GAMING PROJECT: DEEP REINFORCEMENT LEARNING

Initiation, process and effects achieved

Case Study in a German VET school

The Erasmus+ funded European project 'Improving the Skills and Competences of VET teachers and trainers in the age of Artificial Intelligence' (Taccle AI) brings together partners from five countries to provide initial training and continued professional development for VET teachers and trainers in Artificial Intelligence. The project will seek to support VET teachers and trainers in extending and adapting open curriculum models for incorporating AI in vocational education and training. Furthermore, the project will develop a Massive Open Online Course in AI in education in English and German, open to all teachers and trainers in VET in Europe. The course materials will be freely available for other organisations to use for professional development. It follows the tradition of previous successful TACCLE projects. You can find more information on our website: www.taccleai.eu

Authors
Ludger Deitmer (University of Bremen, Institute Technology and Education, Germany)
Wilfried Meiners (former director of studies at the Kerschensteiner VET School in Delmenhorst, Germany)

Co-funded by the Erasmus+ Programme of the European Union

The Taccle AI project has been financed within the framework of Erasmus+ programme (KA2 - Cooperation for innovation and the exchange of good practices KA202 - Strategic Partnerships for vocational education and training; Nr. 2019-1-DE02-KA202-006317)

1. Introduction: topic, realisation, embedding in contexts

The title of the project was: "Deep Reinforcement Learning - Preparation of the topic 'artificial intelligence' and implementation of an agent in the game Sonic the Hedgehog". The innovative content of the student project is the programming of a self-learning artificial agent in a computer game. The project was planned, implemented and documented largely independently by a group of four students at a north-west German vocational school.

The students took part in the "Information Technology Assistant" training course as part of the compulsory practical project in the second year of training at Vocational School II, Delmenhorst, between November 2018 and March 2019. The two-year training course is a full-time school-based vocational training course, its focus is on imparting basic initial vocational knowledge and its application in practical phases with projects and in-company placements.

Based on a suggestion by the coordinating vocational school teacher, a group of four students was encouraged to investigate and learn more about the principles of applying AI. The students liked the proposal and further specified the task. The aim was to program an artificial agent that can act independently, to learn with it and to illustrate the learning progress of the agent as "deep reinforcement learning" using the example of a computer game. The course of the project resulted in extensive documentation and was presented to other students and teachers from the course in a final presentation.

What does AI do in computer games?

The game "Sonic the Hedgehog" is a well-known computer game series by the Japanese game developer Sega. The series' classic main characters are characterised by fast 2D jump 'n' run passages. There the player controls the blue and artificial character 'Sonic The Hedgehog'. This is done through 'zones', divided into individual 'acts'. In all Sonic games, rings are collected, which the main agent loses when touching an opponent. If the agent is without rings, you lose your life and have lost. After using up the credit of 'Extra Life' and 'Continues', the player has to start completely over again after a 'Game Over'.

Why is it important that students deal with AI and its professional application?

From the teachers' point of view, artificial intelligence is seen as a key technology in many areas including automation technology, electrical engineering, and information technology. AI is closely associated with digitisation and Industry 4.0. Basic knowledge in this field is becoming increasingly important for prospective IT Assistants. A large number of pupils from vocational schools attend *the Fachoberschule für Technik* (technical secondary school) following this specialist training, to subsequently embark on a study in Information Technology. These students have to deal with the subject of AI in-depth during their studies at the latest. Students at vocational school who start an apprenticeship (predominantly in technical occupations) must also deal with the topic of AI since, within the framework of the digitisation of the working world, processes can increasingly be influenced by AI techniques.

2. Project phase: preparation, first planning steps, the concretisation of objectives

The AI project took place within the framework of the learning field of "Planning, implementing and evaluating projects" (practice), the total duration of which is 160 hours. The project meetings usually took place on a full day of lessons. The students had the opportunity to work in the computer room or the workshops at the school. They were supervised during this time by a vocational school teacher. In parallel, other groups of students also carried out projects. For the teachers, the focus of the projects was on independent work by a group of students to give the students practical experience around a professional topic. The students of the AI project group should, therefore:

- learn and practise project-oriented work in a group
- set themselves goals and divide and organise their work independently by achieving an independent study of a new programming language (Python)
- learn the basics of central AI elements to such an extent that they were able to understand and create the programmes themselves
- learn about the basics of neural networks and machine learning, so that they were able to explain these terms to their classmates,
- by dealing with the topic of Deep Reinforcement Learning, be able to program a virtual agent in such a way that this agent learns to improve their game,
- become familiar with the programming of the agent to the extent that they could explain to their classmates which parameters they had to adjust/change for their "agent" to improve their game.

Within the scope of project planning and preparation by the group of students, team rules were established, environment analyses were made, a target matrix and a schedule were drawn up and work packages were defined. The work packages for the project implementation included the:

1 Documentation (preparation of the documentation documents)

2 Programming (setting up the programming environment, the first prototype, second prototype)

3 Research (information gathering, tests with the prototype)

4 Documentation of results (preparation of the documentation of results)

5 Presentation (preparation of the presentation)

The individual work packages were assigned performance specifications and results which had to be achieved. Besides, responsibilities and deadlines for the work packages were defined. Furthermore, the pupils were assigned roles within the project group:

Roles	Tasks/ duties
Team leader	Moderates the group work and makes sure that everyone can get involved, that the topic is consistently kept to and the team rules are observed.
Timekeeper	Make sure that the time is respected.
Quality Representative	Make sure that work is done properly and thoroughly according to the appointments.
Arbitrators	Becomes active when there are disagreements in the project team He ‘ she brings the conflicting parties to a table, moderates the discussion and remains impartial.
Maverick	Should express in a friendly way what nobody else dares to say, e.g. thinking out loud.

A reflective observation of the approach of the group of students on the course and procedure of the project.

The group was aware that they were facing a difficult task with this choice of project. Artificial intelligence is a highly complex topic that has mainly been seen as part of university studies, e.g. in computer science or automation technology. The students limited the scope and depth of the work, emphasising that they have only dealt with the topic of AI in a relatively superficial way. Due to favourable circumstances, such as access to meaningful Internet sources, such as Open AI, they have come to a concrete result in the sense of programming an agent in the context of a digital game.

> "*As soon as we tried to delve deeper into an area somewhere, it very quickly became very mathematical and we simply lack the necessary knowledge. Nevertheless, it was surprisingly easy to gain a basic knowledge of artificial intelligence, up to and including deep reinforcement learning*".

For the students, it became clear that artificial intelligence is still a small specific area within computer science, as most information is only available in English. The students consider it a further problem that when choosing this project topic, they could not estimate at the beginning what the final result would be:

> "*(...) how the project will develop at all because especially the development of the agent in Sonic contained a big question mark for us. Besides, the extremely theoretical nature of the project, in terms of research, also harmed our motivation. The many and repeated readings of complex content often led to productivity suffering as a result*".

However, the students emphasize that despite the gaps in their knowledge of mathematical fundamentals and despite the language barriers, they made a good choice with this project, "because artificial intelligence is a very interesting topic, which will become increasingly important in the future".

The students also found it very interesting to realise an AI in the sense of programming an agent and to put the approach of "deep reinforcement learning" into practice.

Furthermore, working with the Python programming language proved to be successful for the students, "because the simple syntax enabled a quick basic understanding of the

libraries used and we were able to concentrate on extending the AI quite quickly". They also stress that they only succeeded to a very limited extent in penetrating the deeper subject of AI. The pupils could not "make extensions" because the majority of the libraries are still difficult to understand. After all, mathematical algorithms are written there that are so foreign that the students could not understand them.

> "*However, once the AI was finished, we could always restart it and let it run in the background so that while we were researching or documenting, it was constantly learning and still making small progress*".

The pupils emphasise the project result as a whole:

> "*(...) it was a good decision to choose this project theme. We have managed to fulfil our expectations, an advanced understanding of artificial intelligence and practical implementation of the knowledge, to a large extent.*

3. Analysis of strengths and weaknesses of the project

About the pupils' point of view: In the following, the feedback from the students on the project, its progress and the greatest difficulties will be given first. This is followed by the point of view of the accompanying teacher.

I. The subject poses a great challenge for learners because there was a lack of prior knowledge (e.g. mathematics, English, basic knowledge of AI, etc.). This underlines the importance of the availability of appropriate sources. The same applies to the need for good support from teachers, who are particularly challenged in this field of knowledge due to the degree of novelty etc. The pupils assess this as follows:

> "*The project topic challenged our group quite a bit because in many points and questions we were entering completely new territory for us. To understand the AI approach at all; to understand the "deep reinforcement learning of the agent"; to find a suitable programming language*".

Teachers were also particularly challenged by this topic and its innovative content, as they had little previous experience from their professional specialisation. This is reflected in the teacher's statement:

> "*I have learned a lot from planning and monitoring and evaluating this project. The topic of AI is still interesting for me today!*"

II. As support in accomplishing the project task, the students emphasise the importance of relevant internet links and sources. Thanks to the help of the Internet, the pupils found it easier to find the right sources, such as Open AI and YouTube videos.

> "*The search for suitable sources of information was a greater challenge for us. With the help of the sources we were finally able to learn the programming language "Python" ourselves. In this way we succeeded in developing a step-by-step and feasible plan for the six-month duration of the project*".

The students point out a very interesting aspect in dealing with these sources of information:

"*It was good to write everything down whenever possible! Some videos could only be understood after listening and watching them several times. A good understanding of the most important terms, commands and/or codes could be better mastered*".

III. The knowledge of project management and corresponding project management techniques introduced and prepared by the teacher is considered useful by the students in the implementation of the project task. The student group said:

"*We found the project journal among the various PM tools to be particularly useful for finding answers to questions like these: What did we do last time? How should we connect? How can we divide our work tasks among ourselves? With the journal, we were asked to write down our previous research on deep reinforcement learning and Python programming. This way we were always well informed about the current project status."*

IV. In particular, the students emphasise a knowledge gap in the application of mathematical principles, which, however, seems to play an important role in AI.

"*In our previous maths class, we had the basics of algebra and geometry. Even e.g. binary or vector calculus was not known by all students. But that is not enough to understand the subject of this project mathematically. The main problem we faced was our lack of knowledge: "How do I quickly recognise where I still have gaps in my knowledge and with which means and sources can we close these gaps? The teachers were able to give us one or two hints, but could only help us partially because they have not involved in the topic themselves and were not always available when problems or deficits occurred."*

V. There is always the risk that students' motivation to stay on the topic will diminish, especially if the task is perceived as insurmountable. The two pupils interviewed point out that as a learning group, they are less likely to be frustrated by obstacles and difficulties:

"*The videos have helped us a lot, despite the problems and obstacles in understanding the complex issues. The exemplary instructions enabled us to achieve useful results when programming the agent*".

VI. The very intensive preliminary planning by the group of pupils resulted in the project documentation being positively striking in its presentation; both in terms of its scope (over 40 pages) and the project results achieved.

"The intensive pre-planning with the help of the many project management instruments helped us a lot in the preparation of the documentation so that no point was forgotten in the end. It was easier for us to become clear about the course of our approach: What went well? Where were the errors? How could we help each other? How were the different sources then best brought together in the outline"?

From the perspective of the vocational school teacher interviewed, his statements can be summarised in the following statements:

I. The importance of project work for students' learning success has recently increased even more, especially if independent work and the independent examination of new topics/contents are to be learned. Concerning the subject of mathematics, it was unfortunately decided several years ago in the "Information Technology Assistant" course of education that this subject should be removed from the timetable and that the application of mathematical knowledge should take place directly in the implementation of the learning fields or remaining subjects. However, this procedure reaches its limits as the complexity of the project topics in the practical segment increases. Experience from this project shows that students should have appropriate basic mathematical knowledge. The level of knowledge of students varies greatly due to their different backgrounds and needs to be taken more into account in the design of the curriculum. The teacher refers to the different levels of knowledge of students in terms of basic mathematical knowledge.

"We have secondary school pupils, high school graduates and pupils who came to our vocational school via other educational paths. I am in favour of including subjects such as mathematics and science in the timetable of this type of school, perhaps at the expense of another subject or field of learning".

II. As success factors for effective project work, two things, in particular, are highlighted: the provision of applicable and practised project management knowledge and the introduction of clear evaluation criteria for the project against which success can be measured. The evaluation criteria should be disclosed at the start of the project (see Annex 1). Working openly in the project requires the pupil team to monitor the course of the project itself. It is therefore advisable that at the beginning of the project work, the teachers disclose the most important evaluation criteria for working on the project task to the students, and that the handling of these criteria is discussed and agreed upon. It is considered very useful to deal with PM knowledge before the actual project, as the team rules, the distribution of tasks, the detailed objectives and work packages are determined by the project team itself. In detail, the students are required to present an environment analysis, the target matrix, the work plan, the project flow chart, a project contract, a work breakdown structure, work packages, a milestone plan and a risk analysis. Teachers' experience shows that the students cope better with the obstacles and document the project better.

III. Experience with this type of project shows that teachers should have good professional skills and be willing to familiarise themselves with AI. Basic knowledge of project management is also an important prerequisite for teachers to be able to prepare students for the projects. Furthermore, teachers should be able to formulate appropriate goals well and should have patience

and empathy. This means being open to new topics suggested by the pupils, as well as to changes in objectives/flexible adjustments during the project. Finally, teachers should also have a clear idea of how to evaluate the project work.

IV. A practical training of several weeks' duration before the project is considered an important factor in increasing the learning effects. For this purpose, an expansion of the learning location cooperation with local company partners is of particular importance. It is generally considered useful to have extra-curricular "sparring partners" to provide advisory support or even material support in the implementation of the project tasks. Particularly when challenging projects are being carried out, contacts with the company's field of reference are also necessary. In principle, there are no limits to the possibilities for cooperation with companies. There are many conceivable forms of cooperation: for example, students can, if necessary, sit in on the companies or complete an internship (a four-week internship is provided for in the "Information Technology Assistants" training course) or later complete vocational IT training there. It is also conceivable to link the project and the internship in terms of topic and time. Workshops or hackathons with industrial companies are also conceivable.

V. The implementation of projects places high demands on the practical and theoretical competence profile of the teachers. As far as AI applications in projects are concerned, the teacher believes that there should be a good team of teachers with basic AI knowledge or industrial practical application knowledge. High professional competence or willingness to familiarise oneself with AI, flexibility, basic knowledge of AI, basic knowledge of project management, ability to formulate SMART objectives, patience and empathy, clear ideas about evaluation, openness to new topics proposed by the students and to changes/adaptations of objectives during the project are expected from the teachers.

VI. The evaluation system was refined or extended in this project in such a way that the pupils can assign more or fewer points to each other (see also Annex 1). The teachers in the education programme have devised a special feature for the evaluation system. Each of the different evaluation criteria is given a certain number of points. The number of points is multiplied by the number of participants in the project group and handed over to the students for internal self-evaluation. The students agree among themselves on how many points are awarded to the individual according to his/her performance. The participants should learn to assess their performance more accurately. This enables them to have a say in their contribution to the project or the assessment of the group's performance. This evaluation is carried out by mutual agreement within the group, otherwise, the supervising teacher

exercises a right of veto and can correct the distribution of points. The fact that this can be successful is also made clear by the feedback on the assessment procedure from the perspective of the two pupils interviewed:

"*The distribution of points makes the whole thing fairer again. However, you have to discuss it among the team. We should talk in detail about who deserves which points. In our case, this could succeed because the four of us were more or less equally involved in the project work. The distribution of the evaluation was therefore relatively consensual and without much debate (...).*"

VII. Exchange with the developers of the systems or product developers or AI manufacturers is important. An exchange with product developers is particularly desirable in the area of teacher training. So far, only the technical aspects of neural networks have been considered here. It seems to become more and more important that the social, political and sociological aspects in areas of AI are also critically considered: what influence will algorithms have on almost all areas of life and work in the future?

VIII. the importance of social policy aspects, such as data ethics, for the design of AI products is also addressed. How could this aspect be taken up in the classroom? The assessment is given that AI strongly intervenes in the ethical and social dimension of the human being or citizen. Due to the algorithms, we can get into conflicts of aims: between the many new technical possibilities and the ethical basic rights and principles, such as data protection and abuse, self-determination, human dignity. In the teacher's opinion, this belongs in the vocational school policy lessons, in particular, concrete cases should be discussed.

"*In particular concerning the aspects of the ethical evaluation of a service or product, the future specialist programmer, information technology assistant or computer scientist or engineer should be well prepared*".

4. Recommendations: Transfer criteria for similar projects

On future action on the part of the school and teachers

Appropriate in-service training for teachers should take place. This should not only impart knowledge, but also jointly develop teaching concepts and jointly review, classify and, if necessary, develop teaching materials. These concepts and materials should then be available to all interested colleagues.

When developing project tasks, the interests of students should be taken into account

Project tasks must be linked to the students' interest if they are to be completed with the motivation and perseverance required of them. They should have a say in the selection of topics. It is also important that the students receive clear assessment criteria for working on the project task.

A list of advice and preparatory steps for those teachers and trainers who can imagine installing and implementing similar AI projects in their VET institutions includes:

- Find out the possibilities and limits of (computer) equipment at the school.
- Find out the knowledge of the school teachers about the chosen project topic.
- Teachers should be able to realistically assess their workload.
- The possibilities of relieving the teachers' workload should be examined.
- The school management should be informed and, if necessary, involved.
- The financial possibilities of the school should be clarified.
- The corresponding capacities in the subject rooms should be clarified and ensured.
- The question of time should be clarified by setting clear time targets and agreeing on them.
- The students and the colleagues at the school are to be informed and involved if necessary.
- The objectives of the project topic are to be discussed and agreed together with the students.
- Binding milestones should be defined or worked out and scheduled together with the school management.
- Regular monitoring of the project work by the teachers should be ensured.

ANNEX

Annex 1: Evaluation of the project results by the project team and teachers

Evaluation criteria	Reachable score	Achieved score of the project team
1. Project documentation		
1.1. Cover page, illustrations	2	
1.2. Table of contents, annexes	3	
1.3. References	2	
1.4. Overall impression	3	
2. Project preparation		
2.1. team rules, team roles	2	
2.2. Environment analysis	3	
2.3. Target matrix	3	
2.4. Project contract	2	
3. Project planning		
3.1. Work breakdown structure	5	
3.2. Work packages with description	5	
3.3. Project schedule	5	
4. Project implementation		
4.1. Project journal	10	
4.2. Project outcome	25	
5. Project presentation	10	
Achievable score of the project group	80	
Score multiplied by the number of participants in the project		
Bestimmung der Punktzahl der einzelnen Schüler aus dem Projektteam		

Explanation on the use of the evaluation form and on the allocation of points for the pupils: The number of points achieved is multiplied by the number of team members and awarded to the project team. The project team divides the points among themselves on their own responsibility; all team members must agree to the distribution of points (written explanation!). The teacher reserves the right of veto: In justified cases, he/she can demand a new distribution of points or, if necessary, carry it out him/herself.

A share of 20 points is distributed for the observed work behaviour (e.g. being late, leaving the workplace during working hours, chilling during working hours, not taking breaks, playing games, chatting, internet during working hours, etc.).