Managing the Quality of Teaching in Computer Science Education

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ABSTRACT

The quality of teaching plays a crucial role in informatics classes. Important elements that influence the quality are inter alia the teachers, the methodology and the environment, which can also be interpreted as elements of a teaching process. Consequently, it makes sense to take a closer look at the teaching process in informatics classes and to assess them in respect to quality. In a similar situation, the Software Engineering Institute (SEI) addressed the issue of quality, and it came up with a model called *Capability Maturity Model Integration (CMMI)* for monitoring and improving the processes for software development. Spurred by the CMMI model and the desire to improve the teaching quality of informatics classes, especially in primary and secondary schools, we propose a *Teaching Maturity Model (TeaM)*. Within this paper, we introduce a draft version of our TeaM model, inspired by the collection of best practices from industry and informatics teachers.

CCS CONCEPTS

• **Applied computing** → *Education*; • **Software and its engineering**;

KEYWORDS

CMMI, Teaching Maturity Model, Primary and Secondary Schools, Computer Science Education

ACM Reference Format:
Elisa Reçi and Andreas Bollin. 2017. Managing the Quality of Teaching in Computer Science Education. In *CSERC '17: The 6th Computer Science Education Research Conference, November 14, 2017, Helsinki, Finland*. ACM, New York, NY, USA, 10 pages. https://doi.org/10.1145/3162087.3162097

1 INTRODUCTION

Nowadays, the influence of informatics on society, economics, art, medicine and on other fields is noticeable. It is a factor that reveals its significance in the market economy and a boost for students and pupils to study informatics. On the other hand, informatics and informatics classes are sometimes considered as "difficult" from large parts of the society. Given this situation, one might raise questions like: "How can we make informatics classes funny and enjoyable?" and "What are the encountered challenges?" The answers to these questions are related to quality considerations, and with it, one has to address issues like measuring and improvement.

Not so long ago, the quality of a product and/or service was also a serious issue in Software Engineering in general and, looking for solutions, at the Software Engineering Institute (SEI) of the Carnegie Mellon University [1]. It turned out that the quality of the process has a large influence on the overall perceived and delivered quality. They thus created the so-called Capability Maturity Model Integration (CMMI), and later on, among others, a model for services (CMMI-services). All variants of the different CMMI models successfully assess the quality of the process by looking at the different practices that are used (and not used) during production or service delivery. The results emphasize the fact that the management and the assessment of the process drastically influence the quality of the products or services [9].

When mapping these findings to the educational domain, one might wonder if such an approach could also help in further improving the level of teaching in our (informatics) classes. The work of Chen et al. [4] shows that there indeed could be an influence of the process on the quality of teaching, but their model only focusses on a limited area of practices and only considers tertiary education. The approach has also not been applied in schools, so, within this problem domain, we are now aiming at:

- Improving the quality of our informatics classes by looking closer at teaching as a process. This means to decompose the teaching process into sub-processes and to define goals supporting these processes.
- Presenting an (understandable as well as acceptable) maturity model for informatics teachers. This includes the definition (and verification) of best practices supporting the teaching process.

Within the scope of this paper we present our approach of constructing and evaluating a maturity model (called *Teaching Maturity Model – TeaM*), which focuses on the teaching process of informatics classes for university, primary and secondary schools.

The rest of the paper is organized as follows: Section 2 describes the background of the work by explaining the CMMI model in some details and by summarizing related work. A detailed description of the research and the resulting TeaM Model is presented in Section 3. In Section 4 we discuss the results of a first study in respect to the understandability and acceptability of the model. Ongoing evaluation and future work is described in Section 5 and Section 6 concludes with a summary. Appendix A then presents the full list of all specific goals and practices defined so far.

CSERC '17, November 14, 2017, Helsinki, Finland

ACM ISBN 978-1-4503-6338-9/17/11…$15.00
https://doi.org/10.1145/3162087.3162097

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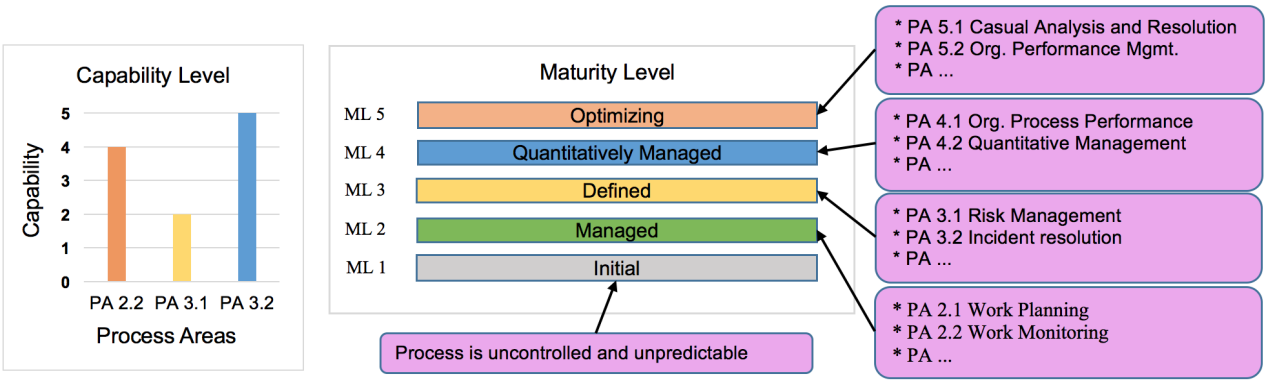

Figure 1: Capability and Maturity levels in CMMI. Either process areas are analyzed and rated on a scale between 1 and 5 yielding a Capability level (to the left), or a Maturity level is reached, when fulfilling all related Process areas (to the right).

2 BACKGROUND

This section introduces the CMMI model and discusses the related work concerning the assessment and the improvement of various aspects in the educational sector.

2.1 Capability Maturity Model

As the major terminology of our TeaM model is based on CMMI, we briefly explain how CMMI is structured and how it works in order to assess and to improve the quality of a product or a service.

The overall idea behind CMMI is to look at all tasks and activities necessary in order to create a system or to deliver a service. In CMMI, these basic activities are so called *Process Areas* (PAs). Each PA consists of some goals (*Specific Goals* (SGs)) dealing with typical products or contracts and clustering a set of *Specific Practices* (SPs), that, when implemented, satisfy the SG. These goals and practices are unique to one particular PA. Meanwhile, all the PAs have some common goals (*Generic Goals* (GGs)) which motivate for the practices and cluster a set of *Generic Practices* (GPs), that when implemented satisfy the GG. They are the same for all the PAs. The generic concept then covers the meaning of process institutionalization.

The implementation of both, specific and generic components is observed at two representation levels:

- *Capability Level* (CL), where only one process area is considered, and
- *Maturity Level* (ML), where a pre-defined set of PAs is considered and has to be fulfilled.

Fig. 1 shows an example for some of the process areas of CMMI-Services to the right. In practice, an assessor would look at all defined process areas and compare the defined practices and goals with the company's practices and goals. He or she would (apart from a rating) provide a summary of the areas covered and missed – offering a chance to the company to learn and improve until the next assessment takes place. In the example in Fig. 1 (left side) we see some results of (potential) a CMMI assessment, where the process area PA 2.2 is at Capability level 4, area PA 3.1 is at level 2 and PA 3.2 is at level 5. When, for example, all process areas defined for Maturity level 3 are mostly fulfilled, then one also gets the certificate for level 3. On the other side, when a company is at Maturity level 3 and wants to step over to the next level, then all process areas defined for level 4 (and below) have to be reached.

Our approach is now derived from the idea behind and the structure of CMMI-Services. Of course, it only used the CMMI backbone structure, as areas, levels, goals and practices have to be put into the context of teaching.

2.2 Related Work

Students' evaluation, feedback, peer evaluation and inspectors are typical traditional forms used to address the quality of teaching. Sometimes, those results are biased and are not objective, depending on personal feelings and subjectivity. This has opened a path for research of alternative assessment models.

Here, a lot of authors address the quality of teaching by mainly focusing either on teachers (preparation, communication, engagement), or pupils/students, or course content or the environment. Taking a closer look at the existing work, one could mention for instance: the AQRT model which addresses the quality of teaching by assessing the teacher's teaching practices [5] or the TEQAS model to assess the teacher's education [7]. Furthermore, there is the competence based model to assess the teacher quality through assessment tests [14] and the Competence-based-model for looking at how teachers teach [6]. These models consider only the teachers.

There are other approaches that consider the pupils/students and the teachers' interactions. Some examples are, inter alia the CEM model that addresses the quality by assessing the teachers' quality based on students outcomes [2], or an approach of the National Education Association that uses a standard-based learning and assessment system to show how student learning standards can be connected with teacher education and assessment [1], or the assessment of teacher competencies and students learning and feelings [20], or the "Angebots-Nutzungs Modell" for assessing the quality based on teacher-student interaction (results, feelings, environment) [10]. Furthermore, there is the TALIS model which assesses the quality based on working condition of teachers and the learning environment [18].

Beyond the traditional forms and the assessment methods mentioned above, some maturity models based on the CMMI's principles

were created. Researchers in the field of computer science education adapted and created maturity models to assess and to improve the curricula or the institution itself [12], [8], [11] and to design courses either in a classroom environment [19] or online [17], [13]. Likewise, in primary and secondary schools, some CMMI-like implementation models with the focus on the institutional level or on the syllabus [16], [21], [22] were created as well. Only Chen et al. established a maturity model for observing the teaching process. But, as mentioned above, it is limited to a subset of possible Process Areas (see Section 4 for more details) and focusses on tertiary teachers [4] only. In their paper, Chen et al. address the implementation of a model for primary and secondary schools, but to the best of our knowledge, such a model has not been implemented and/or published yet.

We believe that the quality of teaching is more than just focusing on the teacher or on the students, and also more than looking at the institution or the course content. It is rather a process that includes all of above and more. So, like Chen et al., we address the quality by looking at the teaching process as a whole. But, unlike Chen et al. we consider not only tertiary teachers but primary and secondary teachers as well. The only restriction is (as we started to evaluate our model in the context of informatics classes and with informatics teachers and curriculum designers), up to now, the focus on a model for teaching informatics.

3 CREATING THE TeaM MODEL

In order to come up with a first, stable version of the TeaM model, we started a project divided into three steps.

- In the first step, a literature survey was conducted for defining the basic (and relevant) phases and sub-phases of a teaching process. From this we generated a first list of PAs.
- In a follow-up step, a working version of the TeaM model was created by considering the result of the first step, the content of the model of Chen et al. (T-CMM) [4] and the CMMI-service model [9]. Additionally, we evaluated and improved that version of the TeaM model by a CMMI expert.
- In the third step, a survey for assessing the model with informatics teachers was prepared. For the assessment, every goal of the TeaM model established in the second phase was mapped to several questions in form of a check-list. Both, the check-list and the TeaM model, were given to the interviewees. The aim of the questionnaire was to test the understandability and acceptability of the model and to test and collect a set of best practices from their experiences.

3.1 Research Objectives

On the one hand, there are shortcomings from the lack of standards to address the quality of teaching informatics in schools with regard to the teaching process. On the other hand, CMMI offers a maturity model for improving the quality, and this model is perfectly adjusted for industry and educational institutions. By keeping this in mind and as presented in the introduction section, the motivation of our work is twofold: First, to build a maturity model for managing the teaching process of informatics classes, and secondly, to assess the maturity model with the help of informatics teachers.

When using a maturity model, we assume that (a) the management of the teaching process influences the way of improving informatics classes, and (b) doing real assessments helps us in finding out whether the model is understandable and acceptable by informatics teachers. Under this assumptions, this lead us to the following question that needed to be answered:

- How should a maturity model that aims at improving the teaching in informatics-classes looks like?

Implicitly, two more questions were then in the focus of our research:

- Are the specific goals and practices defined in the model perceived useful, are any missing?
- To what extend is the TeaM model understandable and acceptable by informatics teachers?

3.2 Research Settings

As mentioned above, the first step of our approach consisted of a literature survey where the teaching model of Meyer and Hilbert [15] (in German), the CMMI-service and T-CMM model were considered in order to come up with the skeleton of the TeaM model. The model was then checked by an international renowned CMMI expert teaching at our University and it was additionally reflected on during a CMMI training that took place in Germany end of 2016. After correction, the output of this phase then formed the first working version of our model.

The first working version of the model was taken as the basis for a questionnaire. The questionnaire had the objectives to check if informatics teachers agree with this model, to provide feedback for improvements and to collect additional practices from the teachers' experiences. The questionnaire was split into four main parts (corresponding to the four phases of our teaching process), and each part contained questions about the goals associated with each practice of the corresponding teaching processes' phases.

For the assessment itself we planned for a survey by involving different types of lecturers. We had the chance to involve four teachers with a lot of different experience. All of them were active in the field of curricula development and competency models in Austria. They all are males, and two of them have long-time experience in teaching informatics in primary and secondary schools. The two other lecturers are teachers in informatics-didactics at Alpen-Adria-Universität Klagenfurt.

Every interview lasted about 90 minutes. It was always the same person conducting the interview, and every input from the interviewees was documented in written form.

3.3 Results

When constructing the TeaM model, we kept the CMMI's basic terminology and structure (PAs, SP, SG, GP, GG, CL, ML), and so what was missing, was the definition of new or re-usable Process Areas (suitable to the computer science education domain). As a result of the first step we were able to provide the definition of the teaching process (see Subsection A.), and the TeaM's Process Areas (see Subsection C.). As an output of the second step, with the feedback of the CMMI-expert, we then were able to define the

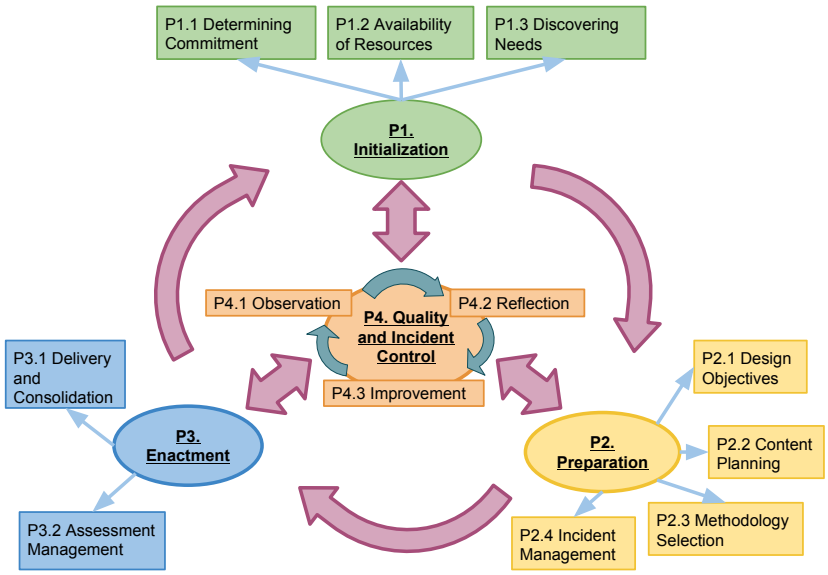

Figure 2: The graphical representation of the teaching process as defined for the TeaM Model.

TeaM's own Maturity and Capability Levels (see Subsection B.), and the TeaM's Specific Goals and Practices (see Subsection D.).

The remainder of this section now just presents the final versions of each of the components of the TeaM model as refined and corrected versions would be out of the scope of this publication.

A. The Teaching Process. Building up a maturity model means, firstly, defining what a teaching process is. Following the textbook of Meyer and Hilbert [15] and considering the results of our literature survey, we defined the teaching process as a process composed of four phases (Fig. 2).

- *Initialization*– the phase where administrative issues of the teaching process are managed and defined;
- *Preparation*– the phase where teachers plan and prepare for the course;
- *Enactment*– the phase where the implementation of the teaching units takes place;
- *Quality and Incident Control*– the phase where possible incidents and the teaching process itself are observed, analyzed and refined.

These phases have then further been split into sub-processes representing the process areas of our model. After some revisions and considering all the feedback we got, we ended up with 12 PAs that are also depicted in Fig. 2 as process areas P1.1 up to P4.3. The process areas can also be found in table column one in Figure 3 where the missing areas of the model of Chen et al. can be discerned immediately as well – especially the selection of the teaching methodology, the reflection and the course delivery step is of importance, but it is not handled there.

B. TeaM Maturity and Capability Levels. One aspect of the TeaM model is that teaching is treated as a service where quality is of high relevance. For assessing the implementation of PAs, two representation paths are defined: a continuous representation (*Capability Level* – CL) and a stage representation (*Maturity Level* – ML). The continuous representation assesses and improves the process by focusing on an individual process areas. For instance, considering again the first column in Fig. 3, one can choose to improve only the Content Planning (CP) Process Area. The stage representation assesses and improves the process by focusing on a set of process areas, like for example the DCOM, DN, IM and OTP Process Areas. We say that a process has improved when it upgrades the steps until the highest level is reached. Table 1 shows the features of the TeaM model related to the Maturity and Capability levels. Unlike CMMI, TeaM has four levels for Capability and five levels for Maturity.

C. TeaM Process Areas. The interviews and the questionnaire at the third step of the study then made it clear that we had to replace one specific goal (Manage Incidents (MI)) by another one (Deal with Incidents (DI)). However, the rest remained the same. Moreover, the feedback that we got also helped us defining the Specific Practices, and we were able to relate the PAs to comprehensible Maturity Levels.

To summarize, the latest version of the TeaM model now has a total of 12 PAs (see Figure 3, first column), derived from the first step of the study and reviewed later on by the CMMI expert and the interviewees. Furthermore, the PAs are mapped to five corresponding Maturity levels (see Figure 5, mapping table to the right). The PAs cover the following objectives:

P1.1 Determining Commitment (DCOM) – The responsibilities of all relevant stakeholders are defined. The stakeholders agree

Table 1: The Capability and Maturity levels of TeaM

Level	Capability Level	Maturity Level
0	Deficient - None of the relevant factors of the teaching process are implemented.	
1	Accomplished - The relevant factors of the teaching process are taken into consideration but there is no plan on implementing them.	Chaotic - the teaching process is neither controlled nor efficient.
2	Reflected - The relevant factors of the teaching process are planned and implemented in accordance to the policy. There is the plan for performing the process, resources are provided, responsibilities are taken, is controlled and monitored.	Initial - the teaching process is under minor control and little efficiency.
3	Defined - The relevant factors of the teaching process are standardized.	Repeatable - the teaching process is sparsely standardized and monitored.
4		Stable - the teaching process is standardized, monitored and controlled.
5		Optimizing - the teaching process is continuously improved and ready for further teaching process upgrades.

Table 2: The relevant Process Areas for each Maturity Level

Maturity Level	Process Areas
Chaotic (1)	No relevant PAs.
Initial (2)	Availability of Resources (AR) Design Objectives (DO) Content Planning (CP) Methodology Selection (MS) Delivery and Consolidation (DC) Assessment Management (AM)
Repeatable (3)	Determining Commitment (DCOM) Discovering Needs (DN) Incident Management (IM) Observing the Teaching Process (OTP)
Stable (4)	Reflecting on the Teaching Process (RTP)
Optimizing (5)	Improving Teaching (IMT)

about their tasks and about the syllabus they are going to introduce during the teaching process.

P1.2 Availability of Resources (AR) – The stakeholders deal with the necessary environment required during the teaching process. The environment includes the physical space (classroom with its main components, like tables, chairs, etc.) and the technical equipment that might help during teaching.

P1.3 Discovering Needs (DN) – Requirements from both, course content level and administration/organizational issues, are defined. They are established by teachers and/or the educational institution.

P2.1 Design Objectives (DO) – The aims of the course are defined. They are associated with a detailed scheme that tells what should be done. In order to measure if the course objectives are achieved, some criteria are established.

P2.2 Content Planning (CP) – The content that has to be transmitted to the pupils/students is generated. The content is structured based on the schedule.

P2.3 Methodology Selection (MS) – The teachers consider different types of teaching methodologies. They assess them and select the methods to be used during their course units.

P2.4 Incident Management (IM) – Possible problems that might occur during the teaching process are foreseen. Additionally, some corrective plans are established to overcome these problems.

P3.1 Delivery and Consolidation (DC) – Teachers conduct their teaching units and consolidate the content. They adapt it also based on new requirements that might arise during the teaching unit.

P3.2 Assessment Management (AM) – The learning outcomes are evaluated. The evaluation is done based on some predefined criteria.

P4.1 Observing the Teaching Process (OTP) – All the phases of the teaching process are assessed and measured (this excludes the assessment of the students). The results are documented.

P4.2 Reflecting on the Teaching Process (RTP) – The outcomes from the observation of the teaching process are analyzed. Corrective actions are derived in cases where there are some needs for improvement.

P4.3 Improving Teaching (IMT) – The corrective actions for improving the teaching process are implemented.

Like the CMMI's PAs, the TeaM's PAs consist of Specific Goals (SGs) which include Specific Practices (SPs) and Generic Goals (GGs) which include Generic Practices (GPs). Specific Goals are unique to a PA, while Generic Goals are common for all PAs (see Fig. 4). For instance, SG2.2.3 (DUS - Define the Unit Schedule) holds only for the Content Planning PA and not for the others. Similarly, SP2.2.3.1 (Plan the Unit Phases) holds only for SG2.2.3 of the Content Planning PA. On the other hand, GG2 (Institutionalize Reflection on Content Planning) deals with the institutionalization of Content Planning (CP), Determining Commitment (DCOM), etc. So, it holds for all PAs. The same holds for the corresponding GPs.

A Process Area should be satisfied in order to pretend its Maturity. In other words, the corresponding sets of Specific Practices associated to a Specific Goal should be fulfilled. A Maturity level is achieved when all the Process Areas assigned to that level and to the previous levels reach the maximum Capability level. For example, to reach Maturity level 3 (Repeatable), level 2 should also be considered, and each of the Process Area assigned to Maturity level 2 (AR, DO, CP, MS, DC, AM) and Maturity level 3 (DCOM, DN, IM, OTP) must achieve Capability level 3. To reach Maturity level 4, all the Process Areas assigned to Maturity levels 2 (AR, DO, CP, MS, DC), 3 (DCOM, DN, IM, OTP) and 4 (RTP) must achieve Capability level 3 (the maximum level). The implementation of the PAs is repeated until ML 5 is achieved. Fig. 5 shows a case study of an informatics teacher named Anna. It shows/assumes that Anna is at ML2 and makes it explicit what she has to do in order to reach the next level, ML3.

D. Specific Goals and Practices. The assessment of a PA is correlated with the implementation of Specific and Generic Goals. The process for defining the specific goals and practices took some time. We looked at it in the second step of the study by comparing our results (see column two of Fig. 3) with those of CMMI-Services (column three in Fig. 3) and the T-CMM (column four in Fig. 3). As clearly visible, there are some PAs with the corresponding SGs that are not covered by CMMI or T-CMM. For example the DCOM (Determining Commitment) Process Area is considered in the model of CMMI but not in the T-CMM model. Also, Methodology Selection (to be found in the TeaM model) is not considered by the other models.

With that, we were able to reuse quite some of the existing goals or at least we were able to adapt them to our domain easily. Of course, missing goals had to be added and adjusted based on the interviews' results. For reasons of readability, the Specific Goals (with the associated Specific Practices) of the TeaM model are summarized in Appendix A.

4 DISCUSSION

By conducting and analyzing the feedback that we got, we noticed that the interviewers liked the intention behind each assessment-question, especially questions related to incident management, appraised as a good issue to be taken in consideration during the teaching process in informatics. Asking them about how skeptical they are about concerns of teachers being assessed (and thus if this model will be used by teachers) they shared the concerns. The model could help informatics teachers in improving their quality of teaching, but it should not be used as a model for ranking and for competition. Well, with the TeaM model teachers can assess themselves in order to check at which level they are. They also can define by themselves which level they want to achieve, by simply implementing the TeaM's practices related to each level.

The main question that we tried to answer was if it is possible to create a maturity model that could, in a follow-up step, help in improving teaching in informatics classes. We presented such a model and, as some necessary preliminary work, we conducted interviews showing that such a model can be constructed.

The two remaining questions about completeness and usefulness/acceptability were also answered positively during the interviews. All the interviewees gave almost the same answers, making it easier for us to come up with unanimous practices and goals.

To summarize, although the number of participating teachers was very low, it turned out that the model proves useful so far. The terminology used was clear and not ambiguous, making it understandable and acceptable.

5 ONGOING EVALUATION AND FUTURE WORK

The TeaM model is an ongoing project that started at the institute of Informatics didactics at Alpen-Adria-Universität, Klagenfurt in 2016. The project aims at assessing and improving the quality of teaching informatics at primary, secondary and university level. Currently, additional best practices are collected and defined and we are now working on further refining the goals and practices. This endeavor already started, and in three lectures at Klagenfurt and Košice (to avoid some bias) we tested some practices on a cohort of 160 students and compared them with the performance of more than 1300 "traditional" students in past classes. Though our results are not generalizable to different types of courses and school types yet, there is statistical evidence that the practice of reflecting on the teaching process and making the reflection transparent to the students (as defined in PA4.2) could lead to a higher performance of the students. In the study presented by Bollin et al. [3], the results (measured in points they could achieve during the semester) of the students where PA4.2 was not taken into account were lower (average points of 110.182 with a standard deviation of $\sigma = 28.193$) compared to students that experienced a teacher taking the suggested best practices into account (139.42 points and $\sigma = 28.707$, out of a maximum of 200 points).

The next step aims at testing the model in informatics classes at both schools and universities, and doing further improvement of the model from the test results and feedbacks. For further reducing impediments in using the model in practice, an online/web application will be created. It will assist the teachers in doing a self-assessment and will provide a check list with hints for reaching higher maturity levels based on the personal rating.

6 SUMMARY AND CONCLUSION

The TeaM model is built up from the necessity of some standards to address the quality of teaching informatics, with the focus on the teaching process and in regard to teachers at all levels, primary,

TeaM PAs	TeaM-Specific Goals	CMMI PAs	T-CMM (Chen)
P1.1 Determining Commitment (DCOM)	-Define Agreements on Duties (DAGD) -Agree upon Embedding into Curricula (AEC)	SD STSM	
P1.2 Availability of Resources (AR)	-Manage the Classroom Settings (MCS) -Manage the Technical Infrastructure (MTI)	SSD, CAM	CMC (SG 2)
P1.3 Discovering Needs (DN)	-Specify the Requirements (SREQ)	(REQM)*SSD	Course req.dev(CRD)
P2.1 Design Objectives (DO)	-Define the Course Aims and the Course Plan (DCAP) -Define the Quantitative and Qualitative Objectives for the Course (DQQO)	QWM WP WP	Course & Teaching P.(CTP) QCM
P2.2 Content Planning (CP)	-Define the Learning Content (DLC) -Prepare and Integrate the Materials (PIM) -Define the Unit Schedule (DUS)		CTP CM ICTM
P2.3 Methodology Selection (MS)	-Analyze Methodologies to be Used (AMU) -Define the Methodologies to be Used (DMU)		
P2.4 Incident Management (IM)	-Identify Possible Problems (IPRO) -Analyze Possible Problems (APRO) -Establish Corrective Plan for Problems (ECP)	RSKM SCON	CTP
P3.1 Delivery and Consolidation (DC)	-Conduct Lessons According to Agreements/Plan (CLAA/P) -Adapt the Lessons based on Requirements (AL)	 REQM	
P3.2 Assessment Management (AM)	-Define the Knowledge Test Criteria for the Delivered Units (DKT) -Implement the Knowledge Test (IKT)	MA	Learn. Verif. & Teach. Val. (VAL)
P4.1 Observing the Teaching Process (OTP)	-Monitor Teaching (against goals/plans in initialization & preparation phase) (MT) -Aggregate the Monitoring Results (AMR) -Monitor Incidents (MONI)	PPQA (based on commitments) WMC MA DAR MA	Course M & C (CMC)
P4.2 Reflecting on the Teaching Process (RTP)	-Analyze the Results (from Observing the Teaching Process) (AR) -Define Corrective Actions (DCA)	IRP CAR CM DAR	
P4.3 Improving Teaching (IMT)	-Improve the Agreements and the Curricula (IAGC) -Improve the Classroom Settings and the Technical Infrastructure (ICTI) -Improve the Course Aims and the Plans (ICAP) -Improve the Learning Content (ILC) -Improve the Teaching Methodology (ITM) -Improve the Teachers Skills (ITS) -Deal with Incidents (DI)	 OT OPF	Teach.Proc. Focus (TPF) Teaching Innovation (TIA)

Figure 3: Process Areas and Specific Goals of the TeaM model (first two columns). The table also presents the differences and commonalities between the TeaM, the CMMI [9] (third column) and the T-CMM [4] (fourth column) models.

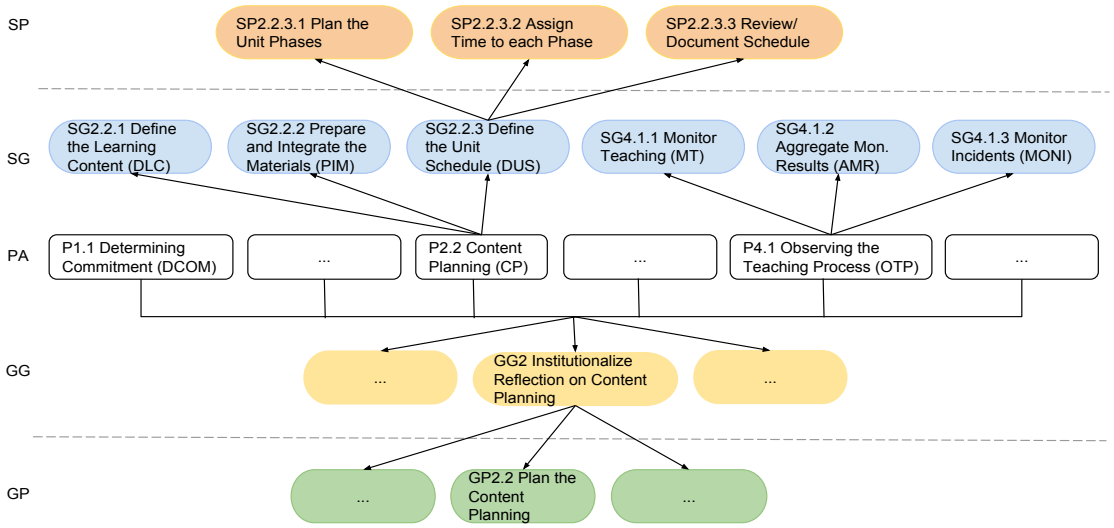

Figure 4: The representation of some Specific Goals (SG)/Practices (SP) and some Generic Goals (GG)/Practices (GP) for the TeaM's PAs. GG/P hold the same for all the PAs.

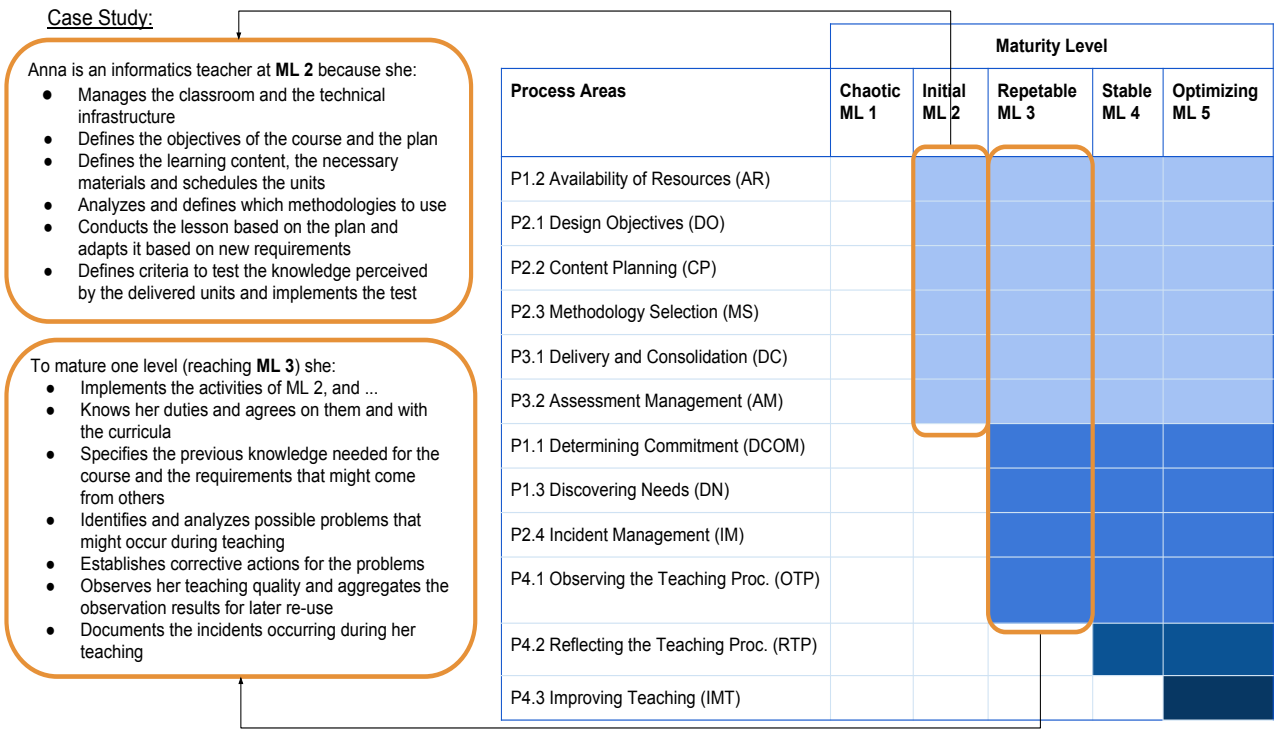

Figure 5: A down-scaled example of a teacher, whose assessment yields a Maturity level of 2, and showing what is to be done by her in order to reach Maturity level 3.

secondary and university for computer science eduction. The applicability of the model can help either the educational institution to evaluate and improve its quality of teaching (by, when required producing a ranking), or it helps the teachers to evaluate and improve their teaching process.

By means of this research so far, we were able to give a definition of the teaching process, to create the maturity model (TeaM) and to provide the content of each TeaM components. We also approved that the TeaM model is understandable and acceptable by (a selected set of) informatics teachers.

The TeaM's Process Areas, Specific Goals and Practices were assessed and confirmed by the study results, and by presenting the model to the community we hope to obtain further feedback and suggestions for improvement.

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APPENDIX A

P1.1 Determining Commitment (DCOM)

- SG1.1.1 Define Agreements on Duties (DAGD)
  - SP1.1.1.1 Establish Responsibilities and Duties
  - SP1.1.1.2 Check for Formal Written Forms of Duties
- SG1.1.2 Agree upon Embedding into Curricula (AEC)
  - SP1.1.2.1 Read the Curricula and the Position of your Course
  - SP1.1.2.2 Coordinate with the Colleagues
  - SP1.1.2.3 Reflect on Content with Colleagues for Optimization

P1.2 Availability of Resources (AR)

- SG1.2.1 Manage the Classroom Settings (MSC)
  - SP1.2.1.1 Arrange the Classroom Settings based on Methodology Used
  - SP1.2.1.1 Arrange the Classroom Atmosphere
- SG1.2.2 Manage the Technical Infrastructure (MTI)
  - SP1.2.2.1 Check for the Available Technical Infrastructure
  - SP1.2.2.2 Plan What Devise to Use and When

P1.3 Discovering Needs (DN)

- SG1.3.1 Specify the Requirements (SREQ)
  - SP1.3.1.1 Predefine Previous Knowledge Requirements for a Course
  - SP1.3.1.2 Consider Requirements from other Stakeholders
  - SP1.3.1.3 Document the Requirements

P2.1 Design Objectives (DO)

- SG2.1.1 Define the Course Aims and the Course Plan (DCAP)
  - SP2.1.1.1 Control the Curricula for Defining Aims
  - SP2.1.1.2 Define the Year/Semester Course Plan
- SG2.1.2 Define the Quantitative and Qualitative Objectives for the Course (DQQO)
  - SP2.1.2.1 Define Measurable Objectives for the Course
  - SP2.1.2.2 Define Questions for Students to Measure the Objectives
  - SP2.1.2.3 Conduct the Questions during the Course or at the End or Both

P2.2 Content Planning (CP)

- SG2.2.1 Define the Learning Content (DLC)
  - SP2.2.1.1 Research and Collect Materials
  - SP2.2.1.2 Define Topics and Sub-topics
  - SP2.2.1.3 Discuss with Colleagues and Document Changes
- SG2.2.2 Prepare and Integrate the Materials (PIM)
  - SP2.2.2.1 Select Available Materials based on the Course Aims and Content
  - SP2.2.2.2 Research and Integrate External Materials
  - SP2.2.2.3 Document the Materials
  - SP2.2.2.4 Discuss the Materials with Colleagues and Document Changes

SP2.2.2.5 Provide more than One Type of Materials
SG2.2.3 Define the Unit Schedule (DUS)
SP2.2.3.1 Plan the Unit Phases (lecture, practical, discussion etc.)
SP2.2.3.2 Assign Time to each Phase
SP2.2.3.3 Review and Document the Schedule
P2.3 Methodology Selection (MS)
SG2.3.1 Analyze Methodologies to be Used (AMU)
SP2.3.1.1 Search for Available Methodologies
SP2.3.1.2 Considered Advantages and Disadvantages related to your Course Objectives
SG2.3.2 Define the Methodologies to be Used (DMU)
SP2.3.2.1 Consider Methodologies Effects on Learning Outcomes and Learner's Commitments
SP2.3.2.2 Compare and Choose those that best Fits to the Course Objectives
SP2.3.2.3 Implement the Methodologies
P2.4 Incident Management (IM)
SG2.4.1 Identify Possible Problems (IPRO)
SP2.4.1.1 Consider and Document Problems on Classroom Settings/Technical Infrastructure
SP2.4.1.2 Consider and Document Problems with Unit Delivery
SG2.4.2 Analyze Possible Problems (APRO)
SP2.4.2.1 Analyze and Document the Problems
SG2.4.3 Establish Corrective Plan for Problems (ECP)
SP2.4.3.1 Define and Document a Corrective Plan for the Problems
P3.1 Delivery and Consolidation (DC)
SG3.1.1 Conduct Lessons According To Agreements/Plan (CLAA/P)
SP3.1.1.1 Follow the Plan and the Unit Schedule
SP3.1.1.2 Inform Learners about the Plan and the Schedule
SP3.1.1.3 Arrange the Plan and Schedule when Time out
SP3.1.1.4 Identify Learner's Requirements
SG3.1.2 Adapt the Lesson based on Requirements (AL)
SP3.1.2.1 Check if the Requirements Exist in the Corrective Plan
SP3.1.2.2 Solve Immediate or Direct for the Next Unit
P3.2 Assessment Management (AM)
SG3.2.1 Define the Knowledge Test Criteria for the Delivered Units (DKT)
SP3.2.1.1 Define What to Assess based on the Course Objectives
SP3.2.1.2 Define Criteria during the Creation of Topics and Sub-Topics
SP3.2.1.3 Consider Conceptual and Application Knowledge
SG3.2.2 Implement the Knowledge Test (IKT)
SP3.2.2.1 Define the Type of the Assessment (test, project, etc.)
SP3.2.2.2 Define the Form of the Assessment (online, paper and Pencil, etc.)
SP3.2.2.3 Manage the Environment Settings for the Assessment
SP3.2.2.4 Apply the Assessment
SP3.2.2.5 Analyze and Discuss the Result
SP3.2.2.6 Collect and Analyze Learner's Inputs
P4.1 Observing the Teaching Process (OTP)
SG4.1.1 Monitor Teaching (from Initialization and Preparation phase) (MT)
SP4.1.1.1 Check Time Plan during the Lesson or Directly after it
SP4.1.1.2 Check Objectives compared by Learners Output
SP4.1.1.3 Check the Effect of the Teaching Methodology
SG4.1.2 Aggregate the Monitoring Results (AMR)
SP4.1.2.1 Document Results from Time Plan Observation
SP4.1.2.2 Document Results from Learners output during the Lesson or after it
SP4.1.2.3 Document the Results from Teaching Methodology
SG4.1.3 Monitor Incidents (MONI)
SP4.1.3.1 Document Problems during Teaching Process
P4.2 Reflecting on the Teaching Process (RTP)
SG4.2.1 Analyze the Results (from P4.1) (AR)
SP4.2.1.1 Do a Periodically Analysis of the good and bad Experiences during Observation
SP4.2.1.2 Reflect about with colleagues
SP4.2.1.3 Document the Results
SG4.2.2 Define Corrective Action (DCA)
SP4.2.2.1 Take Corrective Action for bad Experiences and Document it
P4.3 Improve Teaching (IMT)
SG4.3.1 Improve the Agreements and the Curricula (IAGC)
SP4.3.1.1 Based on Monitor and Analysis establish Changes
SP4.3.1.2 Discuss with Colleagues
SP4.3.1.3 Document
SG4.3.2 Improve the Classroom Settings and the Technical Infrastructure (ICTI)
SP4.3.2.1 Look for new Possibilities
SP4.3.2.2 Integrate and Test them in your Environment
SP4.3.2.3 Document the Test Results
SG4.3.3 Improve the Course Aims and the Plans (ICAP)
SP4.3.3.1 Based on Monitoring and Analysis Improve on Objectives and Plans
SP4.3.3.2 Document the Improvement
SG4.3.4 Improve the Learning Content (ILC)
SP4.3.4.1 Based on Monitoring and Analysis Improve the Learning Content
SP4.3.4.2 Document the Improvement
SG4.3.5 Improve the Teaching Methodology (ITM)
SP4.3.5.1 Based on Monitoring and Analysis Define and Document if Methodology should be changed
SG4.3.6 Improve the Teachers Skills (ITS)
SP4.3.6.1 Do a periodically Training on Personal Skills
SG4.3.7 Deal with Incidents (DI)
SP4.3.7.1 Take Corrective Action for Occurred Incidents