Taxonomy on software engineering education

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This work aims at contributing to the organization of the knowledge of software engineering education through the construction of a controlled vocabulary.

Starting from the guidelines and activities proposed in the guide Z39.19-2005 provided by ANSI/NISO [1] and the recommendation of Hedden [2] we adapted a process for the creation and updating of controlled vocabularies. We applied the process of construction of controlled vocabularies in two instances: firstly, for the exploration of the existing literature and creation of an initial vocabulary on software engineering education; in the second instance, the process was used for the expansion of a category of one of the facets identified in the previous instance.

The result is a controlled vocabulary with 60 terms organized in a taxonomy the highest level of which is made up of three facets. The taxonomy is presented graphically in Figure 1 while the detail of each of its entries are shown in Table 1. It should be noted that only the entries in the category 'teaching approaches and methods' has a definition of each concept, other definitions are proposed as future work.

To the best of our knowledge, this vocabulary is the first one for the software engineering education field. It can be used to create keywords to be used in the labeling of articles, to understand a concept and go further consulting the suggested sources, and it can also be used as basis in future works for the standardization of the terminology of the area. Because of the number of concepts it includes, we believe it is a vocabulary that should be considered initial or in the process of being constructed. Under no circumstances should it be used as if it were complete or exhaustive.

Details of the research done to achieve the results described herein can be found in publications of the authors [3].
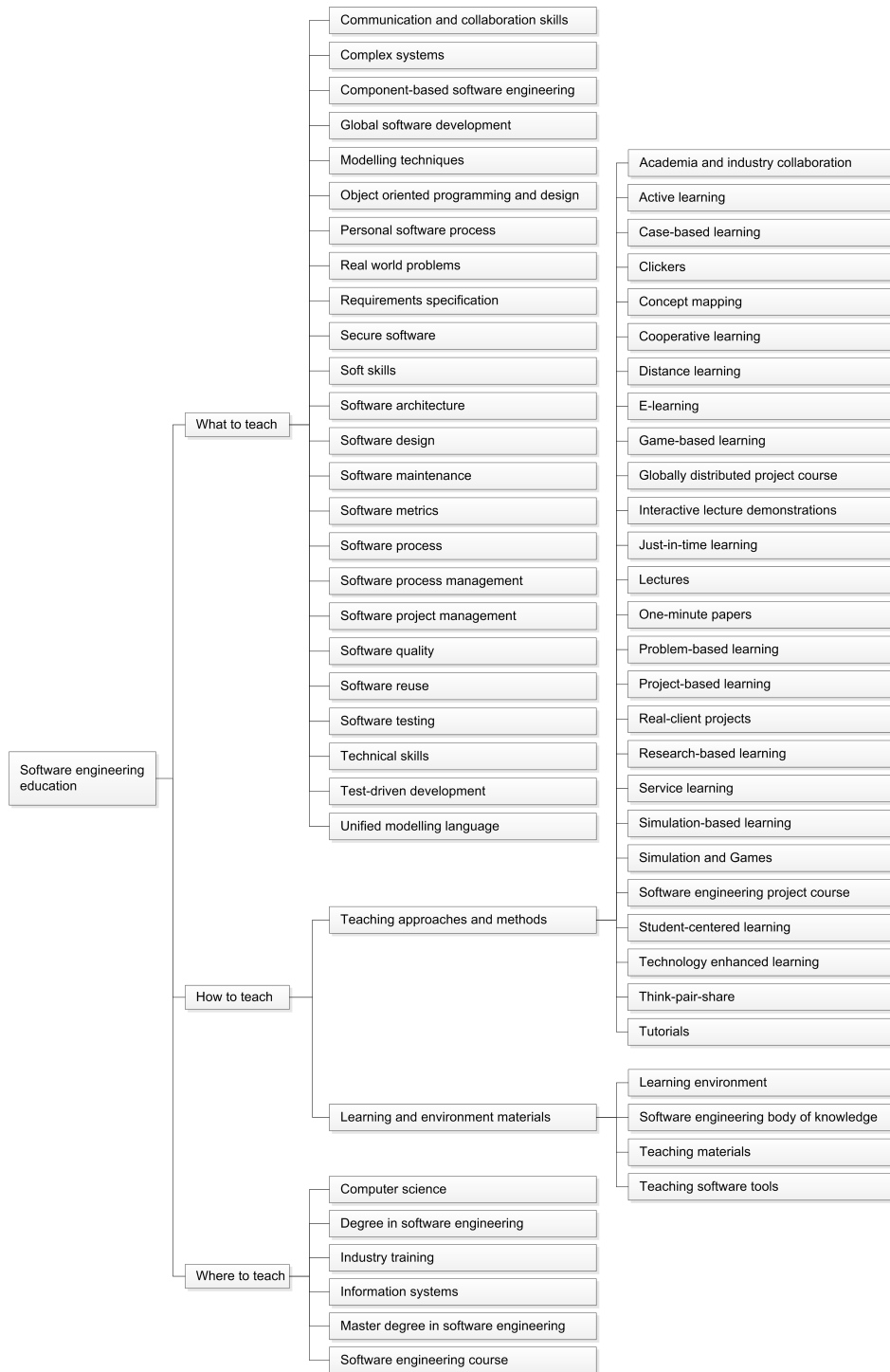
Software engineering education

What to teach
- Communication and collaboration skills
- Complex systems
- Component-based software engineering
- Global software development
- Modelling techniques
- Object oriented programming and design
- Personal software process
- Real world problems
- Requirements specification
- Secure software
- Soft skills
- Software architecture
- Software design
- Software maintenance
- Software metrics
- Software process
- Software process management
- Software project management
- Software quality
- Software reuse
- Software testing
- Technical skills
- Test-driven development
- Unified modelling language

How to teach
- Teaching approaches and methods
  - Academia and industry collaboration
  - Active learning
  - Case-based learning
  - Clickers
  - Concept mapping
  - Cooperative learning
  - Distance learning
  - E-learning
  - Game-based learning
  - Globally distributed project course
  - Interactive lecture demonstrations
  - Just-in-time learning
  - Lectures
  - One-minute papers
  - Problem-based learning
  - Project-based learning
  - Real-client projects
  - Research-based learning
  - Service learning
  - Simulation-based learning
  - Simulation and Games
  - Software engineering project course
  - Student-centered learning
  - Technology enhanced learning
  - Think-pair-share
  - Tutorials
- Learning and environment materials
  - Learning environment
  - Software engineering body of knowledge
  - Teaching materials
  - Teaching software tools

Where to teach
- Computer science
- Degree in software engineering
- Industry training
- Information systems
- Master degree in software engineering
- Software engineering course

Figure 1: Taxonomy on software engineering education.

Table 1: Taxonomy on software engineering education in detail.

Term	Communication and collaboration skills
Definition note	
Synonyms	Collaborative and communicative skills, teamwork skills
Facet	What to teach
Related terms	
Related content	

Term	Complex systems
Definition note	
Synonyms	
Facet	What to teach
Related terms	
Related content	

Term	Component-based software engineering
Definition note	
Synonyms	
Facet	What to teach
Related terms	
Related content	

Term	Modelling techniques
Definition note	
Synonyms	
Facet	What to teach
Related terms	
Related content	

Term	Object oriented programming design
Definition note	
Synonyms	
Facet	What to teach
Related terms	
Related content	

Term	Personal software process

Definition note	
Synonyms	PSP
Facet	What to teach
Related terms	
Related content	

Term	Real world problems
Definition note	
Synonyms	
Facet	What to teach
Related terms	
Related content	

Term	Requirements specification
Definition note	
Synonyms	
Facet	What to teach
Related terms	
Related content	

Term	Secure software
Definition note	
Synonyms	
Facet	What to teach
Related terms	
Related content	

Term	Soft skills
Definition note	
Synonyms	
Facet	What to teach
Related terms	
Related content	

Term	Software architecture
Definition note	
Synonyms	

Table 1 – *Continued from previous page*

Facet	What to teach
Related terms	
Related content	

Term	Software design
Definition note	
Synonyms	
Facet	What to teach
Related terms	
Related content	

Term	Software maintenance
Definition note	
Synonyms	
Facet	What to teach
Related terms	
Related content	

Term	Software metrics
Definition note	
Synonyms	
Facet	What to teach
Related terms	
Related content	

Term	Software process
Definition note	
Synonyms	
Facet	What to teach
Related terms	
Related content	

Term	Software process management
Definition note	
Synonyms	
Facet	What to teach
Related terms	

Table 1 – *Continued from previous page*

Related content	

Term	Software project management
Definition note	
Synonyms	
Facet	What to teach
Related terms	
Related content	

Term	Software quality
Definition note	
Synonyms	
Facet	What to teach
Related terms	
Related content	

Term	Software reuse
Definition note	
Synonyms	
Facet	What to teach
Related terms	
Related content	

Term	Software testing
Definition note	
Synonyms	
Facet	What to teach
Related terms	
Related content	

Term	Technical skills
Definition note	
Synonyms	
Facet	What to teach
Related terms	
Related content	

Table 1 – *Continued from previous page*

Term	Test-driven development
Definition note	
Synonyms	
Facet	What to teach
Related terms	
Related content	

Term	Unified modelling language
Definition note	
Synonyms	
Facet	What to teach
Related terms	
Related content	

Term	Academia and industry collaboration
Definition note	It refers to any effort made together between academia (one or more universities) and industry (one or more companies) for the education of software engineering concepts and practices.
Synonyms	
Facet	How to teach - Teaching approaches and methods
Related terms	
Related content	

Term	Active learning
Definition note	Active learning is generally defined as any instructional method that engages students in the learning process. In short, active learning requires students to do meaningful learning activities and think about what they are doing.
Synonyms	
Facet	How to teach - Teaching approaches and methods
Related terms	
Related content	The definition included here is based in the classic work: Bonwell, C. C., & Eison, J. A. (1991). *Active Learning: Creating Excitement in the Classroom. 1991 ASHE-ERIC Higher Education Reports.* ERIC Clearinghouse on Higher Education, The George Washington University, One Dupont Circle, Suite 630, Washington, DC 20036-1183.

Term	Case-based learning
Definition note	Students analize, draw inferences and make decisions given a case study - a detailed specific situation with a open-ended question or problem (often based on a real life scenario). Case studies can be presented to individuals or groups.

Table 1 – *Continued from previous page*

Synonyms	Case studies, CBL, case study approach
Facet	How to teach - Teaching approaches and methods
Related terms	
Related content	

Term	Clickers
Definition note	A clicker (or a audience response system) is a combination of hardware and software that enables the instructor to pose real-time questions to students during a lecture. The students usually register their responses using handheld clickers, although other input such as laptops may be used. After receivers transmit the responses to the instructor's workstation, the software compiles and displays the results.
Synonyms	Audience response system, personal response system, classroom response system, student response system
Facet	How to teach - Teaching approaches and methods
Related terms	
Related content	In one of the most cited paper Caldwell includes a comprehensive overview of the technique and best-practice tips: Caldwell, J.E. (2007) *Clickers in the Large Classroom: Current Research and Best-Practice Tips*, CBE-Life Sciences Education, vol. 6, n.º 1, pp. 9-20.

Term	Concept mapping
Definition note	Concepts maps can be defined as a knowledge representation language. In short, the students create or use graphic structures that arrange key ideas or concepts in a hierarchical set of nodes with lines or arrows that indicate linkages and relationships between them.
Synonyms	
Facet	How to teach - Teaching approaches and methods
Related terms	
Related content	Concept mapping were developed by Joseph Novak. In this two often cited works he presents the basis of concept mapping and Vee diagrams: Novak, J. D. & Gowin, D. B. (1984) *Learning How to Learn*, Cambridge University Press; and Novak, J. D. (1990) *Concept maps and Vee diagrams: two metacognitive tools to facilitate meaningful learning*, Instructional Science, Volume 19, Number 1, Page 29.

Term	Cooperative learning

Table 1 – *Continued from previous page*

Definition note	Refers to any of a variety of teaching methods in which students work in small groups to help one another learn academic content. Most experts agree that cooperative learning has several components that distinguish it from other small group learning methods. These components may include: positive interdependence (a positive correlation between the gains of individuals and the gains of teams, individual accountability (although learning activities rely on cooperative efforts, individuals are ultimately responsible of their own learning), group processing (group members discuss ther progress towards the achievement of their goals and the maintenance of effective working relations), face-to-face interaction (the size of the groups must be small), social and cooperative skills (that must be taught and motivated by the instructor) and appropiate grouping (some authors recommend heterogeneous teams, reflecting varied learning abilities, ethnic and linguistic diversity and a mixture of the sexes).
Synonyms	
Facet	How to teach - Teaching approaches and methods
Related terms	
Related content	Three important and cited books about this topic are: Slavin, R. E. (1995) *Cooperative Learning: Theory, Research, and Practice*, Allyn and Bacon.; Kagan, S. (1994) *Cooperative learning*, San Clemente, CA: Kagan.; and Johnson, D. W., Johnson, R. T. & Holubec, E. J. (1993) *Circles of learning: cooperation in the classroom*, 4th ed. Edina, Minn: Interaction Book Co.

Term	Distance Learning
Definition note	Any educational or learning process or system in which the teacher and instructor are separated geographically or in time from his or her students; or in which students are separated from other students or educational resources. Contemporary distance learning is affected through the implementation of computer and electronics technology to connect teacher and student in either real or delayed time or on an as-needed basis.
Synonyms	
Facet	How to teach - Teaching approaches and methods
Related terms	
Related content	The selected description is the broader found, taken from: Illyefalvi-Vitez, Z. and Gordon, P. (2004) *Distance learning - how to use this new didactic method in education of electronics engineering?*, in Electronic Components and Technology Conference. Proceedings. 54th, 2004, vol. 2, pp. 1725-1730 Vol.2.

Term	E-learning
Definition note	E-learning can be defined as instruction delivered electronically via the internet, intranet, or multimedia platforms such as cd-rom or dvd. E-learning is used to describe a wide set of applications and processes, such as web-based learning, virtual classrooms, and digital collaboration.
Synonyms	

Table 1 – *Continued from previous page*

Facet	How to teach - Teaching approaches and methods
Related terms	
Related content	The definition included here is based on two works: Smart, K. L., & Cappel, J. J. (2006). *Students' perceptions of online learning: A comparative study* Journal of Information Technology Education, 5 , 201-202.; and Kaplan-Leiserson, E. *E-Learning Glossary.* (www.learningcircuits.org/glossary.html)

Term	Game-based learning
Definition note	This technique deals with games that have defined learning outcomes. A game can be defined as an activity that is voluntary and enjoyable, separate from the real world, uncertain, unproductive in that the activity does not produce any goods of external value, and governed by rules.
Synonyms	Games
Facet	How to teach - Teaching approaches and methods
Related terms	Simulation and Games
Related content	The definition of a game is taken from: Caillois, R. (1961). *Man, play, and games.* New York: Free Press.

Term	Globally distributed project course
Definition note	It refers to some initiatives within Project-Based Learning. In these cases, students face projects distributed between two or more universities which work collaboratively on this initiative.
Synonyms	
Facet	How to teach - Teaching approaches and methods
Related terms	Project-Based Learning
Related content	

Term	Interactive lecture demonstrations
Definition note	Students are asked to predict individually the outcome of a classroom demonstration. Later the students interact in small groups, discussing their predictions and explaining their reasoning. Finally, the demonstration is performed and the students discuss and reflect on the results.
Synonyms	
Facet	How to teach - Teaching approaches and methods
Related terms	The approach was developed by Sokoloff and Thornton and can be found at: Sokoloff, D. R. & Thornton, R. K. *Using interactive lecture demonstrations to create an active learning environment* (1997) The Physics Teacher, vol. 35, pp. 340-347; and Sokoloff, D. R. & Thornton, R. K. (2006) *Interactive Lecture Demonstrations, Active Learning in Introductory Physics*, Wiley.
Related content	

Table 1 – *Continued from previous page*

Term	Just-in-time teaching
Definition note	This approach is based on the feedback loop between the students and the instructor. The instructor use the internet to post course materials and warm up assignments before class, and the students use materials to prepare for each class. The instructor uses students responses to enhance the classroom component.
Synonyms	Just-in-time, JiTT
Facet	How to teach - Teaching approaches and methods
Related terms	
Related content	JiTT was first presented in the book: Novak, G. M., Gavrin, A., Christian, W., & Patterson, E. (1999). *Just-in-Time Teaching: Blending Active Learning with Web Technology* (1st ed.). Upper Saddle River, NJ, USA: Prentice Hall PTR.

Term	Lectures
Definition note	Lectures are (more or less) continuous expositions of a theme by a speaker to a largely passive recipient audience.
Synonyms	
Facet	How to teach - Teaching approaches and methods
Related terms	
Related content	The definition included here is based on the classic work: Bligh, D.A. (1972). *What's the use of lectures?* Harmondsworth, England: Penguin. A new version of this book is available as: Bligh, D. A. (2000) *What's the use of Lectures* London/San Francisco.

Term	One-minute papers
Definition note	The instructor asks the students (often in the last minutes of class) to write a quick response to one o more questions regarding the content of the class (tipically a lecture). Questions might include: what is the most important thing you learned today? what is the muddiest point still remaining at the conclusion of today's class? After collecting the responses, the instructor reads the answers and ideally responds to them in the next class, or privately on an individual basis.
Synonyms	
Facet	How to teach - Teaching approaches and methods
Related terms	
Related content	More information of this technique can be found in two often cited works: Cross, K. P. & Angelo, T. A. (1988) *Classroom assessment techniques: a handbook for faculty* National Center for Research to Improve Postsecondary Teaching and Learning; and Chizmar, J. F., & Ostrosky, A. L. (1998). *The One-Minute Paper: Some Empirical Findings.* The Journal of Economic Education, 29(1), 3-10.

Term	Problem-based learning
Definition note	Students work in groups to analyze and solve a problematic situation, usually a realistic scenario without a single correct answer, under the supervision of a tutor.

Table 1 – *Continued from previous page*

Synonyms	PBL
Facet	How to teach - Teaching approaches and methods
Related terms	
Related content	Two relevant and cited articles about this topic are: Barrows, H. S. (1986). *A taxonomy of problem-based learning methods.* Medical education, 20(6), 481-486; and Schmidt, H. G. (1993). *Foundations of problem-based learning: some explanatory notes.* Medical Education, 27(5), 422-432.

Term	Project-based learning
Definition note	Students, typically organized in groups, face open multidisciplinary projects with the instructor playing the role of facilitator or coach. The projects engage students in authentic real-world problems and usually leads to the production of a final product (a design, a mode, a software product, etc).
Synonyms	PjBL
Facet	How to teach - Teaching approaches and methods
Related terms	
Related content	

Term	Real-client projects
Definition note	It refers to instances of Project-Based Learning with real clients (this means the clients are no teachers or other students, and usually are industry members).
Synonyms	
Facet	How to teach - Teaching approaches and methods
Related terms	Project-based learning
Related content	

Term	Research-based learning
Definition note	It refers to initiatives that connect teaching with research, which allow partial or full inclusion of students in an investigation based on scientific methods, under the supervision of instructor.
Synonyms	
Facet	How to teach - Teaching approaches and methods
Related terms	
Related content	

Term	Service learning
Definition note	A form of experiential learning in which students engage in activities that address human and community needs while allowing students to reflect on their service to gain further understanding of course concepts.
Synonyms	

Table 1 – *Continued from previous page*

Facet	How to teach - Teaching approaches and methods
Related terms	
Related content	

Term	Simulation-based learning
Definition note	This technique deals with simulations that have defined learning outcomes. Simulation is a technique to replace or amplify real experiences with guided experiences, often inmersive in nature, that evoke or replicate substantial aspects of the real world in a fully interactive fashion.
Synonyms	
Facet	How to teach - Teaching approaches and methods
Related terms	Simulation and Games
Related content	The selected description is the broader found, taken from: Gaba, D. M. (2004). *The future vision of simulation in health care.* Quality and Safety in Health Care, 13(suppl 1), i2-i10.

Term	Simulation and Games
Definition note	Both techniques seeks the instruction by guided experiences in ruled environments (usually inmersive). In other words, both have some underlying model, allowable actions that the learner can take, and constraints under which these actions should occur. Additionally, learners observe their actions' consequences. The key distinction is that simulations propose to represent reality and games do not.
Synonyms	
Facet	How to teach - Teaching approaches and methods
Related terms	
Related content	The definition included here is based on: Garris, R., Ahlers, R., & Driskell, J. E. (2002). *Games, Motivation, and Learning: A Research and Practice Model.* Simulation & Gaming, 33(4), 441-467.

Term	Software engineering project course
Definition note	It refers to initiatives within Project-Based Learning related to specific courses in which students work on a software engineering project (generally involving software development).
Synonyms	
Facet	How to teach - Teaching approaches and methods
Related terms	Project-Based Learning
Related content	

Term	Student-centered learning

Table 1 – *Continued from previous page*

Definition note	Ways of thinking about teaching and learning that emphasise student responsibility and activity in learning rather than what teachers are doing. The students exert a degree of influence over both the content of the course and the learning methods.
Synonyms	
Facet	How to teach - Teaching approaches and methods
Related terms	
Related content	The first part of the definition included here is taken from: Cannon, R., & Newble, D. (2000). *A Handbook for Teachers in Universities and Colleges: A Guide to Improving Teaching Methods.* Routledge. Two relevant and cited articles about this topic are: Lea, S., Stephenson, D., & Troy, J. (2003). *Higher education students' attitudes to student-centred learning: Beyond 'educational boulimia'?* Studies in Higher Education, 28(3), 321-334; and Hannafin, M., Hill, J., & Land, S. (1997). *Student-centered learning and interactive multimedia: Status, issues, and implications.* Contemporary Education, 68(2), 94-99.

Term	Technology enhanced learning
Definition note	All approaches in which technology is used to support the learning or teaching process.
Synonyms	
Facet	How to teach - Teaching approaches and methods
Related terms	
Related content	The definition included here is taken from: Schweighofer, P., & Ebner, M. (2015). *Aspects to Be Considered when Implementing Technology-Enhanced Learning Approaches: A Literature Review* Future Internet, 7(1), 26.

Term	Think-pair-share
Definition note	Students are thaught to listen a question, think about the question, to discuss the question in pairs, and finally to share with the total group.
Synonyms	
Facet	How to teach - Teaching approaches and methods
Related terms	
Related content	This technique was first proposed by Frank Lyman in: Lyman, F. T. (1981). *The responsive classroom discussion: The inclusion of all students.* In A. S. Anderson (Ed.), Mainstreaming Digest (pp. 109-113). College Park, MD: University of Maryland Press.

Term	Tutorials
Definition note	It is an activity in which the instructor works with one or a small groups of students and that is characterized as a space for discussion. Usually it served to complement other teaching techniques (e.g. lectures) and can be enhanced if the students have done some relevant prior work. It is considered a technique within the student-centered learning approach.

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Synonyms	
Facet	How to teach - Teaching approaches and methods
Related terms	
Related content	Tutorial teaching is part of the learning system at the University of Oxford and involves some particular features. Palfreyman provide a good review of this technique: Palfreyman, D. (Ed.) (2001) *The Oxford tutorial: 'thanks, you taught me how to think'* (Oxford, Oxford Centre for Higher Education Policy Studies).
Term	Learning environment
Definition note	
Synonyms	
Facet	How to teach - Learning and environment materials
Related terms	
Related content	

Term	Software engineering body of kmowledge
Definition note	
Synonyms	
Facet	How to teach - Learning and environment materials
Related terms	
Related content	

Term	Teaching materials
Definition note	
Synonyms	
Facet	How to teach - Learning and environment materials
Related terms	
Related content	

Term	Teaching software tools
Definition note	
Synonyms	
Facet	How to teach - Learning and environment materials
Related terms	
Related content	

Term	Computer science
Definition note	

<div align="center">Table 1 – Continued from previous page</div>

Synonyms	Computer science course, Computer science department, Computer science program, Computer science curriculum
Facet	Where to teach
Related terms	
Related content	

Term	Degree in software engineering
Definition note	
Synonyms	Bachelor science in software engineering, BSSE, Degree programme in software engineering, Undergraduate program
Facet	Where to teach
Related terms	
Related content	

Term	Industry training
Definition note	
Synonyms	Training programs in industry
Facet	Where to teach
Related terms	
Related content	

Term	Information systems
Definition note	
Synonyms	Information systems course, Information systems department
Facet	Where to teach
Related terms	
Related content	

Term	Master degree in software engineering
Definition note	
Synonyms	Graduate curriculum, Graduate
Facet	Where to teach
Related terms	
Related content	

Term	Software engineering course
Definition note	
Synonyms	

Table 1 – *Continued from previous page*

Facet	Where to teach
Related terms	
Related content	

BIBLIOGRAPHY

[1] NISO - ANSI/NISO Z39.19-2005, "Guidelines for the Construction, Format, and Management of Monolingual Controlled Vocabularies," pp. 1–172, May 2005.

[2] H. Hedden, *The Accidental Taxonomist*. Medford, USA: Information Today, Inc., May 2010.

[3] S. Pizard and D. Vallespir, "Towards a controlled vocabulary on software engineering education," *European Journal of Engineering Education*, pp. 1–17, Oct. 2016.