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An approach to agile management of virtual student teams in smart environment development

Jelena Mihajlović-Milićević [a], Miloš Radenković [b], Aleksandra Labus [a], Danijela Stojanović [c] and Zorica Bogdanović [a]

[a]Faculty of Organizational Sciences, University of Belgrade, Belgrade, Serbia; [b]School of Computing, Union University, Belgrade, Serbia; [c]Institute of Economic Sciences, Belgrade, Serbia

ABSTRACT

This paper studies the problem of coordination and supervision of virtual teams and their capabilities. The goal is to develop a model suitable for managing virtual student teams specialized in the development of smart environments. The developed model is based on SAFe and DevOps, which when combined provide us with a framework for the evaluation of team capabilities in an academic environment. Additionally, DevOps principles can be more efficiently leveraged through an agile methodology to provide students with a better understanding of continuous value delivery. Through the application of the proposed model, virtual student teams gained practical experience in self-organization and virtual team management while being efficiently monitored and guided through the project lifecycle. Virtual student teams were likewise encouraged to be more agile, as this change in mindset is imperative in business, and as such must also be adopted in academic environments. By incorporating best practices of the corporate environments into the existing curriculum, we have proven that by adopting the proposed model these changes can be feasibly incorporated to the satisfaction of both the students and their future employers.

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1. Introduction

Smart environments are complex and require adequate development approaches to overcome their complex technological and environmental aspects. One way of making sure that these complexities can be overcome is to rely on virtual teams. These teams can be distinguished from regular teams by their reliance on IT, modified organizational structures, and a multicultural working environment (Bag et al., 2020). In addition, these teams are often interdisciplinary, with workers having a range of relevant skills suitable for software development and its management (Gilson et al., 2015). The organization of the virtual team workload includes standardization of strategy, installation of appropriate working environments along with necessary training, organization of communication channels, and encouragement of interactions through those channels. (Fan et al., 2011; Hill et al., 2014).

By combining all these workload elements, the necessity for adequate management becomes apparent (Pinar et al., 2014). Performance management strategies ideally suited for virtual teams are agile and seek to maximize efficient work while also fostering a constructive work climate. For this reason, many companies are faced with difficulties in adapting their existing agile and non-agile methodologies to work with virtual teams (Gibbs et al., 2017). While agile methodologies

CONTACT Zorica Bogdanović zorica@elab.rs Jove Ilića 154, 11000 Belgrade, Serbia

can contribute much to the team's performance, the team members themselves need to cooperate and focus on common goals through shared leadership and joint decision-making (Moe et al., 2015). This cooperation is often made more difficult by the diverse skillsets and work cultures of the team members, but it is this same skillset diversity that allows them to define, build, test, and implement values in short iterations (Scaled Agile Inc., 2019d).

The difficulties of smart environment development lie in the fact that they cannot be segregated into pure development and operational activities. By integrating both development and operational activities into virtual teams we can enhance communication, integration, and automation in the planning, development, testing, publishing, and maintenance of smart environments (Maroukian & Gulliver, 2020). This way of implementation often has a direct influence on system development velocity while also offering assurances of system quality and reliability (Wind River Systems, 2016).

To better prepare students for their future roles in corporate environments where virtual teams are becoming the norm, similar principles must be utilized in the educational process (Bogdanović et al., 2019). To better facilitate the management of a large number of virtual teams in academic environments, adequate coordination and supervision capabilities are required. By monitoring each student project and its assigned virtual student teams, any issues can be identified on time, as well as positive behaviors that can be further reinforced. The requirement for being able to monitor student projects is the utilization of well-known agile project management frameworks, to provide a standardized monitoring interface for student projects. In this paper, we provide one such framework, by combining various aspects of leading management frameworks, to better facilitate both the development and tracking of smart environment projects (Mihajlović-Milićević & Mitrović, 2021). By combining an agile iterative approach that focuses on collaboration and DevOps practice of bringing together development and operations teams (*Agile Vs. DevOps: What's the Difference?* n.d.) we hope to improve the process of organizing and managing virtual student teams while providing students with the expertise needed to organize and work in the real world. To evaluate the proposed framework, a survey was conducted alongside a detailed analysis of monitored data.

The core principles, methods, and strategies of the proposed model of virtual team management are examined in the introduction. Next is a full overview of the literature on the topic of virtual teamwork organization, followed by a description of how the model is implemented. The findings of the research will be presented and reviewed. An examination of what has been accomplished regarding the paper's defined aims will be presented in this paper.

2. Literature review

2.1. Smart environment

Any environment built on the connectivity of sensors for interpretation and processing of data generated from IoT sources is referred to as a smart environment (Alberti et al., 2019; Camarinha-Matos & Afsarmanesh, 2014; Cook et al., 2004). A smart environment is an intelligent agent that uses sensors to perceive the state of its surroundings and then acts on that environment using controllers to optimize the specified performance measurements (Atzori et al., 2010). This process of optimization is automated and requires constant communication between sensors who exchange information via the internet (Bhayani et al., 2016). Based on the information gathered, it can acquire knowledge and apply it to adapt to the needs of its residents and improve the experience of the environment (Friess & Herwig, 2017). By integrating smart devices into smart environments we can expand their capabilities to allow users to monitor their environments remotely (Ahmed et al., 2016).

Examples of smart environments are omnipresent: Smart Cities, Smart Homes, Smart Classrooms, Smart Offices, Smart Traffic, Smart Industry, Smart Marketing, Smart Agriculture, Smart Power Grids, IoT in E-Health, Smart E-Government World (Radenković et al., 2017). Smart environment development projects are specific IT projects in that they include Comprehensive Perception, Reliable

Transmission, and Intelligent Processing (Chen et al., 2014), so we need specific management models compared to standard IT projects related only to software development.

2.2. Virtual teams

Like collaboration in traditional teams, collaboration in virtual teams refers to synchronous and asynchronous interactions and tasks to achieve common goals. The use of virtual teams allows organizations to hire professionals, to optimize teams made up of the best staff available in the job market (Karl, 1999; Kirkman et al., 2004; Morrison-Smith & Ruiz, 2020) regardless of their physical location. Additionally, virtual teams reduce the need to travel between locations, which should reduce costs in terms of time, money, and stress (Orlikowski, 2016). It is estimated that by 2016, more than 85% of working professionals were in some way involved in virtual teams (Solomon, 2016). Between 2010 and 2020, the number of employees who work remotely in virtual teams at least once a week increased 400% (Capers, n.d.). Zoom reported that in 2020, there will be over 300 million meeting participants per day (Bursztynsky, n.d.). According to UpWork's Future Workforce Pulse report, 36.2 million Americans will be working remotely by 2025 (Gallagher, n.d.). This represents an 87% increase over pre-pandemic levels (Kreamer et al., 2021). This implies that virtual teams are crucial to maintaining our increasingly globalized social and economic infrastructure (Morrison-Smith & Ruiz, 2020).

However, there are challenges concerning distance cooperation, as well as difficulties in choosing management methodologies for virtual teams. Virtual teams are affected by physical factors such as geographical, temporal, and perceptual distance (Davidavičien et al., n.d.). These factors are closely related to social and emotional factors, including trust, motivation, and shortcomings (Dai et al., 2019). Many more identified factors can significantly influence the workings of virtual teams such as the nature of the job, motivation and trust-building, informal and face-to-face communication, conflicts within the team, socio-cultural distance, diversity, common ground, work culture, and more. All of these factors must be controlled, and each represents a series of challenges that well-structured virtual teams should overcome (Lee Baker, 2018).

Identified challenges with working in virtual teams can be found in Table 1. (Morrison-Smith & Ruiz, 2020).

While the coordination of virtual teams has its challenges, there are likewise difficulties with the formation of teams and sustaining them during the project. Virtual teams, while virtual, still have to conform to the existing organizational structure. Reliance on existing organizational structures can pose some difficulties for virtual teams as their success relies heavily on complementary competencies (Batarseh et al., 2017). Up to now, research has noted four consequences that influence collaborative work in a virtual team (Morrison-Smith & Ruiz, 2020; Yemane et al., 2021): assistance in creating a common idea and standards in work, facilitating communication, ensuring a mechanism for transparency of work, and designing technology that is easy to use. All of these factors should be taken into consideration when models for virtual team management are designed and should represent a cornerstone for all the models' functionalities (Morrison-Smith & Ruiz, 2020).

Table 1. Challenges with working in virtual teams.

Socio-emotional factors	Technical factors	Team configuration factors
Awareness of coworkers and their contributions to the team	Technical infrastructure	Job nature
Motivational sense of others' presence	Technical competence of team members	Explicit leadership
Challenges in building trust		Common foundation
Alignment of incentives and aspirations		Competitive / cooperative culture

2.3. Organization and management of virtual teams

2.3.1. Scaled agile framework (SAFe)

Agile is a way or methodology of project management that is used in all types of projects but was initially made for the IT industry, through which teams deliver products iteratively and incrementally (through gradual improvements) maximizing product value (Fernanda et al., 2018). Many companies are faced with decisions on how to apply agile methods in their virtual teams. Efficient work and a constructive atmosphere in the virtual team are maintained through a suitable performance management strategy. Practice confirms that delegate principles are promising for virtual teamwork, as they deal with the challenge of distributed work and the transfer of leadership functions to team members. However, simply promoting democratic ideals by breaking down the organizational hierarchy has not proven to be ideal in this case. The one-man-one-vote decision-making process cannot create effective, self-managed virtual teams. As with conventional agile teams, agile virtual teams must learn to rely on joint leadership and joint decision-making. The benefits and importance of learning and training of virtual teams were recognized in the effective introduction of agile methods (Moe et al., 2015).

Scaled Agile Framework (SAFe 5.0.) is an online knowledge base of proven, integrated principles, practices, and competencies for applying the Lean, Agile, and DevOps approaches, intending to develop and deliver software for large systems in the shortest implementation time. Scalable and configurable SAFe synchronizes and provides coordination, collaboration, and delivery for multiple agile teams (Scaled Agile Inc., 2019c) (Figure 1).

SAFe 5.0 (Figure 2) introduces seven core competencies required for business agility. Each competence has three dimensions and represents a set of related knowledge, skills, and behaviors (Scaled Agile Inc., 2019a).

SAFe Lean-Agile Leaders are lifelong learners and teachers who help teams build better systems by understanding and presenting Lean-Agile Mindset, SAFe principles, and mastering the competencies required for business agility (Scaled Agile Inc., 2019c).

2.3.2. Devops

DevOps is a set of technical practices and a collaborative culture that enables communication, integration, automation, and close cooperation of all parties needed to plan, develop, test, implement, publish and maintain solutions (Cardoso et al., 2021). The concepts that DevOps relies on to provide suitable lifecycle management are automation, continuous delivery, collaborative culture, and reduction of collaborative and competency gap between development and operational teams. To realize these DevOps concepts it is necessary to use appropriate tools (Ebert et al., 2016).

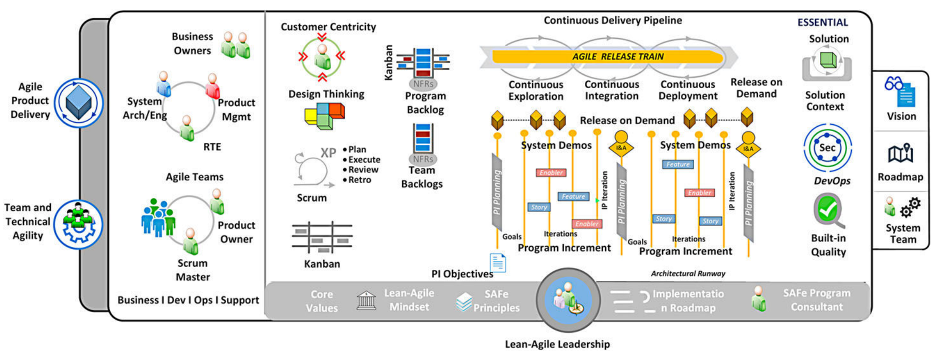

Figure 1. SAFe 5.1 (Scaled Agile Inc., 2019c).

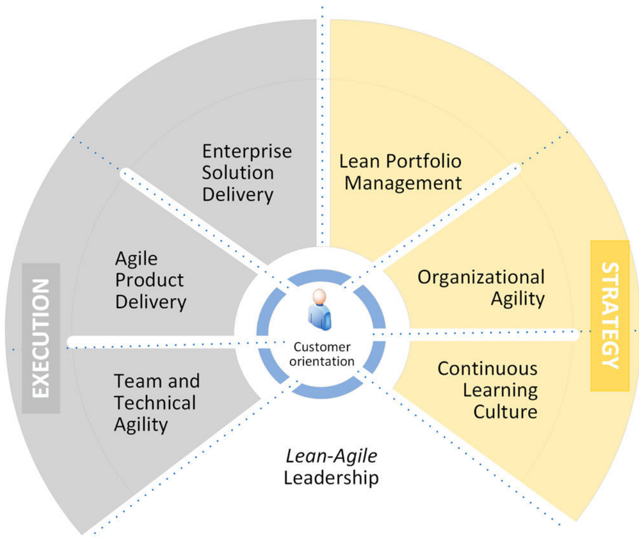

Figure 2. Overview of core competencies in SAFe 5.0 (Scaled Agile Inc., 2019a).

As a result of all these concepts working together, the frequency and quality of deliverables are improved, alongside reduced risk through safer experimentation and reduced the frequency of failures (JakobTheDev, 2019).

DevOps while not strictly a project management methodology, can be considered to be agile. As a result of this agility, its principles can easily be adapted in other management frameworks such as SAFe. For this reason, DevOps is a part of the Agile Product Delivery competency. Through that, SAFe implements some of the more notable DevOps principles such as system thinking and fast feedback (Scaled Agile Inc., 2019b).

DevOps is becoming commonplace in software development, and when combined with SAFe it provides companies with the necessary technological and methodological framework for virtual team management. For this reason, any future virtual team management models must consider the implications and difficulties posed by Devops virtual teams (Morrison-Smith & Ruiz, 2020).

2.4. Virtual teams in education

Academic institutions are seeking to follow the trend of incorporating virtual teams into existing learning structures. Several apps are utilized in academics to create a virtual learning environment. (Kumar et al., 2011), e.g. Moodle open-source platform (Moodle, n.d.; Selwyn, 2007), interactive course materials, labs, and quizzes (Edmunds et al., 2012), as well as tutorials and simulations (Yilirim et al., 2009). While these virtual environments are effective for providing new ways of learning, they do not provide real-world experience in multicultural communication, time management, and virtual socializing for students (Long et al., 2010). By seeking to bridge the divide between corporate and academic environments, students can be provided with invaluable experience that businesses can take advantage of upon employment (Dávideková & Hvorecký, 2017).

Edwards and Sridhar (2005, 2006), and then Sridhar and Paul (2006) developed software development models through virtual team projects and perfected them to apply to any virtual team project (Edwards & Sridhar, 2005, 2006; Sridhar & Paul, 2006). Research on the work of virtual teams, viewed from several different perspectives, was also conducted by Killingsworth et al. (2016), Paul et al. (2016), and Rober (2020). These studies, however, did not include the application of agile methodologies for managing virtual student teams such as the SAFe framework and the DevOps principles within it. Likewise, they did not fully capitalize on the wealth of monitoring data provided by utilizing a uniform management approach for all the virtual teams. Another potential shortcoming of their studies is the lack of open-source software solutions in their collaborative models.

3. Models, methods, and materials

To provide better coordination of virtual student teams in the academic environment, a comprehensive management model was adapted. The use of this unifying model based on SAFe and DevOps allows for finer coordination of a large number of virtual student teams of students for the development of smart environments. In addition to providing a collaborative framework, the use of a single methodology allows for better monitoring capabilities of individual teams and their progress. These advanced coordination and supervision capabilities can provide us with new insights into how virtual student teams collaborate and give us real-time feedback on the communication and coordination tools utilized by the virtual student teams (Mihajlović-Milićević & Mitrović, 2021). By analyzing the ways these tools are utilized we can see how students are diverging from corporate best practices, and provide us with parameters that can be further analyzed to quantify team results.

3.1. Infrastructure model

For virtual student teams to function properly, an infrastructure for their collaboration and tracking must be provided. These infrastructures are made up of many different components and technologies, which must work within a common ecosystem to be utilized properly by the virtual student teams. The model that we propose is made up of three major components: a collaborative system, a smart environment development system, and a management system (Mihajlović-Milićević & Mitrović, 2021). All of these systems are made to be as open-source as possible and open to extension. A more detailed overview of these components can be seen in Figure 3.

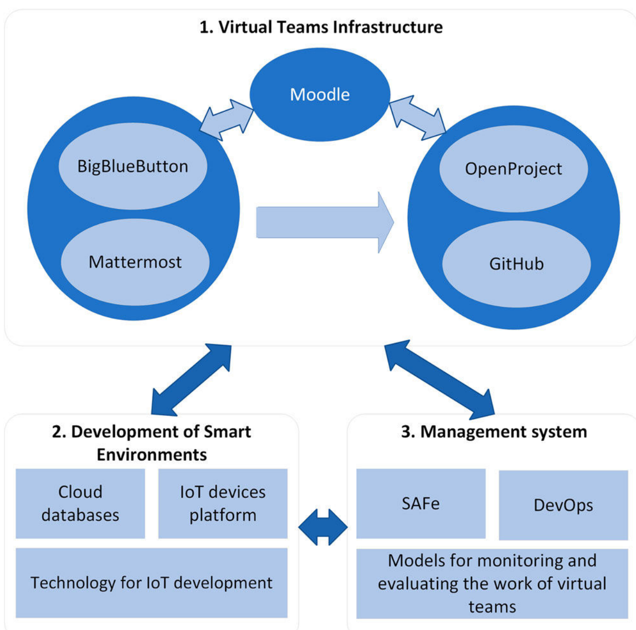

Figure 3. The infrastructure of the virtual team management model in the development of smart environments (Mihajlović-Milićević & Mitrović, 2021).

The infrastructure of the collaboration system can be deployed in the public cloud, in the private cloud of an educational institution, or the hybrid cloud. When deployed in such a way it serves as an integration point for the relevant services: collaboration services, development environments, monitoring services, and project management solutions.

For development purposes, a virtual team relies on software components like application development tools, IoT operating systems, and various additional software development services. IoT applications are often executed on microcomputers, which require their own specialized integrated development environments (IDE), and are often written in standard programming languages such as Python, Java, C, and others (Radenković et al., 2017).

The third component of the system is not strictly technical but serves to provide coordination and supervision of individual projects. By utilizing the SAFe agile framework with DevOps elements we can standardize students' projects, their evaluation and establish a feedback loop. This combination of SAFe and DevOps is critical to the success of the other system components as it serves to unify the technological segments into a unified model for agile coordination and monitoring. The implementation of the SAFE Framework and DevOps approach in this context can be seen in Figure 4.

As with many frameworks, the utilization of tools and applications for different project segments is required. For our model, we have decided on Virtual team collaboration platforms (Mattermost, BigBlueButton), software version control database (GitHub), project management systems (OpenProject), and learning management systems (Moodle). All the components are deployed on the private cloud of the educational institution, except Github. The functionalities provided by these software platforms can be seen in Figure 5.

All educational materials and sources of knowledge are hosted on Moodle. Each team member has access to this shared content and course materials. Likewise, tests are available on Moodle to assess the students' acquired knowledge during their projects.

Communication channels for secure messaging via the web, mobile phone, and computer, between team members are a prerequisite for successful collaboration and are provided through the Mattermost platform, as an open-source alternative to Slack. The platform will provide team members with the option of archiving and retrieving exchanged messages. Video conferencing and online meetings are critical for virtual student teams and are provided through the integration of BigBlueButton with the Mattermost platform.

The student project life cycle is monitored and evaluated through the OpenProject tool, which gives us up-to-date information on the state of each project. Since the student projects primarily

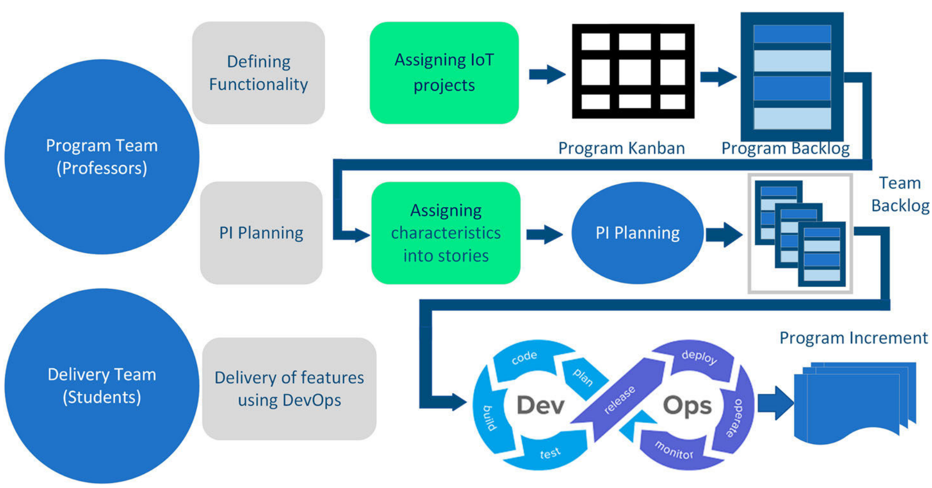

Figure 4. Implementation of the SAFE Framework and DevOps approach (Burndown, 2018).

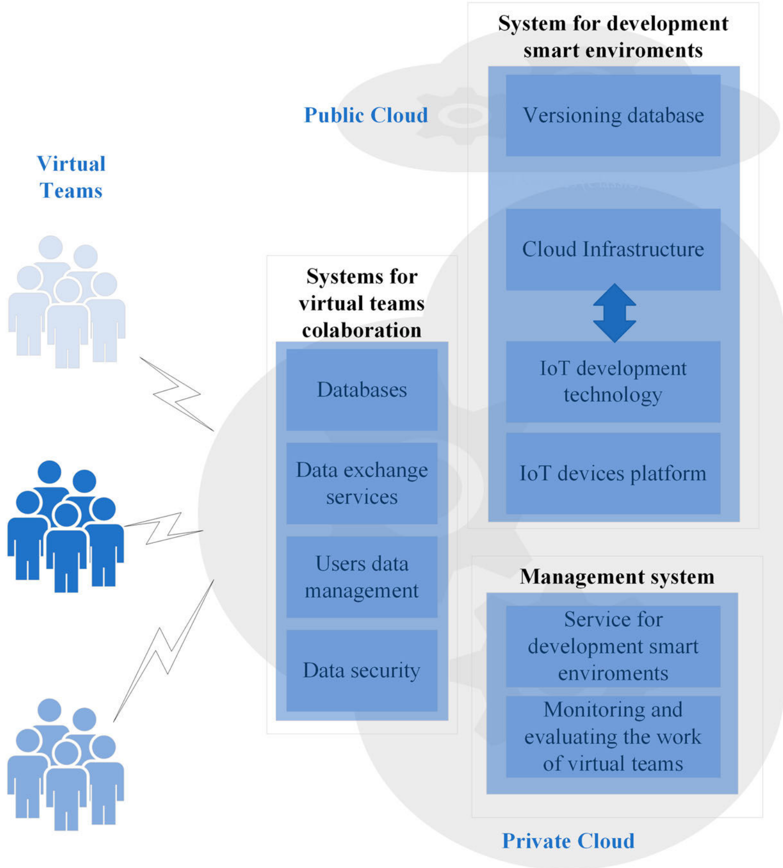

Figure 5. System IT infrastructure.

deal with the development of smart environments, the source code of the resulting applications and their changes are tracked via GitHub, which is integrated with OpenProject and Mattermost for monitoring purposes.

3.2. Implementation

3.2.1. Research context

The research was conducted at the University of Belgrade, Department of E-Business of the Faculty of Organizational Sciences. The participating students were undergoing undergraduate studies in two separate subjects: the Internet of Things and E-business Risk Management. Students in both courses learned about agile approaches such as SAFe and Scrum, as well as the OpenProject project monitoring tool, through lectures and exercises. E-business Risk Management students were given the duty of managing IoT projects as SAFe Scrum Masters. IoT teams were made up of students who shared programming, design, and testing responsibilities. Each team consisted of 3–5 people. Through the role of Product Owner, professors oversaw and controlled the entire work of the students (Mihajlović-Milićević et al., 2019). For project management of individual student projects, the SAFe framework was used. Product Owners (professors) compiled a list of smart environment projects and functions that each virtual team was responsible for implementing (Product Backlog). Each project was assigned to individual virtual student teams. The Product Owners gave the team members and the SAFe Scrum Master clearly defined tasks. Because the virtual student team's work is organized using the SAFe agile framework, students were expected to self-organize in terms of work dynamics, communication tools, work organization within the team, and so on. The SAFe Scrum Master's goal was to keep the team engaged, ensure that they worked according to the intended dynamics, and interact with the Product Owners (Royle & Nikolic, 2016).

3.2.2. Procedure

The students' projects were conducted during the spring semester of 2020/2021, which was during the coronavirus pandemic, the projects had to be done through virtual student teams that relied on various forms of online communication and online meetings. The first challenge that the model needed to overcome was the organization and work assignments of students in virtual student teams. The process of managing all of the student projects through the developed model was done through four stages, which can be seen in Figure 6.

In the proposed model, communication flow is based on job structure. The virtual student teams have naturally split the job into two categories: management and executive. Professors served as Product Owners with students serving as Scrum masters in the management roles. Students who formed the development team were given executive roles.

Information flow, decision making, problem-solving, and other activities were all part of the virtual team's work structure, as were 'negotiation' discussions that required face-to-face contact via communication tools (Lazarević, 2012). Information flowed between all team members as well as between virtual student teams, regardless of whether they were members of management or executive teams. These information flows can be seen in Figure 7.

4. Evaluation

4.1. Research questions

The objective of the evaluation is to understand the parameters that affect virtual team performance and teamwork outcomes in the proposed model. Understanding and analysis of these parameters will yield new ways that the model can be enhanced for the development of smart environments and project effectiveness. Some of the parameters that have been identified for the evaluation include collaboration, coordination, communication, trust and rewarding (Ioannidis & Makridis, 2020).

The findings of the analysis of the virtual team management model's implementation should address the main research questions:

1. What are the students' attitudes towards the proposed approach for managing virtual student teams in the development of smart environments with SAFe and DevOps?
2. Can the analysis of the collected data offer insights into the structure, way of working, and communication within the virtual student teams?

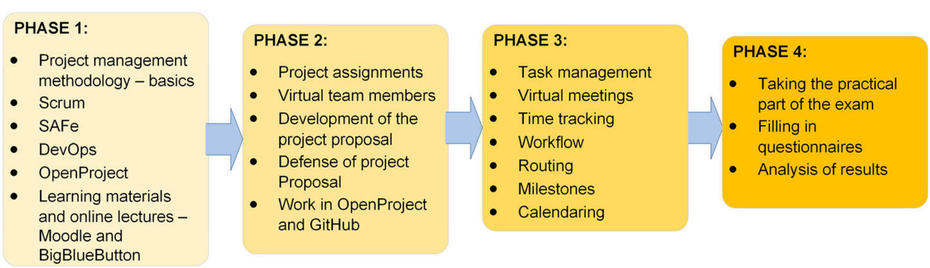

Figure 6. Research procedure.

Figure 7. Communication between virtual student teams.

3. Can the analysis of collected data help professors determine the flows of information exchange in virtual student teams?

4.2. Instruments

During the research, data was collected by surveying and interviewing students, as well as monitoring data within software tools used for the work of virtual student teams. The obtained research results should answer the three research questions and provide an in-depth breakdown of the quality of work in the developed model.

This study's research tool was a structured questionnaire, with a Likert scale for grades of answers. Given the literature's consensus on the importance of communication, organizational commitment, and motivation as important aspects of a virtual project team's performance, these parameters, as well as their mutual relationships, were examined (Gheni et al., 2019). The data was analyzed using statistical approaches and tools.

4.2.1. Questionnaire

The questionnaire was divided into 3 categories:

A. Students' attitudes towards the proposed approach: 26 questions were asked (Table 2). 3 of them were control questions. This group of questions was aimed at getting feedback on how much students like this way of working, whether they understand it, whether they like the change in the way they study and take the exam. By analysing these questions, we can offer an answer to the first research question, and ascertain the sentiment towards the proposed model.
B. Organization of structure, work, and communication within virtual student teams: 40 questions were asked. 3 of them were control questions (Table 3). Students answered questions about the way they worked on the project was organized: did they have clear tasks, did they have enough time to do their tasks, were the communication channels clear and open, were they given learning materials were available or sufficient. By analyzing these questions, we can offer answers to the second and third research question, and present the most likely ways that students collaborate, exchange information and go about their assigned tasks.
C. Analysis of knowledge exchange in students' virtual teams: 6 questions were asked (Table 4). 3 of them were control questions. By introducing an agile approach in student projects, students are constantly learning about technical and organizational aspects of the project, and for the

Table 2. Students' attitudes towards the proposed approach; * – control questions.

	Questionnaire I (partial)	Av. score	Std. dev	Conf. int.
1	The application of the agile Scrum framework on the project had a positive effect on the quality of the obtained solution.	3.94	0.91	3.64–4.23
2	The application of the agile Scrum framework on the project made the implementation of the project more difficult.*	1.97	1.12	1.65–2.3
4	Well-analyzed and clear requirements in the terms of reference affect the quality of the final product.	4.70	0.56	4.54–4.87
5	The scrum framework provides a higher level of team empowerment and collaboration.	4.23	0.85	3.98–4.48
6	Project management could have been more efficient.*	2.97	1.23	2.61–3.33
7	Parts of the project solution can be improved.	3.66	0.93	3.36–3.97
9	Teaching organized in this way increases the interest in learning and working in agile methodologies.	3.92	1.06	3.61–4.23
10	This organization of teaching had a positive effect on the interaction with professors.	3.78	1.11	3.45–4.1
11	This is an educational approach that can be useful to the student in further development and career.	4.43	0.69	4.23–4.64
12	Creating a project assignment is useful for preparing for the final exam on the subject.	4.05	1.05	3.7–4.39
13	The realization of the project in a DevOps organized environment had a positive impact on the quality of cooperation between team members.	3.91	0.79	3.29–4.53
14	The realization of the project in a DevOps organized environment made the realization of the project more difficult.*	2.91	1.24	1.94–3.87
16	Realization of the project in a DevOps organized environment requires connecting technical and non-technical aspects of DevOps.	3.82	0.83	3.17–4.47
18	Learning DevOps from experience is more important and useful than a purely theoretical approach.	4.00	0.77	3.37–4.63
20	The goal of working in a DevOps-organized environment is to enable efficient continuous deployment.	4.00	0.74	3.43–4.57
21	The culture of work created by the application of DevOps has enabled open cooperation and open communication.	3.73	0.75	3.14–4.31
22	The culture of work created by the application of DevOps has enabled engaged mentoring and technical leadership.	3.82	0.83	3.17–4.47
23	The culture of work created by the application of DevOps requires self-organization within the team.	3.64	1.07	2.81–4.47
24	Tools are an important part of the DevOps approach.	4.00	0.74	3.43–4.57
25	Using the DevOps tool would be a challenge.	3.45	0.99	2.69–4.22

success of the project, this knowledge must be constantly exchanged. With this group of questions, we wanted to find out to what extent the students were able to do that through working on the project. While this set of questions is not aimed at answering any research questions, its aim is to offer feedback on the projects themselves, and give insights into how well students coped with their execution.

4.2.2. Social network analysis

The quality of communication, cooperation, and knowledge exchange in virtual student teams was also assessed using social network analysis (SNA) methodologies. Each virtual team inevitably creates a social context that has an important impact on the success of the project, because it influences the decision-making of the project. It can be assumed that the model of managing virtual student teams in the development of smart environments is an innovation project, and as such, it is characterized by the dynamic evolution of the social context of virtual student teams. Therefore, such a structure is suitable for the use of SNA (Cross et al., 2002; Gebhardt et al., 2020). Social network analysis is made up of three components: groups, interactions (connection), and attributes. The group is a virtual team with 3–5 people (students: programmer, tester, designer, SAFe Scrum master) and a professor for this exercise (Product Owner). SNA will examine interactions (relationships) between team members and inside the team. The data attributes of SNA will indicate whether or not any systemic issues are affecting the virtual team's interactions (Milovančević et al., 2019), some of these issues

Table 3. Work of virtual student teams.

	Questionnaire II (partial)	Av. score	Std. dev	Conf. inte
1	Team members understood each other's roles.	4.45	0.88	4.2–4.71
2	I met all the team members before starting the project.	3.62	1.72	3.11–4.13
3	The basic tool for cooperation and communication within the team was	see Figure 11		
5	How many meetings were held during the project?	see Table 6		
6	How often did you meet with other team members?	see Figure 10		
7	Indicate how long the meetings lasted on average	see Table 5		
8	Group meetings are very productive.	4.09	0.85	3.84–4.34
9	Team members initiated communication when solving problems with each other without involving a Scrum Master or Product Owner.	3.90	1.16	3.56–4.24
14	The Scrum Master, in agreement with the Product Owner, listed all the ideas and requirements in the Product Backlog.	4.31	0.87	4.02–4.59
17	There was good understanding and cooperation between the development team and the Product Owner during the work on the project.	4.08	1.06	3.77–4.39
19	Product Owner helped team members maximize the value of their product.	3.97	1.09	3.65–4.3
20	The role of the Scrum master on the project was clear to me.	4.22	1.12	3.89–4.55
22	Scrum master influenced the project to be implemented efficiently.	4.17	1.03	3.87–4.48
26	The possibility of constant review of the work of all team members in OpenProject enabled better planning and organization of work.	3.82	1.03	3.52–4.12
28	The OpenProject tool is intuitive and easy to use.	4.00	0.93	3.73–4.27
30	Using the OpenProject tool has enabled increased productivity.	3.47	1.04	3.16–3.77
36	I exchanged useful information with my team members to solve the problem together.	4.71	0.45	4.4–5.03
38	The BigBlueButton tool is easy to use.	3.36	1.04	2.64–4.08
39	The use of the BigBlueButton tool has made lectures and exercises more accessible.	2.71	1.44	1.72–3.7
40	Working in a DevOps organized environment was the first contact with the software development cycle, through teamwork.	3.71	0.80	3.17–4.26

Table 4. Meeting's duration.

Meeting duration (min)	Number of meetings
15–20	36
30	38
60	14
More than 60	12

are: how information flows within the virtual team, who is the most contacted member, and the effectiveness of shared pieces of information.

5. Results

Students and lecturers completed a questionnaire at the end of the project to answer questions regarding their involvement in the development of smart environments within virtual student teams. 75 students and two professors completed a questionnaire with 75 questions that assessed the process's predicted performance as well as the results of the participants' input. The Professors (2) had a Product Owner role. Students had the Scrum master role (30) and development team roles (45).

5.1. Students' attitudes towards the proposed approach

The average grade on attitudes toward the proposed approach is 3.90. The results of the study showed that students positively perceived the SAFe and DevOps with average grades of 4.07 (questions 1–7, Table 2) and 3.80 respectively (questions 13–26, Table 2). On the control questions, ie. the conclusion that the management of the project could have been better (question no. 6, Table 2), the

Figure 11. View the use of the Wiki and News modules in the Gephi too.

application of the agile Scrum framework on the project made the realization of the project more difficult (question no. 2, Table 2) and the realization of the project in a DevOps framework made the realization of the project more difficult were low rated by the students, they disagreed (average score 2.61).

5.2. Organization of structure, work, and communication within virtual student teams

The average grade for the work of virtual student teams is 3.90. Respondents recognized the importance of good communication and assessed that communication on the project was very good, with an average score of 4.29 (questions 1–23, 36, and 37, Table 3).

The role of the SAFe Scrum Master is well received and highly rated (questions 20–23, Table 3). The students also rated OpenProject as a very good grade 3.87 as a tool for monitoring project activities (questions 24–35, Table 3). Interestingly, OpenProject has got the lowest average score regarding efficiency (3.50) and productivity (3.47). The tool BigBlueButton was rated positively with an average score of 3.04 (questions 38 and 39, Table 3).

The results of the conducted study also showed that during the project, a sufficient number of virtual meetings were held, which were attended by all team members(Yemane et al., 2021). Virtual meetings were held in most cases once in two weeks (42%) (Figure 8).

The basic tools for collaboration and communication within the team were Mattermost (21 participants, 38%), Viber / WhatsApp (39 participants, 51%), OpenProject (3 participants, 4%), and some other tools (5 participants, 7%) (Figure 9). Interestingly, the most popular tools for communication were Viber and WhatsApp despite Mattermost which is one of the most used tools for collaboration in corporate environments.

On average, the meetings lasted 30 min (38%). Only a small number of virtual student teams held meetings lasting more than one hour (Table 4).

The number of meetings held during the project is shown in Table 5.

Most of the students thought that working on such a project was a useful experience and a good way to get acquainted with virtual student teams, IoT development, and agile methodologies. About 70% of the surveyed students stated that the way of working as well as differences of opinion made it difficult to implement the project. There were difficulties in understanding the role of the SAFe Scrum Master, but the greater challenge was to accept the existence of such a role that directs

Table 5. Number of the meeting's on the project.

No meetings	No meetings on the project
1	5
Between 6 and 10	39
Between 2 and 6	28
More than 10	4

Table 6. Knowledge exchange in virtual student teams.

	Questionnaire III (partial)	Av. score	Std. dev	Conf. inte
1	My team worked efficiently.	4.20	0.83	3.65–4.75
2	My team has met the set goals.	4.60	0.61	4.19–5.01
3	My team mostly did tasks on schedule.	4.14	0.74	3.63–4.65
4	I believe that other team members are reliable.	4.67	0.60	4.27–5.06
5	I believe that other team members will work in their best interests.	4.71	0.59	4.31–5.12
6	I believe that other team members are knowledgeable and competent to work on the project.	4.79	0.56	4.4–5.17

and takes care of the work of the team (average score 4.18, questions 20–23, Table 3). They tried to overcome difficulties in communication, time differences, inexperience in coordinating and organizing time for the work of members of virtual student teams. The role which the Professors played, that of the Product Owner was very well accepted by other participants (av. score 4.04, questions 14–17 and 19, Table 3).

5.3. Analysis of knowledge exchange in virtual student teams

The average grade is 4.01. The work of virtual teams was also very well accepted by participants with an average score of 4.52 (questions 1–6, Table 6).

While a smaller proportion of students thought this type of teaching organization was complicated and unneeded, they valued the opportunity to acquire current techniques that could be useful in real-world situations. From the professor's point of view, the team members managed to successfully master the tools for collaboration and documentation monitoring, and the difficulties they encountered while working together in the virtual environment made them rely on each other's competencies. They managed to establish closer personal and professional ties because mutual trust was built and collective abilities improved.

Further, social network analysis was applied to gain additional insights into the information flow and knowledge exchange among students. The virtual student teams were composed of a small number of students, 4–5 members. All teams were viewed as one large student team to obtain some SNA measures.

Figure 10 depicts members of selected virtual teams and their interactions.

It is important to note that the majority of virtual teams have 4–5 members, with each student focusing on the completion of only one project. Some students served as Scrum Master on a maximum of two projects, as evidenced by the graph's connection of more than five nodes (students). Within each team, each team member was linked to other team members, and the existence of a central team member (mediator in communication and cooperation of the other two team members) was removed. Direct connection between all team members, i.e. the maximum number of interactions within the team, represents the maximum team density, which is one. In virtual student teams, isolated team members and substructures formed by grouping several team members were not discernible. However, in the case of larger teams, maximum connectivity within the team is generally impossible, so the presence of central nodes is becoming more common.

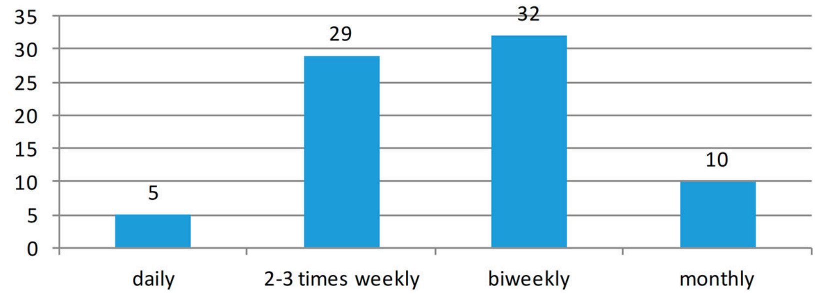

Figure 8. Meeting statistics.

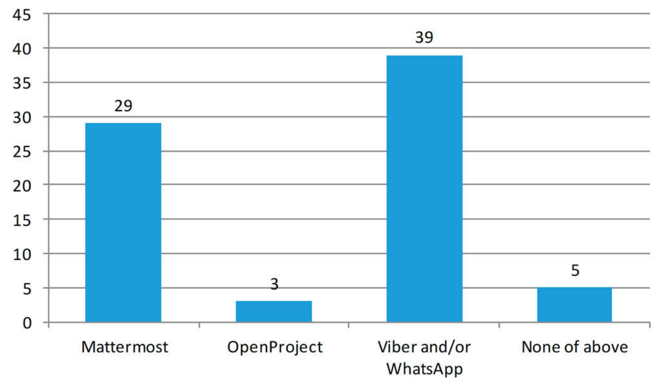

Figure 9. Tools for collaboration.

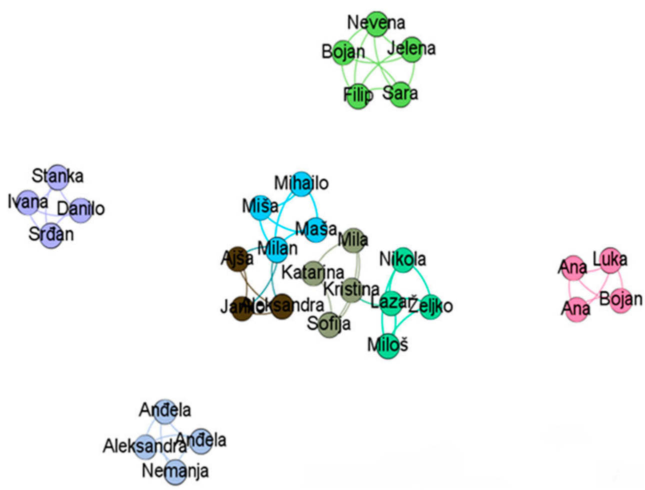

Figure 10. View virtual student teams in the Gephi tool.

The density of the network that presents all virtual student teams as one big team based on the results obtained using the Gephi tool is 0.013. The low value of the network density represents a weak connection between the nodes. The weak connection in this example is due to the connection of team members mainly with all members of his team which has 4–5 members. This result is a useful input for us professors because it allows us to see if there are isolated team members and which way to deal with them.

Figure 11 shows the usage of Wiki and News modules with the OpenProject, visualized using Gephi. The graph shows the extent to which team members used the Wiki and News modules to share and generate knowledge. Different shades of green represent different levels of utilization of the Wiki module as in the previous graph. Interestingly, a lot of virtual student teams showed a great tendency to use the News module in addition to the low utilization of Wiki pages (large nodes with a light shade of green). This section of the analysis shows which virtual student teams have achieved better communication on the Wiki, allowing us to compare virtual student teams and measure the intensity of Wiki use. Due to the organization of classes, professors need to know whether there are virtual student teams that did not share knowledge. To prevent that, the conclusion is that the analysis can be done during the semester, and under the course of work to intervene and guide students.

Documentation is an integral part of every project. At the end of the realization of each project, which was realized by virtual student teams, offering a smart solution in various areas of human activity, the final documentation was written. Within the Wiki module, each team posted documentation of their projects. Based on the set documentation, the analysis was performed using the SNA tool VOSviewer to obtain the most frequently mentioned terms during their writing. The analysis presents terms that are five or more times.

Figure 12 presents a network of terms that appear five or more times in project documentation. Most of the terms refer to parts of the application code implemented by the virtual student teams

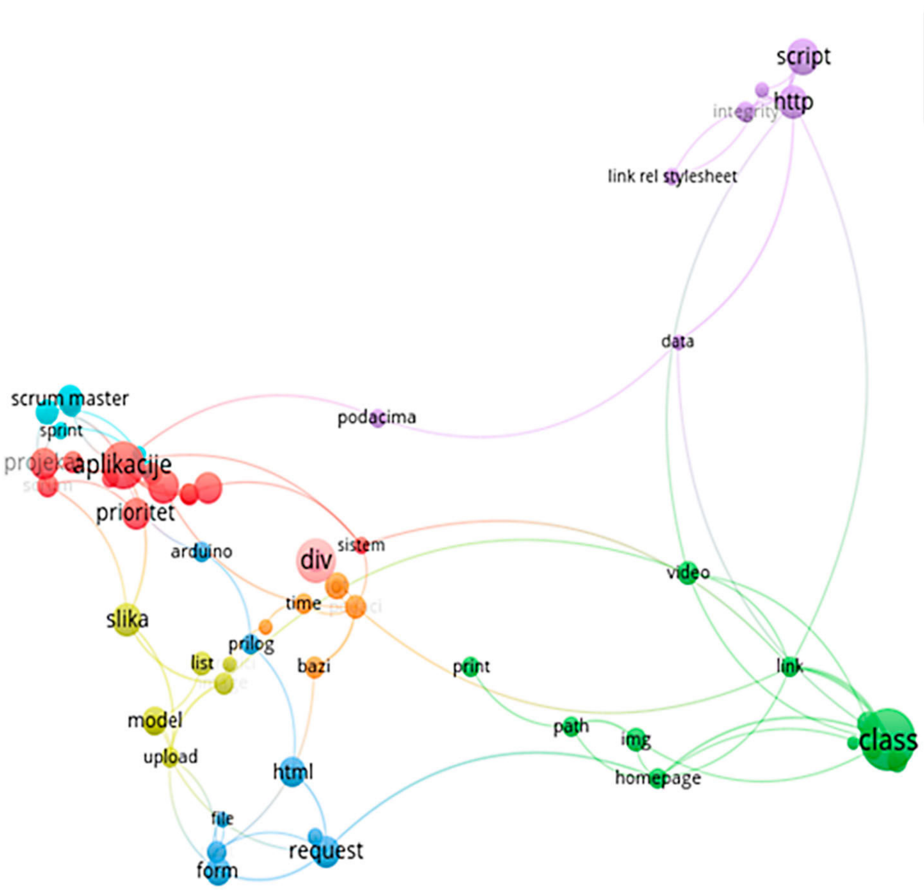

Figure 12. A network of terms that appear five or more times in the documentation.

(terms related to front-end, the back-end of IoT development, such as class, div, script, request, GPIO.IN, GPIO.OUT …). The method of project development was the agile method, Scrum, which can be seen through the emergence of concepts of this method Scrum Master, Product Owner, Sprint, development team. During the implementation of the project, the team members worked on the risks that may arise during the work on the same and the priorities in their solution and elimination, which indicate the terms risks, priority, project that are presented online. Views of the final solutions are visible through the terms of applications, images (which represent parts of applications, various schemes of connected smart devices) as well as parts of code. The terms Arduino, buzzer, computer, database, data, data indicate the representation of the architecture of the system.

From the insight into this part of the analysis, it can be concluded that Scrum Masters performed their part of the project management responsibilities by writing project assignments, but the members of the teams (developers) did not, because there was no detailed documentation on the Wiki. Development Projects have not been documented, which can be seen in the absence of cluster separation. On the other hand, it is not unexpected, because the IoT subject, which is an elective in the curriculum, teaches about specific IoT-related aspects of software engineering, so students cannot entirely apply their general knowledge of software engineering. In future work, it would be necessary to devote more effort in teaching students how to properly document their IoT and smart environment projects.

6. Discussion and conclusion

In this paper, a model for monitoring and management of virtual student teams was presented. The model was specialized for smart environment development. As the model relies on the uniform management approach of all virtual student teams for its monitoring needs, all the teams had to adopt SAFe and DevOps principles in their project management and team interactions. The application of SAFe and DevOps in an educational environment had the aim of bridging the gap between the academic and corporate environments by offering students insights into real-world project dynamics.

The model was evaluated through the analysis of the questionnaire provided to the student participants. Through this evaluation all the research questions were confirmed to be positive, and detailed answers were provided. The evaluation also showed that students were generally pleased with the agile project approach, and had a better understanding of DevOps principles. Additionally, data on their interactions and behaviors was gathered and analyzed via social network analysis, where insights into team dynamics and important issues were identified. The monitoring framework likewise provided us with understanding of individual team activities, their issues, and the most common talking points.

By analyzing the results of the questionnaire, and compiling our experiences in the application of the proposed model, we present some relevant conclusions for three chief parties involved: faculty management, professors, and students.

For professors, the implications are as follows:

- Student access to necessary knowledge sources is critical to the success of their projects
- In order to avoid informal communication, all student communication should be carried out through traceable services.
- Since Devops heavily relies on a multitude of tools, the inclusion of practical exercises related to Devops tools use is mandatory.
- In order to cope with a large number of students, students should be encouraged to be more proactive and self-reliant. This self-reliance should also play the added role of reinforcing their grasp on the agile approach.

The implications for the student are as follows:

- More effort should be devoted to practical work, which is a part of exam obligations,
- Learning to work within a tight schedule provided by the agile approach is necessary in order to complete the projects on time.
- Accept and use the model's official and monitored communication channels while avoiding informal channels of communication.

The implications for the educational institution are the following:

- Professors should be provided with latest sources of necessary knowledge and information required for passing on knowledge related to current corporate trends to the students.
- Business experts should be brought in to showcase new and current project management practices, for both the professors and the administration.
- Working conditions in an academic institution should be equivalent to working in a startup company, in such a way invested funds may be recovered when university-developed projects are sold on the market.
- Technological infrastructure is becoming increasingly more important and its availability is crucial to both the professors and the students, if the technological infrastructure is insufficient, professors will increasingly rely on open-source tools in an effort to bypass the limitations of the current technological infrastructure.
- The proposed model, while specialized for IoT development, is easily adapted for other purposes. The modification and further implementations of the model in other subjects taught in the university should provide a much needed update to the curriculum and make for easier transition from academic into corporate environments for both students and professors.

The application of the described model differs greatly from the previous teaching methods and necessitates considerable changes. However the adoption of these changes is made more difficult by the challenges and limitations such as: insufficient access to knowledge sources, insufficient time for practical exercises related to tool use and the open source nature of the tools where certain required functions were not available. The most significant challenge encountered was that the number of professors and lecturers was small in comparison to the number of students. The students in spite of potential lack of professor involvement were quite enthusiastic about the project, but the application of agile methodology was often difficult for them and could have been easier if more professors were involved.

These challenges have made the application of the model difficult, but the insights gained and conclusions made can be leveraged to reduce these flaws, and even remove some of the flaws entirely in the future. In addition, the model should be extended, and applied to a broader range of subjects. By adopting this model for a broader range of subjects, we can hopefully see a consistent change in culture in both the students and professors. This change in culture when coupled with the required knowledge should provide students with the best possible education for coping with the current economic trends where knowledge and skills required by the industry are constantly on the rise.

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Notes on contributors

Jelena Mihajlović-Milićević is PhD student at Faculty of organizational sciences, University of Belgrade, Serbia. Her areas of interest are: e-education, agile project management, smart environments.

Miloš Radenković is an assistant professor at School of Computing, Union University, Serbia. His research interests include smart environments, software engineering, and DevOps. He is a member of the IEEE and the IEEE Computer Society.

Aleksandra Labus is an associate professor at the Faculty of Organizational Sciences, University of Belgrade. She is a member of the IEEE and the IEEE Computer Society. She is a treassurer of IEEE Computer chapter CO 16. Her research interests include: e-business, internet of things, e-education and social networks.

Danijela Stojanović is a research associate at the Institute of Economic Sciences in Belgrade. She is a member of the IEEE and the IEEE Computer Society. Her research interests include e-education, information technologies and internet of things.

Zorica Bogdanović is a professor at the Faculty of Organizational Sciences, University of Belgrade, and the head of the IoT center. She is a member of the IEEE and the IEEE Computer Society. She is a secretary of IEEE Computer chapter CO 16 and the head of the seminar of IEEE Computer chapter CO 16. Her research interests include: e-learning, internet technologies, and IoT.

ORCID

Jelena Mihajlović-Milićević http://orcid.org/0000-0003-1886-6577
Miloš Radenković http://orcid.org/0000-0002-1708-9799
Aleksandra Labus http://orcid.org/0000-0002-7716-5845
Danijela Stojanović http://orcid.org/0000-0002-9728-8586
Zorica Bogdanović http://orcid.org/0000-0003-4799-1588

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