Novel approach for education in biomedical engineering based on atomic learning

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Abstract. Biomedical engineers are often responsible for preserving and improving the quality of life for ailing patients. Furthermore, engineering and medical students and practitioners must be constantly informed of newly developed methods in the specific domains of interest, properly educated, and widely connected to exchange knowledge and best practices. To meet these requirements, the authors propose improvement and application of the Novel Educational Methodology (NEM), and dynamic collaboration network - DCN of knowledge triangle elements created by the authors of this research. The NEM addition includes the implementation of atomic learning using graph relations and connections and personalised sequence-based learning. The DCN network is represented by atomic structure and collaboration is enabled by different node connections. The enhanced NEM and DCN will be implemented through open-source e-portals dedicated to education and collaboration in biomedical engineering.

Keywords: First Keyword, Second Keyword, Third Keyword.

1 Introduction

Biomedical engineers are often responsible for preserving and improving the quality of life for ailing patients so that the work can be quite fulfilling. However, because of the complex and demanding nature of the work, interested individuals should possess certain character traits and complete their engineering education before beginning to work in the field. Furthermore, engineering and medical students and practitioners must be constantly informed of newly developed methods in the specific domains of interest, properly educated, and widely connected to exchange knowledge and best practices [1,2]. These goals define three pillars of proper education and practice in the field of biomedical engineering: Just in time introduction to the novel methods applicable in healthcare; Proper education and training; Connection and collaboration between scientists, engineers, students and medical practitioners. These three pillars are essential to properly acquire knowledge and implement and develop new engineering methods and medical techniques. The application of novel educational methodologies supported by machine learning, augmented reality, simulation, modelling, e-learning, m-learning, and distance and blended approaches are the focus and the backbone of the enhancement of medical education [3,4], and should provide support for the defined pillars. The main shortcomings of today's approaches in eLearning are missing or inadequate feedback from the students, system adaptation not focused on learning context, course presentation (learning material) limited to one teaching style and standardised learning by using standard software solutions. Besides stated advantages and disadvantages of eLearning methods, other shortcomings are necessary to address: they are weekly adoptable to students with disabilities; they are not suitable for groups with different knowledge backgrounds and cognitive capabilities; they are poorly customisable to immersive business demands [5]. The research outcome aims to thoroughly improve the teaching process of selected branches/disciplines of medical and engineering sciences, by answering the stated issues using ICT and related methodologies and technologies.

The main research goal of this study is to improve Novel Educational Methodology - NEM [6] to make it applicable in complex fields like biomedical engineering and thus create a better learning methodology. To accomplish the main goal, the following research objectives are addressed in this paper:

- The objectives stated in the original NEM: A learning system that will always provide modern content following the requirements of society, universities and companies; A learning platform that will be able to adapt to the specific needs of educational institutions, companies, public institutions and organisations; Work-based learning will allow students to learn using different types of courses developed by SMEs and enterprises, which can be done online using a web platform or learning at a physical company site.
- The application of additional methods will help improve NEM, and enable better learning procedures and outcomes, through the developed E-COOL platform. The enhanced NEM includes adding atomic learning represented by graph relations and connections. Atomic learning is based on the "First principle" method of learning by understanding basic knowledge [7], and on sequence-based learning methodology for the creation of sequential learning [8].
- To define a novel virtual centers network (Dynamic Collaboration Network - DCN) of knowledge triangle elements (innovation, academia, and business), defined in a new innovative way and represented by a developed DCN web application. The basis for the DCN creation is NEM. The atoms from NEM are used as the foundation for defining centers as atomic structures. The DCN formed in the presented way is required to enable the formation of a database of contemporary knowledge to be used in NEM.

The combination of upgraded NEM and support provided by DCN should enable the fulfillment of the research goal, and, therefore constant upgrade of knowledge database, knowledge sharing and distribution, and capability to make a strong impact in the eLearning world.

2 The Methodology and its application

It should be clear that two dependent methodologies are described in this paper. First is NEM, and the second is DCN foundation methodology. The DCN provides resources (people, knowledge atoms, experience) which enable building the NEM knowledge database and improving the NEM application and verification in the real world. Two connected applications are developed, one for NEM (E-COOL) and one for DCN. These applications can use appropriate integrated services to share their resources and form a unique and complex eLearning framework.

NEM combines traditional and eLearning concepts tailored to the needs or requirements of the student, student group, and teacher. This methodology enables the creation or application of standard eLearning content, like context-based learning, feedback-based learning and flexible learning. It introduces new learning methods and approaches in both universities and business educational processes, e.g. work-based education, lifelong learning and long-term learning. The main improvement to NEM methodology is introducing knowledge graphs to represent its structure.

The NEM relations and objects are not an exact copy of knowledge graph structure. Yet, they represent an adapted variant in which atoms reflect nodes, connections between atoms are edges, and labels are atoms main descriptions. An edge (connector) defines the relationship between the nodes/atoms. Knowledge graphs [9] are typically made up of datasets from various sources, which frequently differ in structure. Schemas, identities and context work together to provide structure to diverse data. Schemas provide the framework for the knowledge graph, identities classify the underlying nodes appropriately, and the context determines the setting in which that knowledge exists. This reflects atom definition and atoms connections. The different context can reflect atoms belonging to different molecules (different courses or science fields). Knowledge graphs that are fueled by machine learning utilise natural language processing (NLP)[10] to construct a comprehensive view of nodes, edges, and labels through a process called semantic enrichment. When data is ingested, this process allows knowledge graphs to identify individual objects and understand the relationships between different objects. This working knowledge defined in NEM courses is compared and integrated with other datasets from different sources, like DCN, which are relevant and similar in nature. When a complete knowledge graph structure is defined, it will allow answering a query to find a knowledge atom or a group of atoms that will produce required educational material, i.e. it will be some type of recommender learning system.

In the current stage of the NEM methodology, atomic basic and atomic graph based learning is used to create learning material by using graphs to connect basic elements of knowledge (atoms), enabling the learner and trainer to personalise the course material. In NEM, atoms are defined as a unit of knowledge and can be represented by a different format like textual, video or audio. The graph connections enable the creation of different paths and multivariant combinations of atoms and their representations, resulting in different and personalised online courses. This means that each path define specific context or course. Furthermore, this approach can adapt courses to various students' requirements, including students with specific disabilities or learning issues.

Graphs will provide additional resources for classifying (machine learning method) the learning material and forming an intelligent tutoring system in future work. One of the most important things that can help NEM to form user-adapted courses is knowledge graph capabilities to support the creation of new knowledge, establishing connections between data points that may not have been realised before. The example of one course defined in knowledge graph/NEM context is presented in Fig. 1

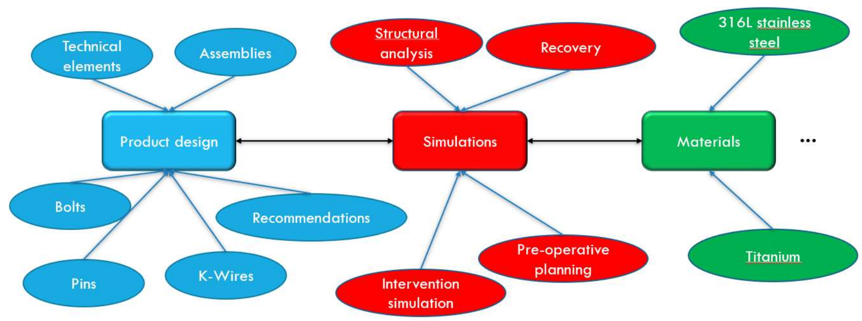
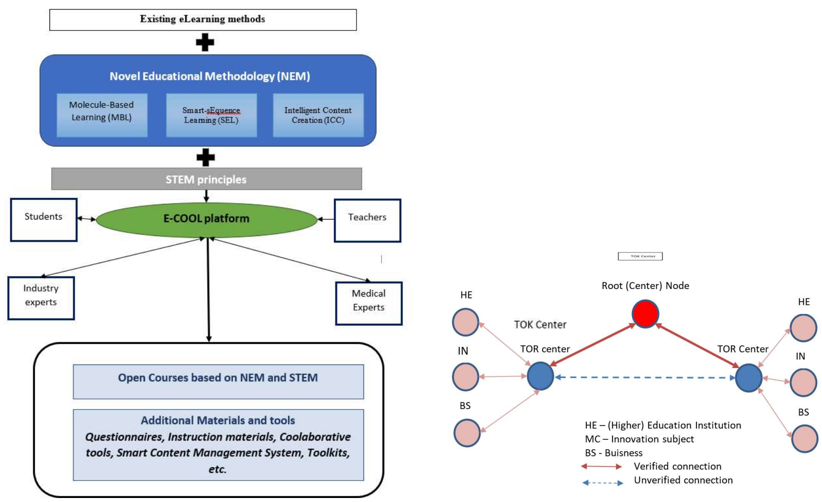


Fig 1. Graph-based atomic learning in medical engineering

Fig 1 presents three molecules of knowledge or complex educational entities: product design and simulations. Both contain individual atoms of knowledge. For example, technical elements for product design can refer to CAD software technical features for 3D modelling; bolts can be defined as standardised elements used for assemblies, etc. Each knowledge atom can be connected to others by different relationships and connections. The graph approach should allow the connection of elements into educational entities, i.e. courses with different orders, which depends on the stated, customised or sequential learning requirements. In the presented example, the course is composed of three molecules, product design, simulation and material, and the course should be conducted sequentially. Still, if different relations are imposed, then graph can define complex routes to the realisation of this specific course and other potentially tailored courses that can be made from these atomic elements. Atomic elements are initially defined as self-contained, but they can be part of any course, which is one of the benefits of the NEM application. The e-platform (E-COOL), presented in Fig 2a, is used to create courses by using atomic elements as a base and course as a representation of the combination and order of the atoms of learning, i.e., graph nodes and connections.

A DCN will be formed by implementing the atomic principle through a collaborative e-platform, thus, enabling creation and implementation of open personalised courses and courses with customised content, for education, innovation, and business (knowledge triangle). Furthermore, this platform enables registration and collaboration between scientist, engineers, students and other participants from the private and public sectors to create current healthcare-required courses. Connection and cooperation between portal participants are essential to properly acquire required knowledge and implement and develop new engineering methods and medical techniques, like one presented in this research.



a) The NEM and ECOOL platform overview b) The TOR structure

Fig. 2 The NEM and ECOOL platform overview

Considering everything stated before, DCN as a virtual network of knowledge triangle centers is and will be connected through existing internet structure. Each center will be defined as node in a network. The main components of each node are virtual avatars of knowledge triangle entities (academia, innovation, business). These three avatars will form a Triangle of Knowledge - TOK). Virtual avatars are currently in the creation process and represent each partner in TOK. Virtual avatars can be considered optimised digital tweens, where only selected parts of behavior and characteristics are transferred into the digital world. TOK currently forms a basic connection which enables bi-directional transfer of knowledge, to help improve education, research, and innovation. The network nodes (centers) will be connected by using proposed inverse tree diagram. This diagram uses one center node as root and connects it to other nodes using branches (Fig. 2b). Each branch has the root node as start node, and end node (individual participant center). In this way one node can be connected directly to root node. This is important because every piece of information from individual centers must be compared and verified before it is sent to others. Direct communication between centers can be done, but final verification must be done by a selected body that works as part of the main center.

The system conforms to the fluctuational staff management [11] and information system management rules. This means that other nodes can take over the main center's function in the case of some interrupts, like unavailability. Each node doesn't need to have a complete TOK triangle. If some of the components are missing, they can be acquired and used from another node. This approach will eliminate a communication bottleneck, which is why network is very important. It will bring resources from around the Europe just click away. The direct communication between nodes in network, and inside node (between triangle components), will be based on web services, and it will use new XML specification for knowledge transfer, which will be developed in future work. In the current version classic SOAP messages are implemented. The one of very important elements of future work is to enable indirect communication between avatars by using AI agents, which will collect data (new knowledge in education and research) from each partner in a node and/or whole network, and alert main center (root node) about detected updates. After verification, main center will propagate updates to each node and new knowledge will be available to all included partners. To show practical example of DCN network application in Fig. 3 is presented a use case of personalised implant application.

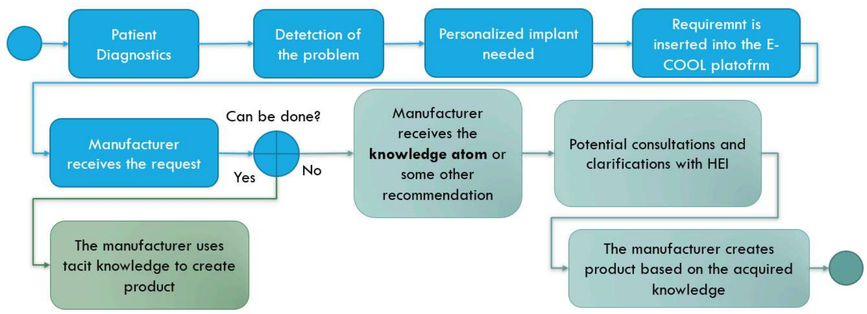
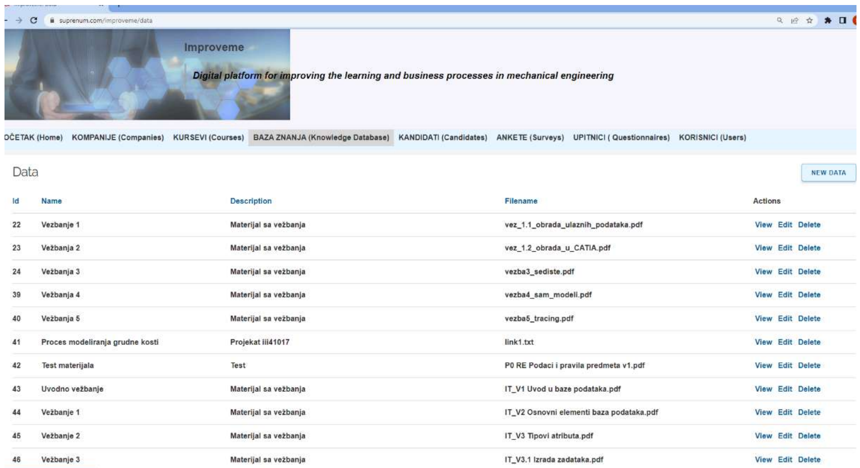


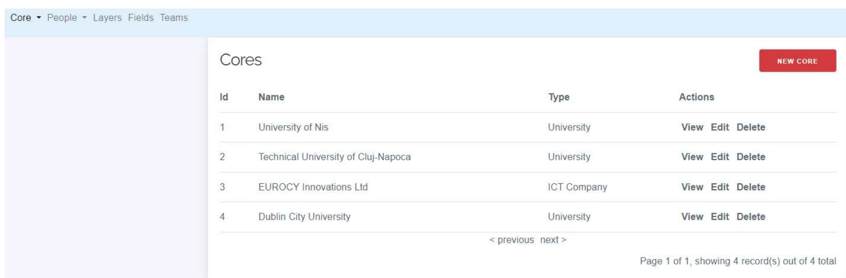
Fig. 3 E-COOL Smart Content Management System Example

The presented use case refers to the classical clinical case in orthopedic for the treatment of bone trauma. The initial step is patient diagnostic procedure done in a medical clinic. The diagnosis is defined, and the conclusion states that a personalised (not standard) implant is required. The personalised implant as one of the atoms in the E-COOL platform is selected, and description (requirement) is inserted. Based on the connection with DCN application the possible manufacturer(s) receive the request to produce the personalised implant. If this specific implant can be manufactured, it is made, and process is finished. Suppose production is not possible because of a lack of required knowledge. In that case, the E-COOL platform can provide instructions from its database and enable collaboration with academia or other businesses for additional consultation using the DCN network resources. When all required knowledge is acquired the production is performed and the plate implant is transferred to the medical clinic.

To enable realisation of the previous use case, two main connected web applications (platforms) are developed and presented in Fig. 4a and 4b, for E-COOL platform and for iCenters (DCN) application respectively. The first one is E-COOL application intended for NEM application and knowledge sharing, while DCN application is oriented for centers forming and their connections through established network. Both applications are in beta development, but all initial and previously described functionalities are integrated. The communication between applications is currently done using web services and messages, but in the final version, one whole application encompassing both platforms will be formed.



a) E-COOL platform data elements (knowledge atoms), current link - https://suprenum.com/improveme/



b) DCN platform with Center cores displayed, current link - https://callmeportaleu.suprenum.com/icenter/cores

Fig. 4 E-COOL and DCN platforms

The main entities of the E-COOL platform are: data atoms, users, candidates, companies, and surveys. The data atoms are main entities, while others are supportive. Companies can contribute by adding data atoms, and courses can be created by manually connecting atoms or by semi-automatic using graphs. Surveys are used for course validation and also users (candidates) testing.

The main entities of the DCN platform are: cores, fields (science, industry), layers (specific fields, or layer with fields combination, e.g. for some project), people (belonging to several fields and layers), organisations (academia, industry, etc), organisation_service used for communication with E_COOL platform (with companies). Companies will be replaced with organisations in the E-COOL platform to have a unique connection. The Fig 5 logic schema diagram of the DCN platform is presented to understand the centers' data model better.

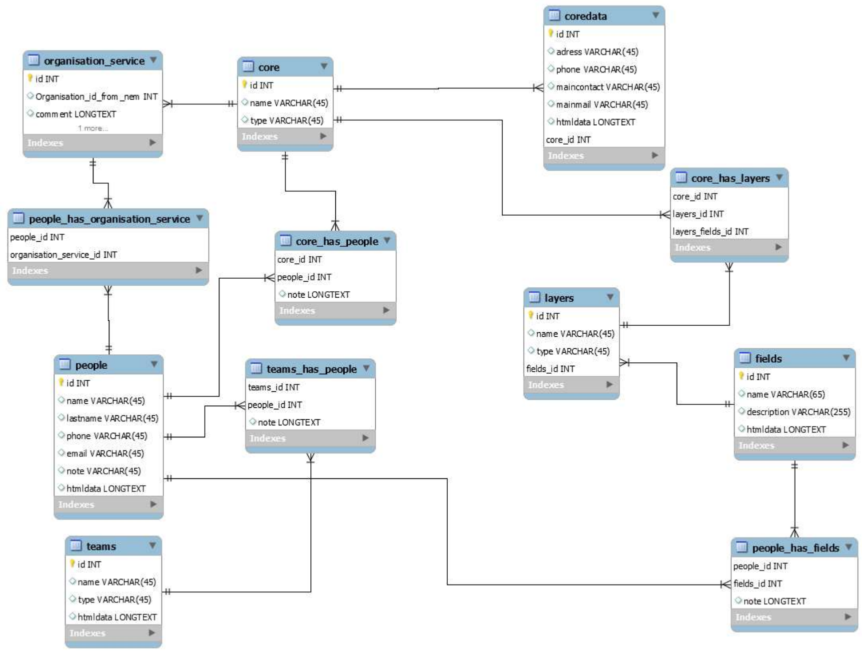


Fig. 5 The database/logic schema of the DCN

3 Conclusion

This study shows how Novel Educational Methodology can be used to create external resources like the Knowledge Triangle Center represented through Dynamic Collaboration Network. The NEM should be a tool for cooperation, knowledge exchange and improvement, skills and competencies upscaling and improving educational processes in higher educational institutions. It can be used as an educational paradigm for improving lifelong, project- and work-based learning and a tool for academia and industry education.

The presented solution for education in biomedical engineering is innovative, includes different actors from private and public sectors and is represented by an open-source e-platforms integrating various modern e-Learning technologies and methods, together with networking. Therefore, it offers complete and contemporary solutions for education in specific fields and the capability for implementation in other complex educational and scientific areas.

Important future output will be open e-platform for collaboration and knowledge exchange, which will enable the application of Novel Educational Methodology (NEM), molecular network structure of knowledge triangle elements (business, academia and innovation), enhancement of existing Higher Education curriculums, creation of innovative patient-oriented products (hardware and software)

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