RESEARCH COMPETENCE DEVELOPMENT PROGRAM FOR PHD STUDENTS

Prof. - Dr. Jozsef Rohacs

Head of Department of Aircraft and Ships
Budapest University of Technology and Economics
Hungary
jrohacs@rht.bme.hu

Abstract

One of the important goals of the doctoral schools is help to PhD students in development of their research competences. Principally, the competence is simple ability to doing something well. From the doctoral school point of view, the PhD students must develop their competence in running the research, e.g. understanding and defining the problem, looking for the possible solutions, generating the idea for solving the given problem, developing the new solution, new method or technology, testing the developed solution and making recommendation for its implementations, as well as running and managing the research and development projects, report and journal article writing, etc. So, the doctoral schools should have creative environment and strategic and knowledge management for developing the research competence of the PhD students.

This paper describes the research competences development of the aeronautical PhD students developed and applying in small country with limited aeronautical industry.

Keywords: *competence, research competence, competence development, aeronautical doctoral schools*

Introduction

The Doctoral Schools at the Hungarian Universities and higher education system had been established for the first part of 1990s (Kárpáti and Schwarczenberger, 1997), after changes in political system of country. The Faculty of Transportation Engineering and Vehicle Engineering at the Budapest University of Technology and Economics has established two doctoral schools: one in field of transportation engineering, in other in vehicle engineering and mobile machines. Both accepting students dealing with air transport and its sub-systems development and developing the aeronautical sciences, investigating and developing the aircraft, their production and operational systems. However, in Hungary the air transport and aeronautical industry very limited. The daughter companies of the international, global economy make their developments at home bases, while the Hungarian small companies have not enough capitalization for ordering developments from the universities.

In this environment, the development of the research skills, competences of the aeronautical PhD students is a very hard and complex task that needs original way of organization, infrastructure, working with students, organizing them practices and intensive international cooperation.

At the Department for last 20 years 24 successfully defended scientific theses had been performed. For last 15 years about 200 students has completed their M.Sc. theses at the Department. From them about 40 have had PhD already. The former students had followed their PhD study at the Department, other Departments of our university, other scientific institutions including many foreigner universities and scientific institutions.

For last 5 – 10 years, an interesting new problem has appeared: reducing number of well educated students would like to complete their PhD in field of aeronautics and in engineering generally. At the same time the several indicators of the doctoral schools, as ratio of students finishing their 3 years study and number of students have contributed their PhD thesis for 7 years related to the number of students entering into the program are reducing continuously, too.

Analysis of this problem has shown that, the students generally look for "easier" jobs required not so large and continuously renewable knowledge; they afraid of not having research position in field of aeronautics (and engineering generally) and they afraid of not having enough competences to run research projects. There is the reason why we have tried to develop and include into the doctoral schools program a special competence development strategy.

The lecture describes the analysis of the problems, definition and evaluation the required research skills combining with research project management, working out the research competence development program, deployment of the developed program.

A program had been developed by use of systems engineering approach, innovation theory, theory of development of the radically new technologies, new rules of identification, evaluation and selection of new technologies and product development philosophies. The program includes the development of communication, article writing, the managerial, and administrative skills, and so on.

1. Doctoral Schools of the Faculty of Transportation Engineering and Vehicle Engineering at BME

The 230 years old Budapest University of Technology and Economics (BME) is a prestigious Hungarian higher education center, mother university of Teodor von Karman, Leo Szilard, Ede Teller and 4 of its famous scientists, Fulop von Lenard, Jeno Wigner, Denes Gabor and Gyorgy Olah got Nobel preemie (Budapest, 2012).

The Faculty (Közlekedés, 2011) of Transportation Engineering and Vehicle Engineering (FTEVE) at BME, is a 60 years old leader Easter – Central European education and research center in field of transportation engineering, vehicle engineering and logistics. It has B.Sc., M.Sc. and PhD. programs in all fields of transport (road, city, rail, water, air), vehicles (railway, automobile, ship, aircraft) and logistics (including the building and material handling machines, logistics machines and supports, etc.). The faculty has more then 100 staff members and about 1400 students. There are 10 different Departments and many laboratories. The info-communication system and software bank is very large containing all the important type of software required for investigation, evaluation, design and development of the transportation systems, vehicles and logistical systems.

The faculty is very strong in research and development. The 60 % of annual budget becomes from the contract based research and national and international research projects. Only the Department of Aircraft is involved into 12 EU FP6, FP7 projects. Another interesting indicator shows that, the staff publish large number of articles on level 1 publication for every 12 635 EUR incomes.

The Faculty had defined its research goals following to major European technological platforms (ETRAC, ERRAC, WATERBORNE, ACARE, EIRAC) – as development, establishing, operation and control and managing of such vehicle – transport – logistics complex system that is user friendly, effective (operating with minimum total life cycle cost), safe, secure, having minimum impact on environment, sustainable, integrated (interoperable, and intermodal) and may support the on-demand free motion of peoples and goods (Rohacs, 2012a).

The Faculty has two Doctoral Schools, that are excellent in model development, model identification, simulation, automation and control, as well as combining the economical, and environmental factors with engineering solutions and developing original solutions. *Gábor Baross Doctoral School on Transportation Engineering (GB-DS)* supports the doctoral research dealing with scientific investigation, development, establishing, operation, measuring, evaluation, managing, economy and control of the transport and logistics systems.

The *Kálmán Kandó Doctoral School on Mechanical Engineering Sciences (Vehicle and Mobile Machines) (KK-DS)* is a basis for doctoral research in field of developing, design, production, operation, control of the all kind of vehicles (automobiles, railway vehicles, ships, aircraft), mobile vehicles (logistic, building, material handling machines) and their systems, element, etc. as well as the integration of the vehicles into the transport and logistics systems.

The Department of Aircraft and Ships has involved into both program. In GB-DS the air transportation system is investigated, while the PhD students of KK-DS are working on aeronautical science, investigating and developing the air vehicles.

The Doctoral Schools accepting students for 3 years program. Students should take part

- in education program (4 semester, 3 subject on each semester at least 6 contact hours pro week and exams on the end),
- in teaching program (4 semester at least 4 hours pro week leading the laboratory works, practical hours, supervising the semester projects and theses),
- in research program (for developing own research program for writing the doctoral thesis),
- in department activities (including contract based research, national and international projects, organization of the conferences, professional events, etc.),
- in scientific – public activities (working in scientific societies, giving lectures on the conferences, etc.).

The PhD students must write a thesis including some original (not published yet) results and write minimum two journal paper and give lecture on minimum two conferences. The thesis must be defended before the evaluation board including 5 independent members and 2 opponents (making criticism on the thesis before the defense).

Generally, the best PhD students can defense their thesis 5 – 6 years after their enrolments into the Doctoral Schools. They as usually publish 12 – 20 articles before their thesis defense.

2. The problems of changes in doctoral schools indicators

The success of Doctoral Schools might be evaluated by use of several indicators as number of students would like to entering into programs, number of PhD students (having scholarships from state, from others (as companies, foundations, etc.), corresponding (like part – time) students, number of students leaving the program before its end, number of student making successful defenses within 7 years, and so on. Very often, instead of indicator absolute values, the ratio of given value to the state support number of students, etc. may use in evaluation.

The Doctoral Schools established at the Faculty of Transportation Engineering and Vehicle Engineering was very successful at the beginning. About 3 times more students apply for entering into the programs then were accepted. As average, to 9 state support (having scholarship) students another 6 – 9 students having scholarships from the companies, foundations and special organizations were jointed to the program every year. Plus about 8 – 12 corresponding students were included into the programs. Nowadays, we have for 10 state scholarships only 8 – 9 applicants, plus 2 – 3 persons having scholarships from other sources, and another 2 – 4 corresponding students.

The number of students would like working at the Department of Aircraft and Ships has not dropped dramatically, only, therefore ratio of students working on development the aeronautical sciences and air transportation system has increased in given doctoral schools.

After rapid development of the transport – vehicle – logistics segment of Hungarian economy, the ratio of student finishing the 3 years programs and having the PhD after 7 years has dropped down from 86 % to 42 %, and from 67 % to 22 %. Especially, these number are very vary depending on the status of PhD students. Still about 75 % of students having state scholarships are finishing the 3 years programs and more than 40 percent from them defended their PhD theses. That means, about 60 % of the corresponding students left the programs after first years, and less than 3 % of them can have PhD finally. (The corresponding students are working at different companies and they are not involved into the departmental research programs and activities.)

Only three Departments from ten could maintain their doctoral schools indicator on the previously level. The Department of Aircraft and Ships has unique position: it has kept the PhD study levels on the high level, while aeronautical industry and air transportation system are quite limited in Hungary.

After appearing the problems associated with changes in the indicators described above, a special investigation was initiated. The analysis of the situations had been organized on three different levels. On the academic level the other doctoral programs and their results had been analysis for comparison. Other works analyzed the requirements of the companies, Hungarian economy and technology development strategy for evaluation of the requirements to PhD students. Finally the PhD students were invited for a special interview and they were asked to fill up a special questioner, too.

The detailed analysis had show that

- the doctoral programs and requirements are nearly the same for all the Hungarian Doctoral Schools,
- the rapidly developing sector transport – vehicle – logistics needs high qualified engineers, but they have no large interest in employing the people having PhD (the engines of this sectors are the global companies, having hear factories, but limited research facilities),
- the students of the Doctoral Schools (as in case of most of the engineering doctoral schools) may find attractive jobs in rapidly developing sector after 1 – 2 years of their doctoral studies,
- the PhD student afraid of their future, they are not sure in finding the high level research position and they very afraid of the working on the administrative and management parts of research (writing the applications, dealing with research budget, etc. they would like to make research, only).

This last conclusion of the analysis was quit new for leaders of the doctoral programs. On the other hand this was that part, which is under control of the leaders of the program. Therefore a special project had been initiated for developing the research competence of the PhD students. It seems, this program will integrated the methodology developed at the Department of

Aircraft and Ships, where the PhD students are taking part in all types of activities running at the Department, as teaching, taking part in conference organization, working on projects starting from writing the proposal up to administrative management, making lectures, etc. So, the Department has developed and applied a research competence developing program. For their PhD students.

3. Competences

The term "competence" first appeared in an article of Lundberg (1972) and became generally used after paper David McClelland (1973) titled "Testing for Competence Rather Than for Intelligence". Since many different visions, models and skill developing concept had been described, defined (see for example Boyatzis, Saatcioglu, 2008).

The competence is an ability to doing something well. The personal competence is the human behavior, that always is combined with social competence and cognitive behaviors depending on the social background of the individuals and ability to concentrate the attention, using the memory, understanding the conversation (and literatures), solving the problems and making decision.

The competency selection and definition (Patricia et al. 1996) is a reader complex task, that can be solved in case of starting from general competency, following by study the special area (Downey et al., 2006; Male, Bush and Chapman, 2010) and finalizing by the special field of professions (NASA's, 2012) .

Up to now, the management, psychology and education are on the front of competencies' investigation and development. The identification and definition of competence in engineering areas just have started (NASA's, 2012). Unfortunately, there is not real information about the development of these type of competencies at the level of doctoral studies.

Generally, the competence development is a four steps process, which must include (or better to say react on) many specific aspects of the developing the research competencies.

In more general form, *competency* is a set of the (standard) requirements for an individual to properly perform his specific job (research). These competencies may different even for different research areas, because in some areas the theoretical knowledge, in others the practical knowledge or using the simulation technologies are more important. For example, in case of optimization of airfoil or wing requires high level theoretical knowledge in fluid mechanics, aerodynamics and good skill in use of CFD technologies; while developing MEMS technology for flow control around the wings basically needs practical knowledge and practical investigations. Developing an optimal non-linear control for gas turbine is very different from optimization of the structural solution of the racing sailing yacht.

The competence-based (1997) strategic management is an integrative strategy deploying the resources in ways that helps an organization achieve its goals. In our case, this is the task of the Doctoral Schools and Faculty management. Therefore the minimum requirements and list of basic research competencies must be defined and deployed in doctoral program in its curricula, practical and laboratory investigation programs and supporting the PhD students in developing their abilities to understanding the problems, finding the possible solutions, evaluating the test results, making decisions and - what is very important, too, - contributing the research reports (even in foreigner language), making presentation on high level conferences, understanding and answering on the questions, publishing the journal articles, etc.

4. Definition of the set of required competences

There are two levels of competences ordinary or common competences (like reading and understanding the texts, ability to communicate) and specific or professional competences (understanding the aeronautical texts, ability to write the paper articles, ability to understand and answered on the questions after giving a conference lecture, understanding how to write a proposal for call for supports, understanding the financial aspects of the project management, etc. This set of specific competences is composed from several groups of competences depending on focus into specific aspects. In case of aeronautical research, the sets of competences starting from engineering competences and going through the areas developing the aircraft, airframe, system or engine, developing new measuring system, new control system etc. up to the real specific problem like optimization of the structural solution for example a wing section.

The most important competences required for excellent performance the given tasks, generally are called as core competences. The core competencies must be defined for developing a competencies' development program for the doctoral schools. The *core competencies*

- are the specific factors,
- help to keep the leading position in the given field
- and they are not so easy to imitate, while
- re-usable widely and
- result to the experienced benefits.

There are many articles about the changes in education systems characterized by

- rapid flare of (common) knowledge to learn,
- increasing the society and economy expectations,
- requirements of combination of wide general knowledge and high specialization
- mass education on higher level, too,
- education time increasing, the education level "decreasing", e.g. developer - engineering role of former engineers has shifted up to the role of PhD holders.

It seems the role of engineers has changes a lot and today must be redefined. However, famous Hungarian writer, Mór Jókai in 1870 already, had described the requirements and skills to modern engineers. The engineer playing leading role in book "Black Diamond" had the following characters:

- he was engineer,
- he has conducted foreign studies, which is strongly supported by the EU nowadays,
- he trained himself continuously (life long education),
- he was aware of the latest achievements of science and technology,
- he spoke several languages,
- he had oversight on questions of (mining) laws,
- he had shares, he had high level of economical knowledge,
- he was an excellent team worker and even team leader,
- he was creative, innovative, full of ideas
- he was able to make decisions by himself,
- he was a man to fit challenges and changing expectations.

As it can be seen, the described skills are nearly the same as they expected for global engineers (Male, Bush, Chapman, 2010).

In reality, the role of engineers had been changed a lot for last 50 years. The role of engineers in success of companies had reduced, while the role of managers had increased. Nowadays, the role of system integrators are increasing.

5. Learning as Skill development process

The competencies include the behaviors, knowledge and skills.

The human behaviors are the set of psycho-physiological ability of human to use and control its endocrine and nervous systems in performing tasks. This ability depends on the social background, accepting the social norms and culture. This ability includes the accepting the scientific approaches to development of the sciences, limits initiated by societies and keeping right for doubting and deliberation that is very important in finding the new solutions.

There are many different approaches to knowledge and skills development (Conscious, 2012). For Example, Dreyfus and Dreyfus (1980) introduced nomenclature for the levels of competence in competency development. They have defined 5 levels of competences:

1. Novice: Rule-based behavior, strongly limited and inflexible
2. Experienced Beginner: Incorporates aspects of the situation
3. Practitioner: Acting consciously from long-term goals and plans
4. Knowledgeable practitioner: Sees the situation as a whole and acts from personal conviction
5. Expert: Has an intuitive understanding of the situation and zooms in on the central aspects

This approach can be applied to development of the research competences at the doctoral schools, too. In our case

1. The PhD students were novice during their study in B.Sc., M.Sc. courses, when they meet first subjects in aeronautics and open eyes for that, how their everyday practice (like using the car, making physical measurements, etc.) is far from the real high technology system and how much they have to learn for understanding aerodynamics, flight performance, flight dynamics and control, how the structure must be design, tested, how engines has to be integrated into the airframe, how the air transport must be organize, what means the air traffic management, etc.
2. As usually, the PhD students before their entering into the doctoral program have had some experiences in model development, simulation and laboratory measurements, but still they needs helps assessment in development their vision on general development of the aeronautical sciences, understanding the methods of new technology development, managing the research projects, managing the new technology implementation and innovation diffusion processes. All these are required for understanding the situations, their boundaries and interactions of situations with the (changes in) surroundings.
3. Our student defending their PhD thesis must reach or must be close to the level of practitioners. (According to our university law, the PhD thesis can be successfully defense, only, if it would contain some theses, that means original results published firstly by candidate - author). They must clearly understand the situations investigated by them, as well recognize and predict the effects of their actions on the long term future.
4. Getting some years real practice our formal students may reach the level of knowledgeable practitioners in some specific areas. The knowledgeable practice professionals should have tacit skills can be owned in practice, only. We must prepare

them for reducing the time of passing from practitioner to the knowledgeable practitioner levels. Therefore they have to involve into the real scientific life, they have to take part in professional actions as conference organization, contribution to development the national sectorial strategy, they must be involved to the international projects including the administrative project management, etc.

5. Finally our formal PhD students will be expert in their working areas, because they can work on very high technology level, they are thinking in original way (“out of the box”), can manage the research project from writing the proposal up to implementation of the results and they able to combine the administrative, financial and technical aspects of the running projects.

The skills are learned capacities to carry the predetermined results. Generally the skills can be classified as hard and soft skills or domain-general and domain-specific. Hard skills are the teachable abilities that can be defined, coded and measured. For example how to develop models of the investigated situations, how to design the theoretical and practical investigations, how to evaluate the results, how to perform a special experiment safely, and so on. The soft skills are the personality-driven behaviors, how to use and keep the learned skills and requirements predefined for research and development. The soft skills are depend on the human personal behavior, etiquette, working environment, etc.

The quality and results of the research project very depend on the right combination of the hard and soft skills, e.g. making the research quit precisely but not afraid of using non-traditional methods, unusual solutions.

Another class of skills is called as the domain-general skills that are the general ability to understand the problems, planning the investigation, apply the time management, lead a team, etc. The domain-specific skills are required to working in special domains, for example making small physical models, developing the mathematical models, evaluating the new technologies, etc.

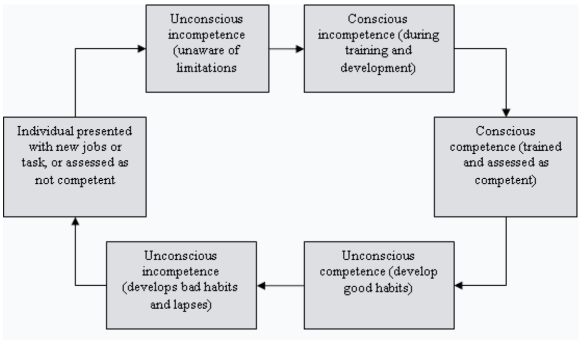

Figure 1. Skill learning - competencies development process

6. Research competence development

The competencies' development process (Fig. 1.) or the skill learning process contains four steps (Conscious, 2012):

- unconscious incompetence – recognition of incompetence, understanding the own, personal limits, the supervisor (teacher) must demonstrate the skills (ability) and benefits that will bring personal effectiveness (in the given field of human activities, e.g. research and development in the given area of science and technology),
- conscious incompetence – recognition of deficit and required new skills, the person realizes that by improving their skill or ability in this area their effectiveness will improve, understanding the role of practices,
- conscious competence - demonstrating the skill required concentration, principally, the person can perform the skill without assistance, but the person will not reliably perform the skill unless thinking about it - the skill is not yet 'second nature' or 'automatic'

- unconscious competence - new skills as second nature, the person may teach others,

The four stages are repeating, when the persons changes his job, field of activities.

The skill learning processes depend on

- area of actions (for example car driving might be learned easier, then aircraft piloting, because the candidates had been used as car passengers a lot, car driving mostly driving in 2D plane, etc.) and
- human personal behaviors, human subjective ability of learning (because some people may learn well from the written materials, but more people learn more from oral presentations, discussion, while engineers very needs practical demonstrations, too).

The PhD students are studying some subjects, taking part in teaching process of the department, and making their work under control of supervisors. So, we have to find the best individual methods of learning and teaching, the best way, how the supervisor can help to PhD student in development of his/her skills, competences.

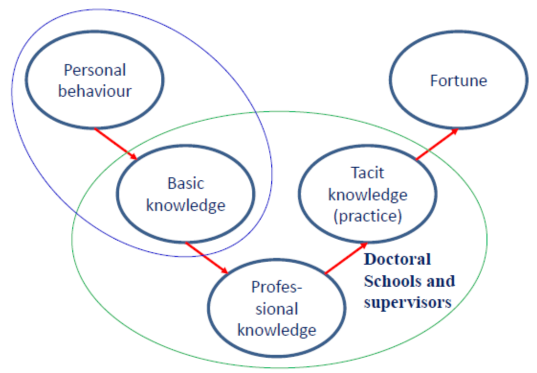

Figure 2. Skill development "V" model for competencies development at doctoral schools

From the systems engineering point of view, the competence development at the doctoral schools can be described by a "V" model (Fig. 2). The personal behavior including the emotional, societal and intellectual abilities to work on the problems together the partners and the basic knowledge must be developed mostly earlier then start of the PhD studies. The doctoral schools have a responsibility on development the high level basic and the professional knowledge. According to the innovation theory, the knowledge is based on the teachable subjects and materials and on the practices that is part of the knowledge which is not codified and can be own during practical works only. The doctoral schools should give chance for PhD students in development their tacit knowledge. So, the PhD students have to be involved into the problem definition, writing the proposals, developing the possible solutions, developing the models, planning the theoretical and practical investigation, giving lectures, taking part on the conferences, etc.

Unfortunately to the success a (little) fortune is required, too. Here fortune means the researcher meets an interesting problem, may have some original ideas, will able to organize investigation process that would be supported, may find and evaluate and understand specific results, may generate solution for problem, will able to organize implementation of his solutions, etc. The practice shows that, the high level researchers finally "would have a fortune", too. We must educate the PhD students to be prepared for recognition "their fortunes" and able to use with fortune.

With accordance to fields of aeronautics and air transport, the role of tacit knowledge may have determining role in development of research competences of young researchers. For example the aerodynamics still is working by using the semi theoretical or semi practical methods, formulas. The aerodynamists should "feel" how the forms, flying conditions, dynamics of changes in flying condition have influences on the aerodynamics of the given forms. Or, the available software may provide a lot of interesting results displayed in nice forms, pictures, but the researcher must understand which pictures are really close to the reality. Generally, now, we have much more information, we can "run" a lot of simulations and we may "generate" large number of results, that over of our ability to fully understanding "the nice pictures", selecting the important results, recognizing the specific aspects. Therefore the development of the tacit knowledge required as usually requires a measuring and testing infrastructure, and investigation of the real problems.

The successes – especially in theoretical investigation and developing the new technologies, methods - strongly depend on the way of thinking. As usually the engineers should use the generally accepted and effective methods, software, etc. the researchers should use their fantasy in looking for the new possible solutions. Such way of thinking is called as "thinking out of the box" (Rohacs 2009, Graaff and Truman, 2007), looking on everything with open eyes and thinking on original ways. Therefore the programs of the doctoral schools should have subjects, practices, discussions on the research methodology, development philosophies, design technique, modeling and simulation as well as on the human way of thinking, thinking on original ways, definition of the problems of the given areas of economy and sciences and study the possible solutions.

7. Specific aspects.

The development of the research competency needs a list of competencies (Passow, 2007, Male, Bush and Chapman, 2009) . This list actually contains two or three lists. At first the list of general aspects needing to perform the work of research and development and innovation must be completed. The second list must contain the specific aspects required to work in the given field of the economy and/or scientific areas. Finally the third list may complete the aspects of the specific are of economy and sciences.

The first list can be completed very easy, if we were thought about the daily business of the researchers (Rohacs 2012b) The list may contain the following aspects.

1. Problem recognition
2. Requirements predefinition
3. Journal article critique
4. Database Search and Retrieval
5. Data analysis – quantitative
6. Data analysis – qualitative
7. Concept development
8. Research definition (goals)
9. Methodology
10. Requirements definition
11. Theoretical investigations
12. Model developing
13. Test design
14. Measuring and testing
15. Verification and validation
16. Analysis
17. Results and their presentations
18. Benefit analysis
19. Report writing
20. Abstract writing
21. Poster
22. Conference lecture
23. Paper writing
24. Paper review
25. Team development
26. Research proposal
27. Project management
28. Project administration
29. Project financial administration
30. PR

The second list should number the specific aspects of the given areas of economy and sciences. This list makes different between the doctoral schools. For example, the transportation engineering sciences must study the society mobility, its dependences on the (global) economy, human habits, environment changes, etc. The studies have more sociological, operational, organizational, managerial, control, etc. aspect, then the vehicle engineering. This last needs more knowledge in mechanics, modeling, system integration, etc.

Finally, the third list is a "virtual list" showing up by supervisors of the PhD students. This list contains very specific aspects required in working on a specific sub-part of sciences and economy. For example working on the technical or social aspect of the air transport security needs different approaches in understanding, investigating and solving of the problems.

Even the second list of competences can be divided into several levels. For example, Our Department of Aircraft and Ships at Budapest University of Technology and economics has a unique situation. It is only the university level education and research centre in civil aviation in Hungary and has to work in country with very limited aeronautical industry environment. Therefore, for us to take part in international cooperation and especially in EU supported projects is extremely important. So, our PhD student has learn how to get and manage such international projects.

NASA has defined already the core competence of project management (Table 1.). They have defined a list of competence containing three levels. The first level defines the core competence required for running the aeronautical project. The second one defines the tasks to be solved in which the professional competences are required. Finally the third level contains the specified duties of the team members, sub-system leaders/managers/, project managers and program managers. For example, in case of developing the project conceptualization, the role of proposal, the role of project proposal (Table 1.) in the conceptualizing, analyzing, and defining program/project plans and concepts and using technical expertise to write, manage, and submit winning proposals. Also involves developing functional, physical, and operational architectures including life cycle costing. In this case – applying the NASA description to the EU FP projects - the role of project team member and sub-system leaders are the following (NASA, 2012):

Project Team Member

- *Be aware* of industry, institutions, universities and SMEs partnering activity internationally and their infrastructure utilization and developing functional, physical, and operational architectures, including life cycle costing.
- *Describe, identify or define*:
  - how EU FP projects are proposed, approved and funded, how can be combined them with the national projects,
  - the basic elements of a successful project proposal those must be react on the given calls for application,
  - the steps involved in getting a project approved and funded,
  - how a current project's proposal meets the needs of EU (and ACARE) strategy plans (as SRIA, Horizon 2020, Flight Path 2050, etc.) and chosen point from the call for proposals.
- *Support* activities involving multiple organizations, developing a network of external (international) contacts.

Subsystem (WP – work package) Leader/Manager

- *Participate* in:
  - developing functional, physical, and operational architectures, including life cycle costing,
  - development, trading, and selecting concepts, along with their technology plans,
  - activities involving multiple organizations, expanding network of external contacts,

Table 1.: NASA's (2012) project management competencies list.

Ciompetency Areas	tasks to be managed
PM 1.0: ***Project Conceptualization***	
Development of a concept, overall plan, and proposal for a successful NASA project. Includes preliminary definition of: program/project plan content; acquisition strategy and plans; risk management plan; development of a realistic cost estimate and a sound rationale for consistency with the NASA vision, strategies, and objectives	**PM 1.1 – Project Proposal** **PM 1.2 – Requirements Development and Management** **PM 1.3 – Acquisition Management** **PM 1.4 – Project Planning** **PM 1.5 – Cost Estimating** **PM 1.6 – Risk Management**
PM 2.0: ***Resource Management***	
Overall planning, allocation, and management of program/project resources. Includes advocacy; budget and operating plan development and management; allocation of financial, facility and other resources; tracking and control of contractor performance using Earned Value Management or comparable approaches	**PM 2.1 – Budget and Full Cost Management** **PM 2.2 – Capital Management**
PM 3.0: ***Project Implementation***	
The overall process of project initiation and implementation, including delegation of systems engineering responsibilities to the technical team (see SE competencies), penetration and insight of all contractor activities, evaluation of contractor performance, control of contract changes, and determination, and approval of contract award fees throughout the design, fabrication, assembly, integration, verification, validation, transition, and operational phases of the project lifecycl	**PM 3.1 – Systems Engineering** **PM 3.2 – Contract Management**
PM 4.0: ***Project Closeout***	
Overall planning and management of project closeout activities, based on assessment of project completion, political and other pertinent factors and stakeholder agreements.	**PM 4.1 – Stakeholder Management** **PM 4.2 – Technology Transfer and Commercialization)**
PM 5.0: ***Program Control and Evaluation***	
Process for controlling the final outcome of the program / project including tracking the performance of all significant contractors, vendors, and other involved entities. Requires penetration/insight of contractors' status and performance, allocation of resources, management of mitigation efforts, exercise of de-scope options when required and leading work-around options. Also includes management of the continuum of internal and external project reviews.	**PM 5.1 – Tracking/Trending of Project Performance** **PM 5.2 – Project Control** **PM 5.3 – Project Review and Evaluation**

  - industry and generally stakeholders partnering activity available infrastructure utilization,
  - the steps of submitting the project for consideration,
  - leading the submission the given WP leading by you and defining its sub-tasks, distribution between the partners taking part in given WP and harmonizing the partners activities,
  - harmonization of the WP leading by you with the project leader and proposal generally.,
- *Contribute* to efforts for managing a proposal writing/submission process.
- *Develop* capability in key aspects related to developing, costing and trading concepts, along with their technology plans.

Unfortunately, the core competences are in interaction with other core competence. For example, the described core competences of management has some interaction with core competences of systems engineering.

From this short analysis, it is clear, the list of competence is a living list and there development very depends on the human ability and situations. So, we cannot defined a set of competences could be developed generally. Each PhD students needs his/her own approach. The supervisor must show and demonstrate the competences required to developed and together the PhD students must find that which competences of the students might be developed. Cannot be all the students the high level modellist, or b

8. … and plus

Because the limited aeronautical industry in Hungary, we must find some competences in original way. We have analyzed the EU founded projects and possible international cooperation and we have found that our PhD students and may have success in case of

- demonstrating excellent competences in development of the models and simulation technologies,
- thinking originally (free of limits – out of the box),
- possible work on developing real pioneering projects,
- developing radically new technologies and
- ability in technology identification, evaluation and selection.

Therefore we have developed and introduced some specific courses as multiphysical approach to modeling and simulation, innovation in aviation, actual problems of aeronautics and air transport, applied systems engineering, product development philosophies, technology identification, evaluation and selection, control used biological principle, alternative controls, human way of thinking, etc. This course are started fro one – two lectures, up to 2 – 4 hours of weeks and one – two semesters. The basic ideas behind of such courses can be understood from papers :

For further demonstration of these original short courses we can make on technology development. Generally development of the new technologies appears in three different forms. The innovative technologies improve the existing technologies, existing solutions. The radically new solutions are called as development of the disruptive technologies that destroy the existing systems to develop a new solution and market for them and finally overcome on the existing technologies. The disruptive technologies initiate radical changes in the given area of economy. Finally, the third types of new technologies are the subversive technologies that cause radical changes on the society levels as happened when aircraft replaced cars in long-haul transportation.

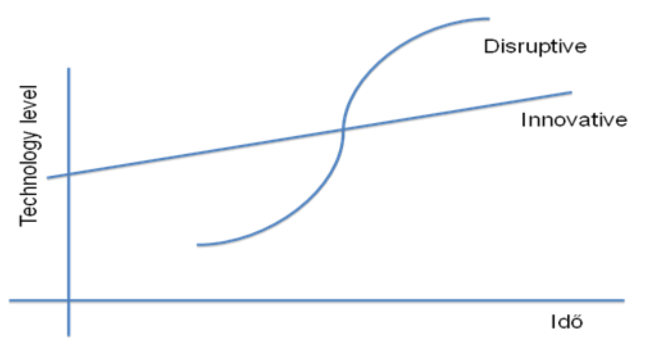

Figure 3. Effect of new technologies' developments on the technology level

The development of the innovative technologies (Fig. 3.) is a daily business of researchers and developers.

For example, the air transportation system has a serious problem according to the aircraft take-off and landing. Airports need to large land, aircraft must have - unacceptable by society - chemical and noise emissions. So, the developments focus on various possibilities to improve the take-off and landing performances, develop and implement new terminal flight procedures, or reduce the emission and noise on the airport surroundings. are the examples of developing new innovative technologies.

Generally, the new (i) scientific results, (ii) simulation and design methods, (iii) materials, (iv) technologies (like MEMS and nano technologies), or (v) developed production and operation systems may improve the existing systems, but these tend to the limits of the given technological system. The real developments are based on step changes in the technological level. In case of aircraft take-off and Landing, the use of magnetic levitation technology as ground based assisting the aircraft take-off and landing (GABRIEL, 2011) may result to developing a radically new technology, radically new solution.

Conclusions

One of the serious problem of the engineering doctoral schools is a lack in training the research and development management. The PhD students need to develop their professional and management sciences related research competencies.

Nowadays, the term competency is used for defining the list of skills required for making well a specific job.

The research is a really specific job required large basic knowledge, many specific knowledge and practice and several important specific skills, like understanding the problems, definition the projects, making application for calls, managing the projects, etc.

There are not special list of competencies about the research competencies. There are not real programs for developing the research competency at the doctoral schools.

This paper after giving short information about the change in indicators of the Doctoral Schools of Faculty of Transportation Engineering and Vehicle Engineering at the Budapest University of Technology and Economics, and the analysis of these changes, tried to define the first draft list of research competency to be developed at the doctoral schools.

The research competence development program is under introducing into the programs of the Doctoral Schools. First results have showed that, the team work of students and supervisors is more interactive, the PhD students are involving more into the national and international projects, and the number of publications in the PhD students are co-authors are increasing.

Acknowledgement

The work reported in the paper has been developed in the framework of the project „Talent care and cultivation in the scientific workshops of BME" project. This project is supported by the grant ***TÁMOP - 4.2.2.B-10/1--2010-0009***

References

60 éves a Közlekedésmérnöki és Járműmérnöki Kar, tanszéki publikációk, (szerkesztette, Rohács J.,), BME Közlekedésmérnöki és Járműmérnöki Kar, Budapest, 2011. CD-ROM, ISBN 978-963-313-040-7

Boyatzis, R., Saatcioglu, A. (2008): A 20-year view of trying to develop emotional, social and cognitive intelligence competencies in graduate management education, "Journal of Management Development" Vol. 27 No. 1, 2008, pp. 92-108.

Budapest (2012) University of Technology and Economics, http://en.wikipedia.org/wiki/Budapest_University_of_Technology_and_Economics

Competence-Based (1997) Strategic Management (ed. by Heene, A., Sanchez, R.), John Wiley & Sons

Conscious (2012) competence learning model, http://www.businessballs.com/consciouscompetencelearningmodel.htm (downloaded: 2012)

Downey, G. L., (et al. 2006), Lucena, J. C., Bigley, T., Hays, C., Jesiek, B. K., Kelly, L., Miller, J., Ruff, S., Lehr, J., Nicols-Belo, A.: The globally competent engineer: working effectively with people who define problems differently, "Journal of Engineering Educatioin", April, 2006, 1 - 16.

Dreyfus, S. E., Dreyfus, H. L. (1980): *A Five-Stage Model of the Mental Activities Involved in Directed Skill Acquisition*. Washington, DC: Storming Media. Retrieved June 13, 2010.

GABRIEL (2011) - Integrated Ground and on-Board system for Support of the Aircraft Safe Take-off and Landing, "Description of Work", GABRIEL Project (Project coordinator J. Rohacs), EU FP7 project, Grant agreement n°284884, 2011

Graaff, de A., Truman T. (2007) , "Out Of The Box, Ideas about the future of air transport - Part 2", 2007, http://mycopter.eu/fileadmin/mycopter_user_upload/files/Downloads/OtherDownloads/Out_of_the_Box__Ideas_about_the_future_of_air_transport_.pdf

Kárpáti E., Schwarczenberger H. (1997): Doktori programok a BME Közlekedésmérnöki Karán (Doctoral programs at the facultzy of Transportation engineering, BME, szerkesztette: Rohács, J.) BME, Budapest, 1997, 132.old.

Lundberg (1972): Planning the Executive Development Program, California Management Review; Fall72, Vol. 15 Issue 1, p10-15, 6p.

Male, S., Bush, M. B., Chapman, E. S. (2009): Identification of competencies required by engineers graduating in Australia, Proceedings of the 2009 AaeE Conference, Adelaide, 2009

Male, S., Bush, M. B., Chapman, E. S. (2010): Understanding generic engineering competencies, Proceedings of the 2010 AaeE Conference, Sydney, Copyright © Male, Bush and Chapman, 2010, 156 - 163.

Mcclelland, D. (1973): Testing for Competence Rather Than for Intelligence, American Psychologist Journal, January, 1973, 1- 14.

NASA (2012) Project Management and Systems Engineering Competency Framework, http://www.nasa.gov/offices/oce/appel/pm-development/pm_se_competency_framework.html

NASA's (2012) Systems Engineering Competencies, http://www.nasa.gov/pdf/303747main_Systems_Engineering_Competencies.pdf

Passow, H. J. (2007): What competencies should engineering programs emphasize? A meta-analysis of practitioners' opinions informs curricular design, Proceedings of the 3rd International CDIO Conference, MIT, Camb ridge, Massachusetts, USA, June 11-14, 2007

Patricia K. Zingheim, P. K., Ledford G. L., Schuster, J. R (1996): Competencies and competency models: does one size fit all?, ACA Journal, Volume No. 5. pp. 55-65

Rohacs J. (2009): Thinking out of the box - developing the radically new aviation technology, Magyar Repüléstudományi Napok konferencia, Budapest, 2009, CD-ROM, (szerk: Rohács, J. Hatfaludi L., Veress Á.), Budapest, 2009,

Rohacs, J. (2005): Transportation – Determining Strategic Element of the Economy (Characterization of Recent and Future), Transport Means 2005, Proceedings of the 9th International Conference, Kaunas University of Technology, Lithuania, 20 – 21 October, 2005, Technologia, Kaunas, 2005, 195-198 pp.

Rohacs, J. (2012a): Research on transport, vehicles and logistics in project BME TAMOP - 4.2.2.B-10/1-2010-0009, Proceedings of the TVL-1 - First Workshop on Transport, Vehicle and Logistics (organized by the PhD Schools of the Faculty of Transportation Engineering and Vehicle Engineering, BME (in the framework of the project TÁMOP-4.2.2-B-10-1-2010-0009), (Ed. by J. Rohacs), Faculty of Transportation Engineering and Vehicle Engineering, BME, Budapest, 2012, ISBN 978-963-313-062-9, paper No. KJK2012-1-P1, pp. 1 - 6.

Rohacs, J. (2012b): Possible developing the research competences, Proceedings of the TVL-1 - First Workshop on Transport, Vehicle and Logistics (organized by the PhD Schools of the Faculty of Transportation Engineering and Vehicle Engineering, BME (in the framework of the project TÁMOP-4.2.2-B-10-1-2010-0009), (Ed. by J. Rohacs), Faculty of Transportation Engineering and Vehicle Engineering, BME, Budapest, 2012, ISBN 978-963-313-062-9, paper No. KJK2012-1-P3, pp. 1 - 8.