On Learning Objectives and Learning Activities to Foster Creativity in the Engineering Lab

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Abstract— **Creativity involves coming up with something novel, something different. Up-to-date laboratory learning approaches in combination with inventive ICT can offer an immense variety of novel opportunities for experimentation and learning in the modes of creative inquiry. Fostering and encouraging creative laboratory learning in engineering education may not only animate what is learned but also includes the chance to tighten students' understanding and creative self-efficacy. The presented conceptual framework proposes a learning space based on portable devices in combination with an e-portfolio system. The aligned teaching and learning approaches aim at facilitating and fostering creative laboratory learning in engineering education. To this end, this article features six different scaffolding tasks to design learning objectives and activities for fostering creativity in the lab. It illustrates how the proposed personal learning environments might enhance or substitute formal classroom activities and laboratory work in order to achieve sophisticated learning objectives.**

Keywords—creative learning; laboratory learning; online labs; personal learning environments; mobile learning; engineering education

I. INTRODUCTION

According to [1] creativity involves coming up with something novel, something different. While creativity mainly deals with generating of ideas and novel solutions to problems, engineering is more concerned with bringing forth technological solutions to the task at hand, e.g. by designing and developing artefacts, processes, models, systems and services. But [2] stresses: "If creativity is so central to engineering, why is it not an obvious part of the engineering curriculum at every university?" Hitting the same line, [3] studied findings on fostering creativity in engineering education, and concluded that there is insignificant provision for creative students, until yet.

To foster the inquiring minds in engineering education, creative laboratory learning may not only animate what is learned but also involves the opportunity to consolidate students' understanding as well as creative self-efficacy [4], [5], [6], [7].

Findings on the virtue of laboratory work delineate that involving students in authentic investigation can encourage them to:

- develop their own comprehension of scientific theories, models, and concepts [8]
- develop knowledge schemes and solve engineering tasks at hand [9], [10]
- experience science as scientists [11]
- cultivate positive mindsets on science and engineering [12]
- develop critical thinking as well as decision-making abilities [13], and
- creatively nurture their own research questions [4], [5], [6], [7]

"Unfortunately, science laboratory materials and exercises usually provided to teachers of science, K-16, are still centred on traditional methods of the past decades" [14].

As opposed to this, laboratories based on research and inquiry flip teachers' roles into inviting students

- to frame problems themselves as well as
- to relate their findings to preceding work
- to indicate the intention of their proposed investigation
- to specify the task at hand
- to project outcomes (deemed possible or impossible)
- to determine problem-solving approaches, and
- to lastly accomplish the study [15], [16]

Beyond this, the utilisation of mobile devices can intensify creative thinking processes since original ideas usually emerge unexpectedly [17]. Having the mobile device on hand gives the opportunity to the user to capture these ideas by making notes, audio recordings, or logging first artefacts and actions by camera for enabling future access and continuative improvement [18].

Four contemporary tides in ICT-based teaching and learning development with the potential to support creative engineering education are distinguishable: personal learning environments (1), flipped or inverted classrooms (2), portable devices (3), and online labs (4).

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1. Personal learning environments (PLE) are “educational technology which responds to the way people are using technology for learning and which allows them to shape their own learning spaces themselves, to form and join communities and to create, consume, remix, and share material” [19]. PLEs “imply redrawing the balance between institutional learning and learning in the wider world” [20], and thus provide more responsibility and more independence for learners.
2. Flipped or inverted learning turns the focus of the class on the students instead of the teacher. With inverted learning, students can absorb the material online as homework, or wherever and whenever they want, and then practice what they’ve learned with guidance from the teacher, when they need it. This novel learning style increases students’ engagement and achievement, and provides to all forms of personalized learning [21].
3. Portable devices are perhaps the most increasing kind of technology for informal learning. The propagation of portable devices like tablet PCs and smart phones offers a distinguished capability to nurture new ways of informal and creative learning—anytime and anywhere [22].
4. The practice of remote and virtual experimentation [23], [24], [25] can be delivered to the learner by integrating them into technology enhanced and didactically aligned collaborative online learning systems [26] like cloud-based PLE.

This raises three crucial questions:

- How can engineering education foster (and be fostered by) creativity and creative engineering in general? How can students be enabled to gain the chance of executing lab work in a more creative mode in particular?
- Which might be the best manner for learners to capture and document their creative learning process documentation and to write their laboratory reports, even exams? How can teachers guide through these processes?
- How can this be nurtured by PLEs, portable devices and online experimentation facilities?

In this regard, the proposed solution is a personal learning environment based on portable devices assimilating online experimentation test beds and an e-portfolio system to expedite and cultivate creative learning in science and engineering studies.

II. CREATIVE LEARNING WITH PLES AND ONLINE LABS

A. E-portfolios as Personal Learning Environments

E-Portfolio-based PLE software, e.g., ‘Mahara’ can conveniently be combined with an LCMS based on Moodle. The integrating application ‘Mahoodle’ assimilates properties and functions of the teacher-led LCMS ‘Moodle’ and the learner-led system ‘Mahara’ for e-portfolios. This mesh-up can be regarded as “a facility for an individual [or a group] to access, aggregate, configure and manipulate digital artefacts of their ongoing learning experiences” [27].

B. Changing In and Out of Interaction with Portable Technology

Especially smart phones and portable computers open up a wide-ranging diversity of situations for creative inquiry regardless of time location and ambiance. As students are permanently on the move and changing in and out of interaction with technology, spare time periods can be spontaneously utilized for learning and working with e-portfolio software and the related laboratory equipment. This can be initiated virtually anywhere, regardless of most conventional software limitations, once access to a respective learning environment had been obtained: a far-reaching feature which is widely spread throughout cloud computing [28], [29].

C. Interactive Web Labs

Many programs are going to include Web labs into their education for enhancing the efficacy of rare equipment as well as to share it with other institutions and locations [23], [24], [25], [30], [31], [32], [33].

According to [7], in Web labs students can be engaged in:

- “blended and online learning scenarios regardless of time location, as far as Internet access is available
- learning activities which take longer than a typical class meeting time
- multi-part assignments which require students to use equipment for several short periods over the span of one week or longer
- socio-technically enhanced opportunities for student collaboration
- building up their own knowledge schemes using tele-operated equipment provided by the online labs” [7]

Even risky experiments which may be too dangerous for human interactions or experiments with precious equipment can be conducted in a completely virtual fashion.

D. Digital Documentation of Learning Processes

By establishing personal portfolios, e.g. a digital field diary, learners are allowed for documenting their specific learning and research developments [34], [35]. As stated in [7], students will learn to be able to:

- “arrange all data and information they would choose to collect or share with others in different orders
- present experiments and their results or to show photos from the experimental set-up
- write notes and reflections on their experiments during their research-based learning processes
- explain their research results and thoughts to themselves and others
- collect ideas in creative moments, and to organize and improve them whenever desired

- support collaboration by allowing other learners and teachers to have access to their e-portfolios
- prepare, write and revise the lab report as a living document drawing on their learner-generated multimedia content" [7]

These considered learning objectives and related learning activities are significant and essential to nurture the students' personal creative learning cycles [36]. Above, the e-portfolio as a digital field diary and personal learning documentation can always offer guidance and reflection in topics of students' own inquiry [7], [37], [38], [39]. Beyond that, other eligible persons or groups are able to view the collection within the portfolio. It can be stated that the e-portfolio is not only a versatile instrument for both individual learning documentation and learning-related reflection processes but also an especially valuable tool for collaborative communication. Finally, course instructors get the opportunity to guide and appraise the students' outcomes by observing, intervening, considering and reviewing their learners' e-portfolio work [7].

E. Learning Objectives and Aktivities to Foster Creativity in Higher Engineering Education

According to [40], learning objectives "are statements, written from the students' perspective, indicating the level of understanding and performance they are expected to achieve as a result of engaging in the teaching and learning experience". In addition to that, learning activities describe the actual related students' actions that indicate the cognitive (and psychomotor and affective) engagement they are expected to mature and finally master. Whilst general learning objectives and related activities for the engineering lab are well established by [41], creativity still remains marginally addressed in this context.

To this effect—foster creativity in the context of education—a model of six facets for defining, formulating, stimulating, and analysing learning objectives and activities is established by [42], [43, [44], [45], [46].

F. The Six Facets of Creative Learning Objectives and Activities

According to [7], these six facets are:

1. ***Students (are able to) develop self-reflective learning skills:*** Learners are relieved from the constraints formed by their receptive habits and empowered to question information given by the teacher. An internal dialogue takes place and knowledge becomes "constructed" rather than "adopted".
2. ***Students (are able to) mature independent learning skills:*** Teachers stop to restrain the way students learn. Instead, students are free to discover relevant literature on their own and, for example, to make their own guidelines about structuring a text or even to find their own research questions and to choose appropriate methods of answering them.
3. ***Students (are able to) nurture curiosity and motivation:*** This aspect is related to all measures that contribute to increased motivation, for instance, linking a theoretical question to a practical example or representation.
4. ***Students (are able to) learn from "learning by doing" tasks:*** Students learn by creating a kind of "product", their respective artefact. Depending on the discipline, this might be a presentation, an interview, a questionnaire, a machine, a website, a computer program or similar. Students are guided into the role of "real" researchers.
5. ***Students (are able to) develop multi-perspective thinking skills:*** Learners overcome thinking within the limits of their respective disciplines or prejudiced thinking. Along with that, they learn to consider an issue from different points of view and to use thinking methods which prevent their brains from being trapped in ordinary disciplinary paths.
6. ***Students (are able to) reach for original ideas:*** Learners are facilitated to embrace new, original ideas and to prepare themselves to be as ready-to-receive as possible. Although the acquirement of original ideas cannot be forced, the reception of original ideas can be fostered by applying appropriate creative techniques and by creating a suitable environment (allowing students to make mistakes and to express unconventional ideas without being laughed at or rejected).

Hereafter, six different model tasks to scaffold creative learning in the engineering lab are presented in order to explicate how personal learning environments containing the combination of Web labs, e-portfolios and portable devices can improve formal laboratory learning.

G. Model Tasks to Scaffold Creative Laboratory Learning Objectives and Aktivities

The model tasks are established on the six creativity facets framework.

1) Students (are able to) Develope Self-reflective Learning Skills by Evolving Critical Thinking with Technological Pitfalls

In order to nurture critical awareness of technological pitfalls, a misleading environment can be deployed to introduce a critical approach to given or default information. In order to achieve this goal, teachers can create tasks which are impossible to solve, or can provide false information that leads to seemingly correct but erroneous results of the experiments. In both cases, the students will be irritated while performing the experiment as well as challenged to find the cause.

A common engineering topic is surface coating in the field of *micro technology*. In order to foster *self-reflective learning*, teachers could ask their students to produce a surface coating for a substrate that is suitable for frying eggs. To stimulate a critical attitude towards given information, teachers can provide students with faulty instructions for developing and producing such non-stick coatings. The result could be a surface that would melt under high temperature and intermingle with the fried egg (have a look that students do not start to eat it). In this case, students would have to verify the given information as well as to clarify the mistake and reproduce the surface coating which fulfils demand.

The achieved learning outcome would comprise (besides technical knowledge about surface coatings and their behaviour) that students mistrust and reflect given information rather than simply receiving it, as they can experience the consequences of applying misleading information without putting it into question.

2) Students (are able to) Develope Independent Learning Skills by Improving Self-reliance and Self-confidence Towards Technical Issues.

Online lab work combined with PLEs make it possible to let students learn more autonomously. For instance, PLEs permit searching for information, planning and running experiments as well as learning independent decision making.

Advanced materials are another common topic in higher engineering education. Instead of simply handing students pre-selected information about the characteristics of selected advanced materials, teachers could ask them a relatively open question, for instance: “Which material is the best choice to attach an iPhone to a mirror in a fashion (in order to be able to watch it during the morning toilet) that it cannot be separated manually but by use of a second material without any damage of both?” Students are asked to collect the necessary information for themselves in the Internet rather than in textbooks.

In order to give assistance, teachers have to carefully monitor their students’ learning progress. If they notice difficulties or confusion among their students, teachers will have to help them “to help themselves” without providing completed solutions which will only lead to well-known solutions. For this purpose, PLEs are valuable tools that enable teachers to monitor their students’ learning steps and provide feedback to them, while students on the system’s other end can ask for help at any time.

As a reward for using this learning scenario, students will not only incorporate a wide range of aspects about advanced materials but will also learn to plan small research projects, as well as putting them into practice and feeling responsible for them as well as their individual learning successes. In the long run, performing small learning tasks on their own will improve their self-reliance and self-confidence towards technical issues.

3) Students (are able to) Nurture Curiosity and Motivation by Intertwining Technical Issues with Students’ Real-World Experiences

The question of rendering subject matter more interesting for students in order to tackle their curiosity and motivation is always worth asking.

A renowned methodology to increase students’ motivation is to apply practical questions and tasks. Therefore, combining practical issues taken directly from the students’ daily environment as well as online experiments or simulations might be the silver bullet of situated experimental learning.

For example, a lecture in *electronics engineering* about the characteristics of transistors could be very boring. But it can easily be spiced up with a small homework as a preparation for the transistor lecture: Ask the students to spend one day completely without the use of transistors. Collect their experiences in the lecture and try to find transistors they used even if they thought were absent (it is not that easy to raise awareness of the ubiquitous use of transistors). By noticing the relevance of transistors for modern life, students might become more interested in lab works on for example the temperature limits of those transistors keeping their life civilized.

To this end, the use of online labs may have several advantages regarding students’ creativity: they are readily available throughout the day, so students can pursue experiments whenever they have a good idea and therefore do not have to wait for the next lab lesson to test their personal ideas. They can conduct it whenever they feel creative and wherever they are, all they need is simply their online mobile device.

4) Students (are able to) Learn in the Mode of “Learn by Doing” by Designing and Building Functional Models

Since experimental learning as a means of scaffolding always inherits some sort of product to be created, this learning method appears suitable in order to achieve this goal as it might also strengthen the students’ awareness of their creative potential. Besides, exposing the learning outcome to a larger interest and external assessments are valuable factors in tackling students’ intrinsic motivation. For this purpose, the PLEs can be used to render the readily documented learning process accessible for externals.

For example, in *aerospace engineering* students are expected to learn the fundamentals of rheology. Instead of just presenting them the contents of a course book in a lecture, students could be asked to develop the most effective paper plane by assistance of several materials which can be found in the laboratory. By doing so, students should parenthetically be enabled to determine the drag coefficient of different designs. Moreover, by using online simulations of wind tunnels to try several varieties of their paper plane, students get involved into increasing its range by reducing its drag in an informal, playful manner. Furthermore, they would have to find the proper material for realizing the best design with regard to ductility and – of course – weight.

At this point, with emphasis on rheology, different aspects of aerospace engineering would be mentioned and the coherences would become visible. Students would be enabled to see a bigger part of the picture while applying and thus internalizing the necessary professional knowledge.

Finally, the inventors of the most effective paper plane (is it really the one with the lowest c_d value?) would receive a prize.

5) Students (are able to) Evolve Multi-perspective Thinking by Overcoming Cognitive Barriers

This scenario can raise students' capability to reconsider their questions from varying viewpoints: envisaging a student who had executed a lab task that generated odd results or does not know how to construe them appropriately. While writing his e-portfolio as documentation for the teacher’s evaluation, s/he could start the "creative-help app", a wizard application within the PLE intended to help him develop different perspectives on the same problem: The student is asked to do a (mental) headstand following the question: “What else could I do to get the wrong results from experimenting?” If this should not suffice, the student will be asked to describe his experimental design and assumptions in a way that a ten-year-old could understand it. If those methods which are fairly close to the problem still cannot help him, the "creative-help app" will suggest a force-fit technique by showing a picture that does not have anything in common with a problem and asking the student to find relationships between the picture and his experiment.

To depart from the beaten track can help students to look at their problem from completely different perspectives. This may result in unconventional or provocative ideas at first sight, but rethinking the obviously unsuitable solutions sometimes leads to the one really good idea which would not have appeared without making the detour [7], [46], [47].

6) Students (are able to) Reach for Original Ideas by Breaking all Rules and Posing one's Own Questions

The admission for “breaking all rules and posing one's own questions” is the actual challenge in creativity education. There are several options available to arrange for learner-led inquiries, investigation, discovery and reasoning. However, serious “Breaking all Rules and Posing one's Own Questions” may also create a lot of severe resistance from colleagues, superiors, institutions and others who still need to be involved and convinced to transform an idea into innovation. At this point, it is up to the reader to design a “Reach for Original Ideas by Breaking all Rules and Posing one's Own Questions” learning scenario for the lab course.

III. 6. CONCLUSION

The integration of online labs and e-portfolios into mobile personal learning environments can establish unique scenarios to nurture students’ creative performing in engineering education. Permitting students to learn this self-governing mode already integrates fostering their creativity with regard to the introduced and adapted model of six facets for defining, formulating, stimulating, and analysing learning objectives and activities to cultivate creativity in engineering education. This is one crucial approach to engage students in high-level learning outcomes and by this means developing the basis of fundamental domain-specific and generic competences for their successful participation in the prospective world of work. Moreover, the depicted methods can nurture attitudes like curiosity, creative self-efficacy, agency and responsibility. If students are empowered to evolve their own research questions, to choose suitable experimentation designs and finally to perform the experiment, they will be able to develop a spirit of inquiry and research. This spirit is one important premise for developing original ideas. And, generating of original ideas may the prerequisite for bringing forth technological solutions by designing and developing artefacts, processes, models, systems and services—or in short: engineering.

REFERENCES

[1] D.H. Cropley (2014): “Creativity in Engineering” in: G. E. Corazza, S. Agnoli (Eds.): *Multidisciplinary Contributions to the Science of Creative Thinking*. Springer, in press.

[2] Kazerounian, K., & Foley, S. (2007). Barriers to creativity in engineering education: A study of instructors and students perceptions. *Journal of Mechanical Design, 129*, 761.

[3] Cropley, D. H., & Cropley, A. J. (2005): "Engineering creativity: A systems concept of functional creativity" in: J. C. Kaufman & J. Baer (Eds.), *Faces of the Muse: How People Think, Work and Act Creatively in Diverse Domains* . Hillsdale: NJ: Lawrence Erlbaum, pp. 169-185.

[4] C. Terkowsky & T. Haertel, (2013) “Fostering the Creative Attitude with Remote Lab Learning Environments: An Essay on the Spirit of Research in Engineering Education,” in: International Journal of Online Engineering (iJOE) Vol. 9, Special Issue 5: "EDUCON2013", pp. 13-20. DOI: 10.3991/ijoe.v9iS5.2750

[5] C. Terkowsky, I. Jahnke, C. Pleul & A.E. Tekkaya, (2011) “Platform for E-Learning and Telemetric Experimentation (PeTEX) - Tele-Operated Laboratories for Production Engineering Education,” in: Auer, M.E., Al-Zoubi, Y & Tovar, E. (Eds.): Proceedings of the 2011 IEEE Global Engineering Education Conference (EDUCON) – "Learning Environments and Ecosystems in Engineering Education". IAOE, Vienna, 2011, pp. 491-497. DOI: 10.1109/EDUCON.2011.5773181

[6] T. Haertel, C. Terkowsky, D. May & C. Pleul, (2013) ”Entwicklung von Remote-Labs zum erfahrungsbasierten Lernen,“ in: Niclas Schaper, Tobias Schlömer, Manuela Paechter (Eds.): Themenheft Kompetenzen, Kompetenzorientierung und Employability in der Hochschule (Teil 2), Zeitschrift für Hochschulentwicklung ZFHE Jg.8 / Nr.1, pp. 79-87.

[7] C. Terkowsky, T. Haertel, E. Bielski & D. May, (2014): “Bringing The Inquiring Mind Back Into The Labs. A Conceptual Framework to Foster the Creative Attitude in Higher Engineering Education,”.in: Proceedings of *EDUCON2014 – IEEE Global Engineering Education Conference:* "Engineering Education towards Openness and Sustainability", April 3-5, 2014, Military Museum and Cultural Center, Harbiye, Istanbul, Turkey.

[8] G. Roehrig, A. Lulie, and M. Edwards, (2001) “Versatile Vee maps,” *The Science Teacher*, 68, pp. 28-31.

[9] J. German, S. Haskins, and S. Auls, (1996) “Analysis of nine high school biology laboratory manuals: promoting scientific inquiry,” in: *Journal of Research in Science Teaching*, 33(5), pp. 475-499.

[10] C. Terkowsky, D. May, T. Haertel & C. Pleul, (2013) “Experiential Learning with Remote Labs and E-Portfolios - Integrating tele-operated experiments into personal learning environments,” in: *International Journal of Online Engineering (iJOE)*. 9(1), Vienna, IAOE, pp. 12-20. http://dx.doi.org/10.3991/ijoe.v9i1.2364

[11] A. Okebukola and B. Ogunniyi, (1984) “Cooperative, competitive and individualistic science laboratory interaction patterns effects on students’ achievement and acquisition of practical skills,” in: *Journal of Reserach in Science Teaching*, 21(9), pp. 875-884.

[12] R. Lehrer, L. Schauble, and A. Petrosino, (2001) “Reconsidering the role of experiment in science education,” in: *Designing for Science: Implication from everyday, classroom, and professional settings*, Mahwah, NJ, Erlbaum, pp. 251-277.

[13] F. Abd-El-Khalik, S. BouJaoude, R. Duschl, N.G. Lederman, R. Mamlok-Naaman, Hofstein.,(2004) “Inquiry in science education: International perspectives,“ in: *Science Education*, 88, pp. 397-419.

[14] D.W. Sunal, C.S. Sunal, C. Sundberg, and E.L. Wright, (2008) “The Importance of Laboratory Work and Technology in Science Teaching,” in: *The Impact of the Laboratory and Technology on Learning and Teaching Science K-16*, D.W. Sunal, E.L. Wright, and C. Sundberg, Eds. IAP-Information Age Publishing, pp. 1-28.

[15] P. Tamir, (1977) “How are Laboratories used?” in: *Journal of Research and Science Teaching*, 14(9), , pp. 311-316.

[16] C.W. Keys, (1999) “Revitalizing instruction in scientific genres: Connecting knowledge production with writing to learn in science,” in: *Science Education*, 83(2), p. 115-130.

[17] T. Haertel, and I. Jahnke, (2011) “Wie kommt die Kreativitätsförderung in die Hochschullehre?” *Zeitschrift für Hochschulentwicklung*, (6) 3, pp. 238-245.

[18] D. May, C. Terkowsky, T. Haertel & C. Pleul, (2013) ”The laboratory in your hand - Making remote laboratories accessible through mobile devices,” in: *Proceedings of the 2013 IEEE Global Engineering Education Conference (EDUCON)*,"Synergy from Classic and Future Engineering Education", Technische Universität Berlin, Berlin, Germany, March 13-15, 2013. IEEE, 2013, pp. 335-344.

[19] G. Attwell, (2007) “Personal Learning Environments - the future of eLearning?” in: *eLearning Papers*, vol. 2. January 2007, p. 5.

[20] M. v. Harmelen, (2006) “Personal Learning Environments,” Proceedings of the *6th International Conference on Advanced Learning Technologies* (ICALT'06).

[21] J.Bergmann & A. Sams (2012): *Flip Your Classroom*. ISTE, Washington, D. C.

[22] E. Scanlon, A. Jones, and J. Waycott, (2005) “Mobile Technologies: Prospects for their use in informal science learning (Portable learning: experiences with mobile devices),” in: *Journal of Interactive Media in Education* (Special Issue), . Retrieved June 20, 2013 from http://jime.open.ac.uk/article/2005-25/303

[23] J. García Zubía and G.R. Alves (Eds.), (2011) *Using Remote Labs in Education. Two Little Ducks in Remote Experimentation*. Engineering, no. 8. Bilbao, Spain: University of Deusto.

[24] A.K.M. Azad, M.E. Auer, and V.J. Harward, Eds. (2012) *Internet Accessible Remote Laboratories: Scalable E-Learning Tools for Engineering and Science Disciplines*, Engineering Science Reference.

[25] J. García Zubía and O. Dziabenko, Eds. (2013): *IT Innovative Practices in Secondary Schools: Remote Experiments*. University of Deusto Bilbao

[26] M. Faßler & C. Terkowsky, (2006): Urban Fictions. Die Zukunft des Städtischen. W. Fink.

[27] R. Lubensky, (2012) The present and future of Personal Learning Environments (PLE), http://www.deliberations.com.au/2006/12/present-and-future-of-personal-learning.html [blog entry, accessed 14.10.2012]

[28] D. May, C. Terkowsky, T. Haertel & C. Pleul, (2012) “Using E-Portfolios to support experiential learning and open the use of tele-operated laboratories for mobile devices,” in: *REV2012 - Remote Engineering & Virtual Instrumentation,* Bilbao, Spain, Conference Proceedings., pp. 172-180. DOI: 10.1109/REV.2012.6293126

[29] W. Rochadel, S.P. Silva, J.B. Silva, T.D. Luz and G.R. Alves, (2012) "Utilization of Remote Experimentation in Mobile Devices for Education," in: *International Journal of Interactive Mobile Technologies* (iJIM), 6(3), July 2012, pp. 42-47.

[30] C. Terkowsky, I. Jahnke, C. Pleul, R. Licari, P. Johannssen, G. Buffa, M. Heiner, L. Fratini, E. Lo Valvo, M. Nicolescu, J. Wildt & A.E. Tekkaya, (2010) “Developing Tele-Operated Laboratories for Manufacturing Engineering Education. Platform for E-Learning and Telemetric Experimentation (PeTEX),” in: *International Journal of Online Engineering (iJOE)*, Vol.6 Special Issue 1: REV2010, Vienna, IAOE, pp. 60-70. DOI: 10.3991/ijoe.v6s1.1378

[31] C. Terkowsky, I. Jahnke, C. Pleul, D. May, T. Jungmann & A.E. Tekkaya, (2013) “PeTEX@Work. Designing CSCL@Work for Online Engineering Education,” in: Sean P. Goggins, Isa Jahnke & Volker Wulf (Eds.): *Computer-Supported Collaborative Learning at the Workplace - CSCL@Work*, Springer (Computer-Supported Collaborative Learning Series, Vol. 14), pp. 269-292.

[32] C. Terkowsky, C. Pleul, I. Jahnke & A.E. Tekkaya, (2011) “Tele-Operated Laboratories for Online Production Engineering Education. Platform for E-Learning and Telemetric Experimentation (PeTEX),” in: *International Journal of Online Engineering (iJOE)*, Vol.7 Special Issue: Educon 2011, Vienna, IAOE, 2011, pp. 37-43. DOI: 10.3991/ijoe.v7iS1.1725

[33] C. Pleul, C. Terkowsky, I. Jahnke & A.E. Tekkaya, (2011) “Tele-operated laboratory experiments in engineering education - The uniaxial tensile test for material characterization in forming technology,” in: Javier García Zubía and Gustavo R. Alves (Eds.): *Using Remote Labs in Education. Two Little Ducks in Remote Experimentation*. Engineering, no. 8. University of Deusto Bilbao, Spain, pp. 323-348.

[34] G. Reinmann and S. Sippel (2011) "Königsweg oder Sackgasse? – E-Portfolios für das forschende Lernen,“ in *Kontrolle und Selbstkontrolle – Zur Ambivalenz von E-Portfolios in Bildungsprozessen*, T. Meyer et al., Eds. Wiesbaden: VS Verlag für Sozialwissenschaften – Springer Fachmedien Wiesbaden GmbH.

[35] R. Reichert, (2011) “Das E-Portfolio - Eine mediale Technologie zur Herstellung von Kontrolle und Selbstkontrolle,“ in *Kontrolle und Selbstkontrolle – Zur Ambivalenz von E-Portfolios in Bildungsprozessen*, T. Meyer et al., Eds. Wiesbaden: VS Verlag für Sozialwissenschaften – Springer Fachmedien Wiesbaden GmbH.

[36] T. Haertel, C. Terkowsky & I. Jahnke, (2012) “Where have all the inventors gone? Is there a lack of spirit of research in engineering education?” in: 15th *International Conference on Interactive Collaborative Learning and 41st International Conference on Engineering Pedagogy in Villach*.

[37] C. Pleul, C. Terkowsky, I. Jahnke & A.E. Tekkaya, (2011) “Platform for e-learning and telemetric experimentation - Holistically integrated laboratory experiments for engineering education in manufacturing technology,” in: Jorge Bernadino & José Carlos Quadrato (Eds.): Proceedings WEE2011. *1st World Engineering Education Flash Week Lisbon*, Portugal, SEFI - European Society for Engineering Education, pp. 578-585.

[38] C. Terkowsky, C. Pleul, Isa J. & A.E. Tekkaya, (2011) ”PeTEX: Platform for eLearning and Telemetric Experimentation,” in: Bach, U., Jungmann., T. & Müller, K. (Eds.): *Praxiseinblicke Forschendes Lernen, TeachING.LearnING.EU*, Aachen, Dortmund, Bochum, pp. 28-31.

[39] D. May, C. Terkowsky, T. Haertel & C. Pleul, (2013) “Bringing Remote Labs and Mobile Learning together,” in: *International Journal of Interactive Mobile Technologies* (iJIM). IAOE, Vienna, Vol 7, No 3 (2013), pp. 54-62.

[40] J. Biggs & C. Tang (2009): Teaching for Quality Learning at Univerfsity. What the Student Does. McGraw Hill: Society for Research into Higher Education & Open University Press.

[41] L.D. Feisel & A.J. Rosa (2005): "The Role of the Laboratory in Undergraduate Engineering Education," in: *Journal of Engineering Education*, 2005, pp. 121-130.

[42] I. Jahnke, & T. Haertel, (2010) “Kreativitätsförderung in Hochschulen - ein Rahmenkonzept“, *Das Hochschulwesen*, 58, pp. 88-96.

[43] T. Haertel & I. Jahnke, (2011) “Kreativitätsförderung in der Hochschullehre: ein 6-Stufen-Modell für alle Fächer?!“ in: *Fachbezogene und fachübergreifende Hochschuldidaktik. Blickpunkt Hochschuldidaktik, Band 121*, Ed. by Jahnke, I. and Wildt, J., W. Bertelsmann Verl., pp. 135-146.

[44] I. Jahnke, T. Haertel and M. Winkler, (2011) “Sechs Facetten der Kreativitätsförderung in der Lehre – empirische Erkenntnisse” In *Der Bologna-Prozess aus Sicht der Hochschulforschung, Analysen und Impulse für die Praxis*, Ed. by Nickel, S., CHE gemeinnütziges Centrum für Hochschulentwicklung, pp.138-152.

[45] T. Haertel and C. Terkowsky, (2012) “Where have all the inventors gone? The lack of spirit of research in engineering education,” in: Proceedings of the 2012 *Conference on Modern Materials, Technics and Technologies in Mechanical Engineering*. The Ministry of Higher and Secondary Specialized Education (MHSSE) of the Republic of Uzbekistan, Andijan Area, Andijan City, Uzbekistan, pp. 507-512.

[46] C. Terkowsky and T. Haertel (2012): "Where have all the inventors gone? The neglected spirit of research in engineering education curricula," in: Proceedings of the 2012 *Conference on Actual Problems of Development of Light Industry in Uzbekistan on the Basis of Innovations.* The Ministry of Higher and Secondary Specialized Education (MHSSE) of the Republic of Uzbekistan and The Tashkent Institute of Textile and Light Industry (TITLI), Tashkent, Uzbekistan, pp. 5-8.

[47] C. Terkowsky, T. Haertel, E. Bielski and D. May, (2013) “Creativity@School: Mobile Learning Environments Involving Remote Labs and E-Portfolios. A Conceptual Framework to Foster the Inquiring Mind in Secondary STEM Education,” in: Javier García Zubía and Olga Dziabenko (Eds.): *IT Innovative Practices in Secondary Schools: Remote Experiments*. University of Deusto Bilbao, Spain, pp. 255-280.