in B, but there is a concept from some other discipline K, which in turn has a concept from A, then K acts as an intermediary discipline. In this case we should find a path between the appropriate concepts in K using the same algorithm again.

An example is given below. Assume the previously studied discipline called Power Electronic Converters (PEC) includes some concepts like these ones:

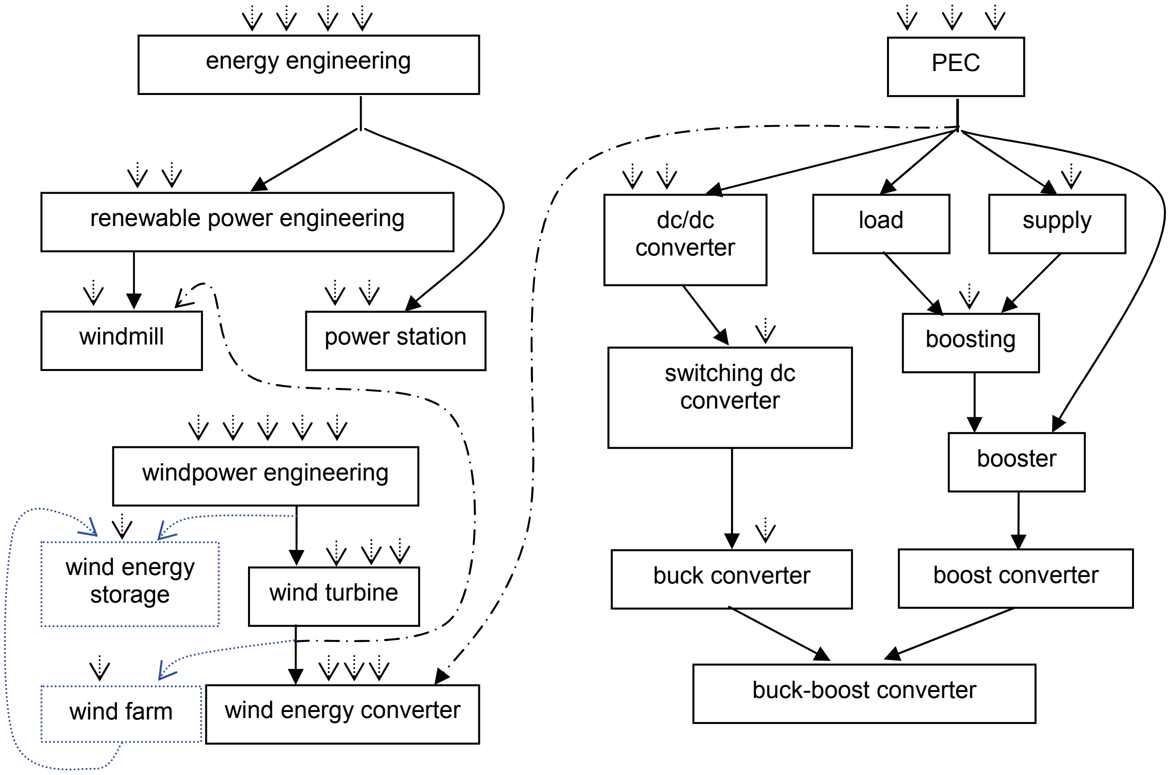

Fig. 2. Semantic graph of a fragment of the ET

1. **power electronic converter (PEC)** − *electronic converter* that converts *energy* within a *power electronic system*
2. **dc/dc converter** − **PEC** converting *dc* to *dc* of another level
3. **load** − object connected to the **PEC** output
4. **supply** − *power* line feeding the **PEC**
5. **switching dc converter** − **dc/dc converter** using a *switching* principle of operation
6. **boosting** − production of a **load** *voltage* above the **supply** *voltage*
7. **booster** − **PEC** with **boosting** possibilities
8. **buck converter** − **switching dc converter** which output *voltage* is below the input *voltage*
9. **boost converter** − **booster**
10. **buck-boost converter** − **buck converter** combined with a **boost converter**

Here, the concept terms are given by a bold type and an italic font is used for the terms coming from prior disciplines, such as Electronics and Electrical Engineering. The defined concept terms occupy the left side of each entry whereas the definition functions of their parents are to the right. In Fig. 2, the graph of these concepts is shown to the right, where the dotted arrows mark the incoming terms.

Let the new discipline Energy Engineering includes the concepts given below:

1. **energy engineering** – field of *engineering* dealing with *energy management*, *plant engineering*, and *environmental compliance*
2. **power station** – **energy engineering** *system* for the generation of *electric power*
3. **renewable power engineering** – field of **energy engineering** dealing with *energy* which comes from the renewable *natural resources*
4. **windmill** – *machine* used in **renewable power engineering** to apply *mechanical energy* directly from a *wind turbine*

An intermediary discipline Windpower Engineering includes the following concepts:

1. **windpower engineering** – discipline focused on the *design engineering*, *maintenance*, *installation*, and *projects* related to the *wind power.*
2. **wind turbine** – *rotary device* used in **windpower engineering** to extracts *energy* from the *wind*
3. **wind energy converter** – *machine* to convert *mechanical energy* of **wind turbine** to *electricity* using *PEC*
4. **wind farm** – group of **wind turbines** in the same location used for production of *electric power*
5. **wind energy storage** – equipment used in **windpower engineering** to store *electricity* of **wind farm**

The graph fragments of Energy Engineering and Windpower Engineering are given in Fig. 2 to the left. Clearly, there are no terms of *PEC* among the terms in Energy Engineering. At the same time, the concept *windmill* is defined by the term *wind turbine*, which participates the discipline Windpower Engineering and there is a concept *wind energy converter* defined by *PEC* in the discipline Windpower Engineering. Therefore, Windpower Engineering acts as an intermediary discipline, in which one should find a path for a *wind energy converter*. Thus, the length of the full educational trajectory is equal to the length of the new discipline Energy Engineering plus the length of the educational trajectory in the intermediary discipline Windpower Engineering for the concept of the *wind energy converter* that is 3+2=5. The remaining concepts of a *wind farm* and the *wind energy storage* of this discipline are optional for study.

Conclusion

Many researches and surveys indicate that small and medium enterprises have a limited capacity and participation in continuous education and training;

companies are slow to implement new educational approaches and the staff does not benefit much from training because of their context of work, productivity and time. A novel model of the curriculum built on the educational thesaurus supports the overall set of concepts actual for definite enterprises and applies them to solve the practical problems thus proposing a flexible and easily upgradeable educational system. This tool is suitable for numerous educational trajectories to be developed for different groups of learners where the learning outcomes are described in concepts and terms that make institutions to be more responsive to the needs of the market and to reinforce the links between studies and employment needs. An application example linking three disciplines across their conceptual basis confirms the effectiveness of the proposed methodology.

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***Authors**: eng. Zoja Raud, Tallinn University of Technology, Ehitajate tee 5, Tallinn, 19086, Estonia, email: zoja.raud@ieee.org; prof. Valery Vodovozov, Tallinn University of Technology, Ehitajate tee 5, Tallinn, 19086, Estonia, email: valery.vodovozov@ieee.org.*