AI-Supported Observation of E-Portfolios

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AI-Supported Observation of e-Portfolios: an Analysis of the System Context and Possible Usage Scenarios

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Introduction

Innovative learning environments aim to support students' learning in an individual and personalized way. Applying proven technologies and methods such as e-portfolios support individualized learning [17]. E-portfolios help students to develop their individual competencies by documenting them in the form of self-authored texts and selected multimedia learning artefacts. Furthermore, e-portfolios allow teachers to get an insight into the complex processes of individual competence development and enable them to provide targeted feedback to the students. Using e-portfolios as a tool for performance assessment requires teachers to evaluate the diverse artefacts contained in an e-portfolio based on suitable assessment criteria and so-called rubrics [3]. Due to the complex structure of the competencies to be achieved, the assessment of e-portfolios is a very challenging and time-consuming task. In the project "AI-supported Observation of E-Portfolios (AISOP)", we aim at developing AI-based tools and methods to support both students in the composition of their individual e-portfolios and provide teachers with adequate tools for assessing the students' e-portfolios in a thorough and efficient way.

As a first step towards this goal, we conduct an in-depth analysis of the state-of-the-art research and technologies of e-portfolio analysis, and elicit the current situation and the needs of students and teachers in the context of e-portfolios in higher education. This report summarizes the results of this problem and context analysis within the AISOP project and builds the foundation for developing a user-centred tool infrastructure for AI-based e-portfolio analysis. The structure of the report is as follows: First, we present the related work and categorize the knowledge by layers. By outlining different usage scenarios, we provide an overview of how e-portfolios are used in practice and highlight the challenges of using e-portfolios as a learning and assessment tool. Based on the identified usage scenarios, we derive requirements for AI-based tools that support students and teachers in the e-portfolio creation and assessment process. Finally, we map existing assessment criteria to measurable indicators of e-portfolio artefacts and use those as a basis for selecting suitable techniques and methods to evaluate these indicators automatically. We conclude by providing an outlook on how AI-based technologies could enhance the identified usage scenarios of e-portfolios in higher education in the future.

E-Portfolios: A Contemporary Proof of Knowledge

E-portfolios are digital works that learners create to express their knowledge and the process of acquiring this knowledge. As a composition, an e-portfolio lets learners express themselves with digital artefacts (texts, graphics, videos, ...) using a vocabulary that is both accessible to them and to their readers. As a digital composition, e-portfolios enjoy the ease of re-use to create a representation of their learning process and knowledge that is their own.

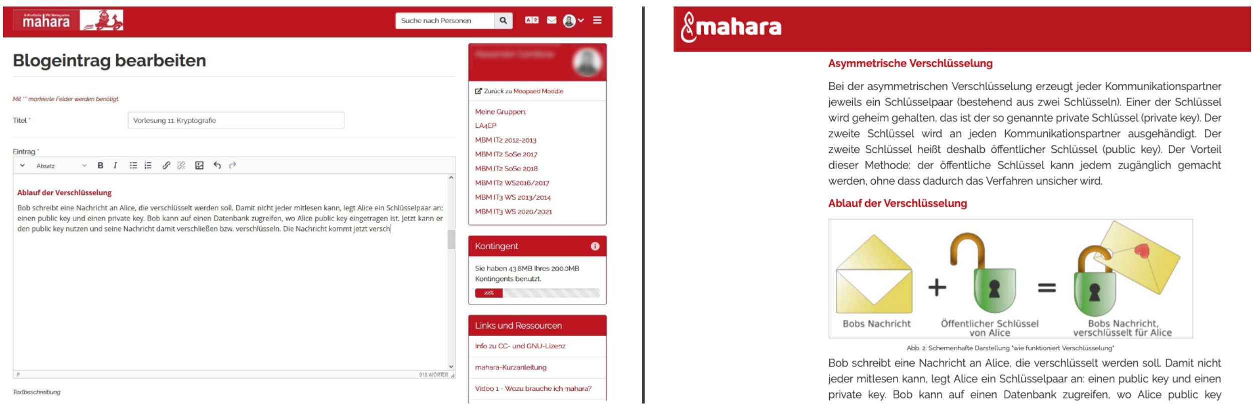

Fig. 1 Example of an e-portfolio

Fig. 1 shows an example of an e-portfolio. The composing view as the student sees it on the left and the final view on the right. In a course, teachers can request students to create e-portfolios in order to testify their knowledge: They should represent what they have learned in the course, and how they have learned it [23]. The realization can be far beyond a mere repeat of the instructor's material, with the knowledge expressed in a re-appropriated manner and with individually deepened subjects. For a teacher, reading an e-portfolio is like reading in the students' mind and observing the individual learning processes, provided he or she played the game of self-writing in his or her own words. Contrary to many of other knowledge assessment techniques, the creation activity of e-portfolios is done open-book with references accessible. This ubiquity of knowledge imitates the contemporary professional life, where keeping knowledge sources at hand and adapting them to the real world is a key exercise [17].

At the University of Education Weingarten, e-portfolios are used as means of assessing the learning: Students have the mission to create e-portfolios to represent their knowledge of selected courses and the knowledge of individual chosen subjects in greater details. They not only document the general knowledge of the course, but also the process of acquiring this knowledge and the process of realizing chosen projects. E-portfolios are written as witnesses of the processes. Among the current practice, one row of courses at the University of Education is about programming and computer concepts, where realizations include the implementation of a small game program and the shot of an explanatory video. E-portfolios about each of these aspects are written. Teachers of these courses assess the acquired competencies and knowledge of the students by evaluating criteria such as the topical completeness, the subject-specific depth, the use of source material, the originality of the presented artefacts, the quality of the explanations, the formal aspects, and the expressed reflection about the relationship to the subjects (e.g. the connections to their own environment). Upon reading the portfolios, teachers can assess how well these criteria are met and can classify what subjects were (more or less deeply) treated. This evaluation is, currently, mostly manual, and in certain classes due to the large number of portfolios and the time needed to assess those very elaborate and time-consuming. For instance, in a project module linked to foster digital competences of students in teacher education about 600 students a year document the learning processes with e-portfolios, and typical assessment may take between 1–2 hours.

Text-Analysis and Visualisation Techniques for Supporting the Assessment of e-Portfolios

While a first concept and evaluation have been reported in [14], very little pre-existing research has been found about the automatic analysis of e-portfolios in particular, a more general literature needs to be explored. E-portfolios and their usage in higher education have been defined by classic works such as [11]. Their relevance for lifelong learning has been described in [17]. These works highlight the formative role of the creation of e-portfolios in the learning processes: The concrete nature of this creation is a visible process for students and can support an early (formative) assessment. Students, peers and teachers are in a position to orient the learning process when viewing the portfolio, this contributes to a formative assessment [28].

Text analysis techniques have largely progressed, and techniques to extract structured information from texts based on machine learning have been investigated with promising results. For example, transformers [15], [24] and language models building on transformers, like BERT [6] or Sentence-BERT [19] bring the ability to model each section of the portfolios in vector spaces and to extract comparisons and knowledge.

The research we are describing is embedded in learning processes at the University of Education in Weingarten. As with any technology application research, the spectrum of possible developments is broad, and we aim at demonstrating and evaluating the technology potential in real learning. To this effect, Design-Based Research [18] offers us a research methodology that can deliver knowledge and experience about the technical artefacts inserted in real learning situation. Among the outputs of this project, the objective is to deliver an open-source prototype. Moreover, we aim at delivering corpora in the form of anonymized and annotated e-portfolios and in the form of collaboratively built ontologies [10] for the subjects of the courses we are applying this to.

The tools that we are developing are among the artificial intelligence supported learning tools. However, compared to the many tools described in [30], our contribution aims to deliver information that is not directly related to a prediction or an automatic score evaluation. Instead, we target to deliver dashboards and visual representations to present synthetic information about the content of the e-portfolios that ease the analysis and assessment of e-portfolios by human assessors. The design of visualisation and dashboards for the analysis of learning processes have been the object of a number of studies, among others [2], [20], [25]. A recent review can be found in [29]. Visualizations and dashboards are aimed at providing various perspectives on the e-portfolio content, both for teachers and for students. While teachers need to quickly grasp the overall content of the e-portfolio and identify relevant parts of the e-portfolio for closer inspection, students need feedback on the current state of their e-portfolio with regard to the underlying assessment criteria. Applying both, a suitable design and development process, as recommended in [2], and state-of-the-art visual design concepts [7], are the prerequisites for developing dashboards that communicate useful insights and efficiently support both learning and assessment processes.

Text-analysis methods are among the classical applications of artificial intelligence. While they may deliver strong services, a challenge remains the trust-level that a user can put in the these, since any machine-learning-based system is based on a learning process that can be biased or missing under multiple aspects. Principles of trust as in [26] for general artificial intelligence or in [9] have to be considered. However, the problem of trust is an old problem as demonstrated by Weizenbaum in [27] and may be related to how the system made available lets users expect being helped or advised: Instead of taking the role similar to a human coach, a system to analyse e-portfolios should take the role of an instrument [16] supporting a transparent synthesis and an active navigation.

Layers of Representation of Knowledge

E-portfolios represent media artefacts created by learners in the context of their learning processes. As such, they depict only one of the forms of knowledge representation involved in the sequence of learning. In a more complete and comprehensive picture, the following representations of knowledge may be involved in a learning process:

- Knowledge maps and lesson plans created by teachers in the preparation for classes. Here, the bird's-eye perspective is essential.
- Learning materials or course books conceived by teachers. Detailed descriptions of the knowledge are included, often used with oral presentations.
- Additional open learning material provided to support individual learning processes accessed by students, possibly also originating from students. Beyond the knowledge presentation, focused explanations and task-specific guidance are found here.

- Exercises, project results, and other artefacts designed and produced by students in the context of their learning processes. The individual understanding and competencies are important differentiators of the works realized here.
- Student's e-portfolios as the main documentation of learning processes and achievements. These constitute a textual representation of the learners' knowledge, competencies, and learning process.
- Teachers' rubrics guiding the assessment of learning processes, but also representing a prioritization and ranking of learned knowledge.

That is, from the perspective of assessment, a wider context has to be considered, and additional representations of knowledge can be considered available to support a more comprehensive assessment of the individual learning processes and achievements of students. E-portfolios represent the core knowledge artefact and the starting point for an individual assessment. Still, in the process of assessment, teachers will implicitly always try to consider this wider context. Technologies targeting to effectively support teachers in the assessment of learning artefacts and e-portfolios in particular therefore need to provide access to the various knowledge representations and to allow for relating bits of knowledge. In the context of the assessment, a major objective is to analyse and rate the student's gained knowledge in corresponding learning processes. That is, the completeness and correctness of knowledge can and must be assessed in relation to the various representations of knowledge available in the learning process. We envision to systematically enhance the layers of knowledge representations available in the assessment with additional elements either provided manually by teachers to enhance assessment, or automatically during the assessment process, the latter in particular by machine learning approaches. We consider expert knowledge maps on learning content provided in advance by teachers and aggregated learner knowledge based on the subject-specific learner portfolios. Fig. 2 provides a more comprehensive overview on the different layers of knowledge representation in the context of the e-portfolio assessment process. As mentioned above, the assessment of students' learning processes always requires teachers to relate documented student knowledge to other available layers of knowledge. As such, supportive technologies for e-portfolio assessment not only require the integration of different layers of knowledge, but also have to provide effective access to these layers. In particular, the completeness of the query and extraction can be supported by the use of adequate interactive information visualizations and dashboards, enhanced for instance by focus and linking [4], to depict structures, such as the map of broad topics or ontological trees of conceptual objects, and to explore interrelationships.

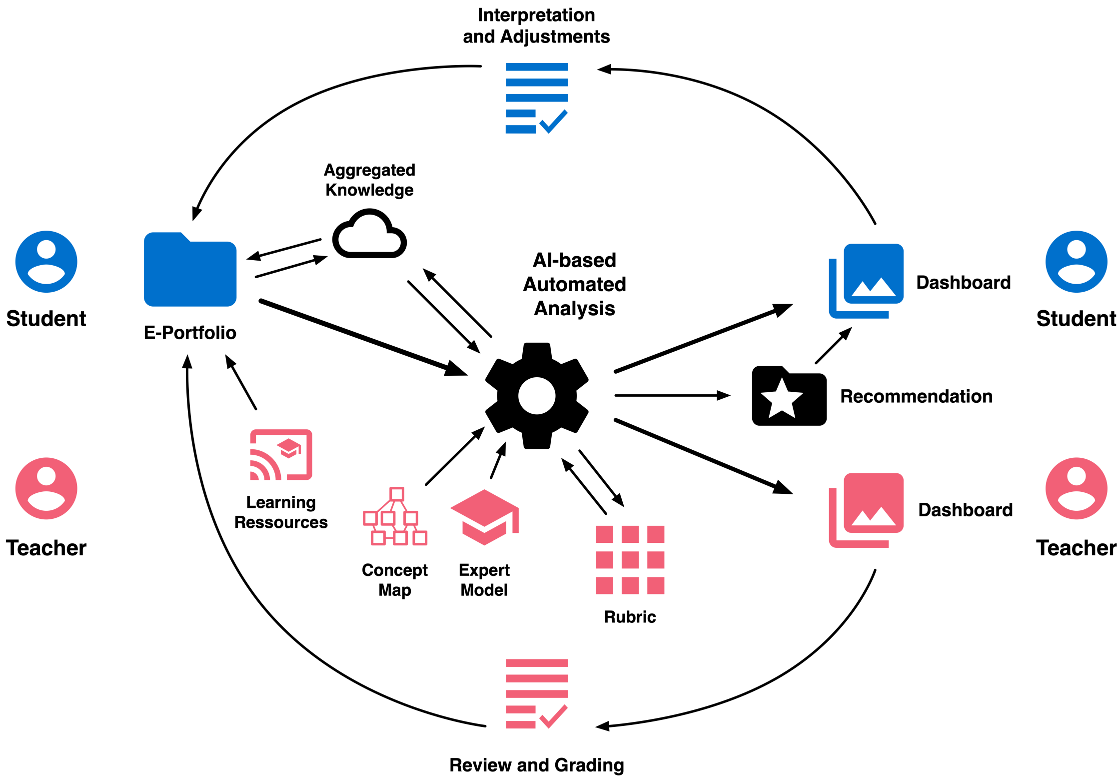

Fig. 2 The processes: On the left the input to the automatic analysis system, on the right the services it provides to teachers and students.

Automated Support for the Assessment of e-Portfolios

Navigating through the various representations of knowledge is an important task when composing an e-portfolio, but also when assessing students' e-portfolios in light of the criteria above. This is the object of the project AISOP, which aims at employing state-of-the-art Natural Language Processing (NLP) to display connected representations of knowledge around submitted e-portfolios. The idea of automated assessment support for e-portfolios is based on the following steps:

- Elicit and represent expected learning outcomes: In order to elicit the expected learning outcomes, an ontology representing the underlying domain knowledge of a course is constructed using concept-mapping as a method for knowledge representation. The outcome of this step is a concept map of the expected learning outcomes: the expert model (see Fig. 2).
- Build a domain-specific corpus as a basis for NLP: Different kinds of learning resources (e.g., slides, book excerpts, video transcriptions) as well as portfolios in past editions of the course provide the basis for a domain-specific corpus that is set up and enriched with annotations referencing the appropriate concepts from the expert model. The corpus is used as a basis for training a domain-specific machine-learning (ML) pipeline for analysing the digital content of e-portfolios.
- Extract student knowledge from e-portfolios: The digital content of an e-portfolio is used as input to the trained ML pipeline. As a result, the found concepts and topics in the e-portfolio are annotated and returned as an extraction of the student knowledge.

- Compare extracted student knowledge with expected learning outcomes: The semantic similarity between the extracted student knowledge and the Expert Model is calculated and represented visually in a combined concept map of student knowledge and expert model: overlapping concepts, missing concepts, and supplementary concepts are highlighted and provide insights into knowledge gaps, specific expertise, and individual areas of interest. Criteria such as topical depth or topical coverage are both visualizable in topic maps of the courses: Given an e-portfolio, a topic map of the course can be graphically coloured to indicate topics covered or those that have been left relatively light, thus helping teachers to grasp faster which part of a portfolio is about which topic.
- Compare extracted student knowledge with aggregated learner knowledge: All e-portfolios entering the system form the aggregated learner knowledge (see also the "Group reference model" as defined by [21]). Analysing the aggregated learner knowledge for contained concepts and topics provides the basis for comparing the extracted student knowledge with the collective knowledge acquired by the whole learning group.
- Visual navigation within e-portfolios: The combined concept map of student knowledge and expert model are also being used as a tool for visual navigation [22] within an e-portfolio. Providing a Student and Lecturer Dashboard that integrate both the concept map and the digital contents of an e-portfolio, clickable nodes in the concept map can be used to link to the corresponding sections in the e-portfolio. In the same way, the concepts covered in the currently visible extract from the e-portfolio can be highlighted in the concept map.
- Continuous enhancement of the corpus: The underlying corpus for performing NLP is continuously enhanced by newly created and annotated e-portfolios.

Techniques such as entity-recognition and topic-recognition, calibrated to the subjects of the courses are applied to this effect. Such techniques are being explored within the AISOP project.

Identifying Indicators for Automatic Assessment

As described above, rubrics are typically used as an evaluation instrument for assessing students' competencies documented in individual e-portfolios. Rubrics are represented as scoring grids structured in a list of criteria for evaluating the expected learning outcomes [3]. For each criterion, students can reach a certain performance level. In the rubric, a competence description for each criterion and each performance level is given. As a first step towards automatically analysing e-portfolios, we have derived a list of indicators which are suitable to describe relevant e-portfolio characteristics based on the assessment criteria contained in the rubric. For each indicator, appropriate techniques from the area of NLP and descriptive statistics were identified which support the automatic measurement of the corresponding indicator. Our results are presented in the following. The criteria that we use for assessing e-portfolios can be grouped into three categories: content-related criteria, formal criteria, and criteria related to the learning process. In the following, we discuss these categories, possible indicators, and manageable approaches to assess those indicators in the context of our work in some more detail.

Content-related indicators: In this category, one important indicator is the completeness of the representation. Determining the covered topics by applying topic and/or entity recognition techniques and comparing the results to the underlying expert model provides a measure for completeness. Additionally, topic recognition allows a user to identify topics that go beyond the core contents and might indicate special engagement of the student. Highlighting unexpected content areas can draw the attention of the teacher to the corresponding sections of the e-portfolio and allow for closer inspection. Visually representing covered topics in the form of interactive concept maps support the teachers and students to quickly get an overview and navigate to the relevant section of the e-portfolio. The depth of content of the written text is another criterion. Possible indicators related to this criterion, are the information density of the text [5] and expected discourse patterns that can be analysed by discourse mining [1]. However, it might be a challenge to identify irrelevant content. Indicators for assessing the quality of the academic and domain-specific language comprise information measures on terminology usage as well as general measures such as repetitions, punctuation, spelling, and sentence structure. Another criterion is the use of relevant literature and other resources. Statistics on the referenced resources, included links to online resources, and the number of embedded figures indicate how much effort was spent in researching the existing knowledge base of the topic domain. By comparing the cited resources to a standard set of relevant literature, an indicator can be derived whether the e-portfolio content is based on the expected readings. A plagiarism check is important for assessing independently created artefacts and exercises. Here, copied work among peers as well as content from available learning materials such as slides, provided articles, or text books must be identified. For example, image recognition can help in detecting plagiarism with respect to graphical representations. Because e-portfolios are multimedia documents, the creation and inclusion of graphics for illustrating the learning content are an important component of documenting learning processes. While it is important to check for plagiarism, drawing the attention of the teacher to genuine work and artefacts is key in supporting efficient e-portfolio assessment. Indicators such as the number of included exercises or self-researched examples, the degree to which exercises have been elaborated and explained, can give clear hints on the engagement with the learning content. Again, methods such as discourse mining and measures related to text quality [12], [13] will provide useful insights here. Finally, creating links between the sub-modules of the course proves that the learner has gained an overall understanding of the topic domain and is able to connect concepts across the boundary of individual courses. Extracting discourse markers for cross references as well as for explicit references to other sub-modules support the automatic detection of these links. Teachers specify expected connections between sub-modules by creating semantic links in the concept map representing the underlying knowledge domain. Based on this, the proportion of explicitly stated links in the individual e-portfolio can be visualized.

Formal indicators: E-portfolios are also assessed based on formal criteria. The focus areas here are design, media usage, language and correct citing. Evaluating the design is mainly about clarity, and only secondarily on aesthetics and individuality. Indicators based on the number and size of sections and paragraphs, application and proportion of different font styles and sizes, colour highlighting, and design elements such as headings, tables, figures, and icons provide information on the overall document structure and the effort that has been put into creating an appropriate design for the e-portfolio. For assessing media usage, it is important to determine the ratio between the number of embedded media artefacts and the text length. Media can easily be categorized into graphics, video, and audio, and thus, the number and variety of included media artefacts provide a good indication on how confident the student deals with digital media. Further categorization of included images into text, code, photograph, or illustration can be obtained by established image recognition services. First results in applying these services show that the technology is mature at recognizing these. Moreover, the analysed information would even give the ability to replace text visually in a web-page, for example to offer text-search, other NLP tasks, or navigation services. When assessing the language, criteria such as orthography, choice of words and linguistic style are considered. A suitable technique for analysing word choice and style is to determine the lexical diversity [8] which calculates the ratio of different unique word stems (types) to the total number of words (tokens). Furthermore, omissions of letters in words indicate colloquialism in the German language. Checking for such omissions provides an indication as to whether the language of the text is appropriate. Finally, it can be examined whether abbreviated words were written out the first time they were mentioned, thereby introducing the abbreviations. The last formal criterion to be examined is the references, in particular the consistency, completeness and correct allocation. Automatic verification of the availability of the bibliography, correct formatting of the entries, and the consistency between citations in the text and the listed references, support students and teachers in applying and assessing formally valid citations.

Indicators related to the learning process: Assessment criteria in the category of the learning process aim at evaluating the curiosity, the openness, and the individual commitment that students exhibit when dealing with the learning content. This is probably the most difficult area for automatic assessment. How does one measure the commitment, openness or curiosity of a person? One approach could be the comparison of the portfolio contents with slides or other learning materials provided in the course. The ratio of copied sections and self-written texts could provide conclusions about the commitment of the student. As described, recognizing topics covered by an e-portfolio can be compared to the concept maps created by the teacher. This way, new topics and examples added by the student can be identified. An indication for high involvement with the topic at hand and for individual work is definitely the personal reflections of the student. The length of the reflective text can be determined quite easily, but a long reflection is not necessarily a good one. The elements of a high-quality, in-depth reflection can be extracted by identifying text markers introducing the reasons for choosing a specific focus topic, explaining the individual work process for developing the presented artefacts, describing personal objectives and challenges, analysing strength and weaknesses of the applied approach, and reflecting on what could be improved. Indicators for this type of reflective content provides valuable information on the degree to which students have consciously and intensively engaged with the learning content.

If it is possible to provide assessments of e-portfolios with regard to the indicators mentioned above, advantages for teachers become obvious. They can focus on specific areas, compare and classify portfolios better, and thus, significantly reduce the time it takes for an evaluation. But as mentioned earlier, the project AISOP is also aimed at the students, who can also benefit greatly from getting feedback on their e-portfolios with regard to the indicators. During the composition of an e-portfolio, they have the opportunity to use visualizations to discover gaps in content or even to identify missing topic areas. Formal criteria can also be easily checked this way. Is the amount of typographic highlights adequate? Is the use of media appropriate compared to the length of the text? Is there still room for improvement on the language level? Students also have the possibility to check the representation of their learning process. They are able to examine the formal and content-related criteria of the reflections on individual chapters. A comparison of the reflections on all chapters to identify the reflections that still need to be revised would also be possible. Some might even compare various statistics with fellow students, to see where they are and what still needs to be done.

Beyond Assessment

E-portfolios are a rich means of expressing the knowledge students have acquired during a course. This expression is likely a powerful mechanism to reflect on the course: What has been the social dynamics between the students? What topics are more deepened than others or are simply scratched? What knowledge is often cited and thus can be assessed as being well understood? These insights can be a key analytical tool to reflect on the current cohort, its learning effect, and courses' quality. Moreover, students may benefit of declinations of such tools. For example, being hinted on a (missing) coverage and the related support materials. These three categories of tools will be investigated in AISOP. Open-source software and corpora will be published for them.

Summary and Conclusion

In this paper we presented an approach and first results from a research initiative related to the automated AI-based analysis of e-portfolios, targeted to provide teachers with tools and dashboards to reduce work related to the assessment and grading of such digital learning artefacts, and at the same time students with automated feedback in the process of designing and writing such portfolios in the context of competence-based learning activities. We explained that a more complete perspective that considers all types of different knowledge resources available and used in the context of students' learning processes allows for a wider range of analytical approaches, promising to get a more comprehensive understanding of these processes and their results in terms of competences gained. We presented general steps and processes as well as indicators used to perform such an extensive analysis and a corresponding system architecture and a sketch of an infrastructure to process e-portfolios so that the evaluation and the elaboration is supported by modern technological means powered by natural language processing. Furthermore, first prototypes were presented that already showcase the value of the corresponding system and tools to teachers and students. To our knowledge, the taken approach has been little investigated so far, with [21] being among the rare studies that aim beyond fully automatic assessment using NLP. In particular, the design of visualizations and dashboards fed by AI-based analytics techniques to analyse e-portfolios more efficiently and more effectively have not been explored. Albeit, the technical nature of e-portfolios and other related layers of knowledge opens possibilities to better understand, depict and communicate patterns in documented students' learning processes. This not only eases assessment, but also is likely to enrich students' vision, leaving them tangible traces of their learning. These traces form the carrier of a dialogue where the feedback provided by the visualised dialogue, by the teachers help students affirm their knowledge in a visible way.

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