

Teamwork Effectiveness of Virtual Teams Supported by the Knowledge Management System

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Abstract—Virtual teams and Knowledge Management Systems (KMS) create a research gap: if knowledge management systems influence on effectiveness of teamwork in virtual teams. Therefore the scientific problem of this paper concerns the level of activity in the use of knowledge management systems related to subjective evaluation of achieved effectiveness during teamwork in virtual teams.

In order to solve the research problem, the research was conducted among 26 participants working in 5 groups during the long-term observation focused on a specific organizational task. The participants' activities were recorded by a knowledge management system (TransistorsHead.com) and interviewed by a survey.

On the theoretical and research foundations 4 research questions were answered. It appeared that (1) it is not clear what is a relation between activity of using KMS and their subjective evaluation of creative behavior, (2) there is a quite strong relations between activities in using KMS and subjective effectiveness in the area of task performance, (3) the activity of using KMS strongly related to evaluation of teamwork and (4) the relation between using KMS and evaluation of organizational citizenship behavior is very weak.

Index Terms—teamwork effectiveness, knowledge management system, virtual team

I. INTRODUCTION

On the one hand, nowadays virtual teams are becoming an increasingly important factor in a way to increase productivity [1], produce better outcomes [2], attract better employees and reduce relocation costs [3]. In addition to the COVID-19 pandemic people were forced to stay at homes, leading to a radical shift from on-site to virtual collaboration for many knowledge workers [4].

On the other hand, research on knowledge management, especially together with a use of artificial management, slowly appears as a challenge for the future [5]. AI in knowledge management seems to exceed any other technological breakthrough that humanity has ever seen [6] and human-machine teaming (HMT) seems to be a promising paradigm to approach future situations in which humans and autonomous systems closely collaborate [7]. Knowledge management is concerned with identifying and leveraging the collective knowledge in an organization to help the

organization compete [8]. Earl [9] assumed that strategic school “sees knowledge management as a dimension of competitive strategy”.

Both aspects of team management–virtual teams and Knowledge Management Systems (KMS)–create a research gap: if knowledge management systems influence on effectiveness of teamwork in virtual teams [10]. Therefore the scientific problem of this paper concerns the level of activity in the use of knowledge management systems related to subjective evaluation of achieved effectiveness during teamwork in virtual teams.

On the theoretical foundations of teamwork effectiveness, described in Section II, we concluded four research questions which we tried to answer during the research. They are as it follows: (1) To what extent is the activity of using KMS related to evaluation of creative behavior? (2) To what extent is the activity of using KMS related to evaluation of task performance? (3) To what extent is the activity of using KMS related to evaluation of teamwork? (4) To what extent is the activity of using KMS related to evaluation of organizational citizenship behavior?

The aim of this paper is to present answers to these research questions in the perspective of teamwork effectiveness and knowledge management systems. In Section II there is a literature review of (a) virtual teams, (b) knowledge management systems, and (c) aspects of teamwork effectiveness. In Section III there is a description of (a) a methodological concept called the system of organizational terms together with research tools TransistorsHead.com as well as (b) the effectiveness evaluation methodology. Both methodologies were used to examine activities of using KMS and subjective evaluation of teamwork effectiveness. Section IV contains results of the research conducted in 2022 and 2023 among 26 participants by the long-term observation focused on a specific organizational task. Section 5 describes conclusions and further directions of studies in the field of teamwork effectiveness.

II. THEORETICAL FOUNDATIONS OF THE RESEARCH

A. Virtual Teams

Virtual teams in organizations appeared in the last decade of the 20th century and they are associated with accelerating business activities and increasing innovations [11]. A virtual team as a group of people who do not stay geographically, organizationally or temporally in the same place, but co-operate with each other through the use of ICT for one or more organizational tasks [12]. The degree of use of new technologies then becomes an indicator of the level of

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virtuality of such a team (from semi-virtual to pure virtual) [13].

The virtual team is also described by the category of temporality when short, undefined time of the team's activity is conditioned by the needs of the organization and individual motivations of its members [14]. Virtual teams are also found in organizations which bring together specialists who design and conduct research or collect data [15]. During the COVID-19 pandemic virtual teams appeared in organizations as a necessity to meet the challenges of isolating employees and virtual teams became a hallmark of the pandemic [16]. The pandemic has boosted the implementation of virtual teamwork, with many employees working at homes using virtual tools to collaborate with their teammates [17].

The changes during the COVID-19 pandemic are linked to uncertainty because of the growing variability and complexity of many work processes. Result of this is that work has become more cognitively demanding due to increased technology, task variety and knowledge-based work. Therefore, we see a great need for research and effectiveness of virtual teams using knowledge management systems.

B. Knowledge Management Systems

Knowledge management has been defined as the process of gathering, creating knowledge and facilitating knowledge sharing so that it can be applied effectively throughout the organization [18]. Knowledge management involves four main processes: (a) knowledge generation, which includes all activities that find "new" knowledge; (b) knowledge capture, which involves continuous scanning, organizing and packaging of knowledge after it is produced; (c) knowledge codification, which is the process of representing knowledge in a way that can be easily accessed and transferred; (d) knowledge transfer, involving the transmission of knowledge from one person or group to another person or group and the absorption of that knowledge [19].

Earl [9] identifies seven schools of knowledge management forming three distinct clusters based on purpose: (a) technocratic (based on information technologies and serves to support workers in their day-to-day operational tasks), (b) economic (commercialization and exploitation of knowledge and intellectual capital), (c) behavioral (being proactive in the creation, sharing, and use of knowledge as a resource). Mayasari and Chandra [20] argued that the creation of knowledge is a social process and as a result requires social interaction between individuals.

Thus, a knowledge management system is a specific combination of some subset of people, processes, and technologies concerned with identifying and leveraging the collective knowledge in a specific organization to help that organization compete. Alavi and Leidner [21] have summarized the relationship between perspectives on knowledge and their implications for knowledge management and knowledge management systems.

The knowledge management system (KMS) could be an IT-based system developed to support and enhance the organizational processes of knowledge [22]. Organizations invest in KMS for the same reason they invest in other information systems: they believe that the value derived from using the system will exceed its cost [23]. KMS can make a

difference only if they are utilized to improve the application and reuse of knowledge. Companies that have flourished are not the companies that implemented knowledge management technology but those that applied it [24].

Against this, the International Standards Organization (ISO) released a Management Standard on Knowledge Management Systems [25], which aims "to support organizations to develop a management system that effectively promotes and enables value creation through knowledge" (Section 0.1, ISO 30401). According to ISO key components of the KMS are: Knowledge Development, Knowledge Transformation, as well as Enablers.

The organization supports the KMS by providing the physical and human resources needed for it. Also, the organization needs to create awareness by communicating and providing information about the KMS to all internal and external stakeholders. Strassmann [26] said that "having computers for organizational operations is not what matters, rather it is what people do with the computers". According to this Ishaq and Dominic [27] tested the relationship between KMS technical factors (system quality, knowledge content quality, knowledge linkage quality, innovative value), emergent factor (autonomous motivation to use) and KMS utilization and competency development.

As stated Alavi and Leidner [21] the theoretical assumption was that KMS will aid knowledge sharing positively when it enables faster and easy codification of knowledge provides easy and fast access to experts. It allows for collaboration and facilitates the visualization as well as the development of relational base of organizations social systems [28]. Ishaq and Dominic [27] found that the existence of innovative norms in organizations and KMS that provide adequate linkages or connections among knowledge workers are significantly and positively related with the development of autonomous motivation towards KMS use. The empirical results reveal that both KMS utilization (use) and autonomous motivation to use have positive significant relationship with competency development. Autonomous motivation to use also has a positive significant relationship with KMS use.

KMS should be tailored to the organization, but it should also incorporate learning and feedback cycles. These ideas are borrowed from the organizational learning literature as well as the cyclical models of KM. The guiding principles (ISO 30401) state that KM should create "shared understanding," which can be reached by "interactions between people". It emphasizes the human nature of knowledge bearers building on the distinction of knowledge, which is located in people's minds, from data and information, which may be stored in inanimate locations [25].

In the research we used the knowledge management system called TransistorsHead.com which is a research platform containing 10 online management tools for teamwork. The theoretical and technical details of this KMS was described in Section III.

C. Effectiveness of Teamwork

Team effectiveness is defined as the productivity and output of a team in relation to the concern that a team has for its fellow members [29]. Effective teams must provide the

output of high level and of high eminence as goods and services, where outputs may be at team level, individual level or at organizational level [30].

The analysis of the literature on team effectiveness indicates that we can deal with static and dynamic perspective [31]. The static perspective focuses on the best allocation of resources and the avoidance of waste. The dynamic perspective focuses on long-term development, towards entrepreneurial activities consisting in discovering and creating new goals and means, towards discovering new profit opportunities. Therefore, it can be assumed that effectiveness shifts more from the economic calculation of actions (comparison of effects to inputs and the degree of goal achievement) towards the assessment of the potential of existing solutions (innovativeness of actions). Effective teams are expected to lead to greater adaptability, productivity and creativity and will provide more innovative and integrated solutions to complex organizational problems compared to what individual staff can offer [32].

Effectiveness contains also behavioral aspects, going beyond its assessment through productivity. It concerns psychosocial elements, making the team's ability to work dependent on the level of satisfaction and cooperation, where one can experience a significant decrease in effectiveness when members of a given team feel dissatisfied or frustrated. In extreme situations, this can lead to deviant (counter-productive) behavior that violates organizational norms, threatening the well-being of the organization, its members, or both [33]. Ineffective teams can cause an organization to waste resources, not achieve performance goals, redo projects and extend time to market [34].

Teams are viewed as complex, adaptive, dynamic systems, and they are embedded in organizations and contexts and performing tasks over time [35]. The ways of achieving goals, e.g. carrying out tasks, as well as the team's potential, especially in a service-oriented organizations, are crucial when the performance is closely related to the behavior of the employees toward their customers and fellow teammates. Some authors suggested additional motivation and job satisfaction, which refer to attitudes and behaviors of the team members with psychosocial elements at the interface between the group and the individual [36].

There are numbers of factors creating an effective team, such as supportive team environment based on mutual trust and respect among team members, when a person in a team cannot complete the assigned tasks only by his own efforts, thus, the perception of human support will lead to cooperation with colleagues and will contribute to the further development of trust [37].

Employees who perform more than their usual job duties and provide performance that is beyond expectations, which is called Organizational Citizenship Behavior (OCB). Such behaviors mean helping colleagues who have a large workload, helping new employees in their work, promoting the organization in the community and proposing constructive proposals for the development of the organization [38]. It becomes necessary for each team member to transfer knowledge by sharing information with the colleagues responsible for the next phase of the work process and some kind of dependency between teammates to complete their phase of the work process [39].

Nowadays issues related to the effectiveness of virtual teams are very important, especially that workings of virtual teams are highly complex, and without doubt there are many factors that could influence its effectiveness. In the literature some investigators found that team effectiveness are positively associated with trust and knowledge sharing, whereby knowledge sharing was found to be a partial mediator in the relationship between certain types of trust and virtual team effectiveness [40]. This emphasizes that organizations need to work on organizational support structures that increase trust, which will then help to promote knowledge sharing by knowledge management systems and finally boosts the virtual team effectiveness.

According to above assumptions virtual team effectiveness will be analyzed from four perspectives: (1) creative behavior, (2) task performance, (3) teamwork, (4) organizational citizenship behavior.

Firstly, creative behavior can be defined as the development of ideas about products, practices, services or procedures that are novel and potentially useful to the organization [41]. Creative behavior is a complex behavior affected by various factors at individual or organizational level [42] and the link between proactive personality and creative behavior, with thriving at work and the perceived presence of high-involvement HR practices acting as a moderator of the link between proactive personality and thriving at work [43].

There is a prominent theory, which also guides the model developed in our study, is the componential theory of creativity [44]. This theory states that four main components contribute to individual creativity: three within-individual components and one component outside the individual. The within-individual components include (a) intrinsic motivation, (b) domain-relevant knowledge, and (c) creativity-relevant processes that promote risk-taking or taking new perspectives on problems. The component outside the individual is (d) the surrounding environment, which interacts with the within-individual components to either increase or reduce creativity. Ideally, creativity is maximized when a highly motivated individual with high levels of domain-related skills and a personality that is conducive to creativity works in a supportive environment [44].

New research drives a shift from the study of creativity exclusively as an outcome to the broader study of the dynamics of "creative work" provides evidence of an expansion toward the dynamics of creative work, focus more on process and relationships, and understanding of the conditions under which varied creative work processes and the outcomes of those processes emerge [45].

Therefore, there is a need to answer the first research question, stated in Introduction: To what extent is the activity of using KMS related to evaluation of creative behavior?

Secondly, task performance is defined as employees' behaviors that are under their control, observable and measurable, and at the same time related to or contributing to organizational goals, but not identical with them [46]. In addition, in the research we assumed that efficiency is a latent feature (for which a specific value cannot be indicated, but only inferred by manifestation) and following Kozlowski and Bell [47] that it is not necessary to conduct dynamic

measurements and continuous observation of performance, which results in the use of sensors to measure performance determinants (flow, communication), but a multi-factor approach to variable efficiency.

Subjectively perceived task performance could be measured using four items adapted from Hertel [48] rating items i.e.: (a) the overall degree on how well the team accomplished their set goals; (b) the quality of the team results; (c) the quantity of the team results; and (d) the innovative initiatives of the team members (e.g. the quantitative outcomes of the team, such as finishing all the tasks and meeting the deadlines).

On the foundation of these theoretical assumptions it is possible to formulate the second research question: To what extent is the activity of using KMS related to evaluation of task performance?

Thirdly, teamwork refers to the interactive and interdependent behavioral processes among team members that convert team inputs (e.g., member characteristics, team member composition, organizational funding) into outcomes (e.g., team member satisfaction, team performance) [49]. Teamwork models focus on behaviors that function is to regulate a team's performance and keep the team together and coincide with the respective processes i.e.: locomotion and maintenance [50].

Such a teamwork behaviors include those that occur during three phases: (a) before preparation for team task performance, (b) during the execution of team performance, and (c) after completing the team task [51]. In addition to task performance, teamwork is positively related to group cohesion, collective efficacy, and member satisfaction [52]. Teamwork encompasses activities that aim to foster positive interpersonal relationships within the team [51].

This is critical to the overall efficiency of a team as it acknowledges that success is not just reliant on material factors, but also the needs and expectations of individual team members [53]. This leads to team members adopting behaviors that align with the team's goals, ultimately promoting better conflict resolution, motivation, and trust [49]. The network effect of these dynamics is improved performance and outcomes for the team as a whole [54].

This enables us to formulate the third research question: To what extent is the activity of using KMS related to evaluation of teamwork?

Fourthly, citizenship behavior is a concept derived from Bernard's [55] concept of cooperativeness and Katz's [56] division between role-required and role-optional performance and innovative and spontaneous behavior. Katz [56] emphasized that cooperative and helpful behaviors beyond formal role prescriptions are important for organizational functioning. Such a behavior is called organizational citizenship behavior (OCB). OCB was defined as extra-role, discretionary behavior that helps other organization members perform their jobs or shows support for and conscientiousness toward the organization [57].

OCB has been studied primarily in relation to its links with job satisfaction and organizational justice [58]. OCB contains substantial elements in common with the definition of citizenship performance developed by Borman and Motowidlo [59] and close to the concept of the prosocial organizational behavior (POB) defined as "behavior that is

directed toward an individual, group, or organization, with the intention of promoting their welfare". Organ and Ryan [60] separately considered the altruism dimension of OCB, behaviors intended to benefit individuals within an organization and the conscientiousness, or generalized compliance dimension, of OCB, behaviors intended to benefit the organization. They also divided the findings into those that were based on both self-reports and other-reports of OCB and those that were based on only other-reports. Organ and Ryan [60] found that, among the personality variables, only conscientiousness correlated significantly with OCB.

Citizenship performance contributes to the organizational effectiveness [59]. The major sources of support for the citizenship performance taxonomy comes from OCB, POB and a model of soldier effectiveness and socialization yields teamwork, and socialization and commitment merge to form allegiance. An important distinction between citizenship performance and task performance is that task activities vary across jobs (differentiate one job from other jobs). Citizenship activities are quite similar across jobs. Activities as volunteering and cooperating with others are largely the same for different jobs.

Organizational citizenship behavior includes such activities as helping others with their jobs, supporting the organization and volunteering for additional work or responsibility. In particular proposed a five-dimension model [59]: (a) persisting with enthusiasm and extra effort as necessary to complete own task activities successfully; (b) volunteering to carry out task activities that are not formally part of own job; (c) helping and cooperating with others; (d) following organizational rules and procedures; and (e) endorsing, supporting and defending organizational objectives.

There is a meta-analysis which identified seven organizational citizenship behaviors [61]. These include: helpful behavior, sports behavior, organizational loyalty, civic virtue, compliance with organizational procedures and strategies, individual initiative, self-development. The authors conclude that organizations do not directly impact individuals' organizational commitment, but it is inspired by social exchange principles and reciprocity norms, rather than expressing an individual's identification with the organization [62].

Basing on this literature review we asked the fourth research question: To what extent is the activity of using KMS related to evaluation of organizational citizenship behavior?

III. RESEARCH METHODOLOGY

A. Knowledge Management System based on the System of Organizational Terms

As it was mentioned in Section II, the knowledge management system, used in the research of team effectiveness, was TransistorsHead.com. This KMS was designed and implemented by Olaf Flak, one of the paper's authors. It was tested, validated and used in a few research projects [63–65].

In order to understand how this KMS works, it is necessary

do describe theoretical foundation of its design which is the system of organizational terms. It is a methodological complex which consists of ontological and epistemological aspects designed for research team management aimed at team management automation. The philosophical foundation of the system of organizational terms is based on Wittgenstein's philosophy, his theory of facts (the only beings in the world) and "states of facts" [66].

According to this approach the organizational reality can be represented by events and things. Specifically, as shown in Fig. 1, each event and thing have the name n.m, in which n and m represent a number and a version of a thing, respectively. Event 1.1 causes thing 1.1, which in turn releases event 2.1 that creates thing 2.1. Thing 1.1 simultaneously starts event 3.1 which creates thing 3.1. Then, thing 3.1 generates a new version of the first event, i.e. event 1.2. In such a way, a new version of the first thing (1.1) is created and it is called thing 1.2. [67].

Every event and every thing is an organizational term, although the things are called primal organizational terms and the events are called derivative organizational terms. The way of labelling comes from the answer to a simple question: what would exist when a team manager stops doing anything? The answer is: things would exist as they are more stable and coherent over time comparing to events [68].

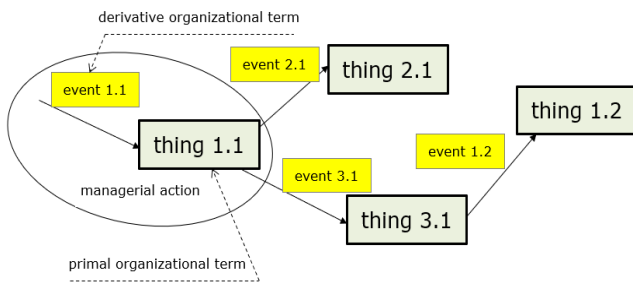


Fig. 1. Fundamental structure of organizational reality based on occurring facts.

Things (primal organizational terms) in the organizational reality represent resources. Events (derivative organizational terms) in the organizational reality represent processes. By the same token, the system of organizational terms combines the resource approach [68] and the process approach [70] in the management science in a way that team management processes effect in team's resources.

Therefore the managerial actions is defined as a real activity, which a manager does in order to play a managerial role when he has a certain managerial skill, the managerial action structure consist of, e.g. event 1.1 and thing 1.1. This is shown in Fig. 1 [65].

Despite the fact that on the abstract level this approach is quite clear and easy to understand, a real problem concerns a method of measuring certain organizational terms. It is quite obvious that data which describe organizational terms should be recorded in a way, which allows to represent a team manager unambiguously without any doubts or subjective conclusions. This problem can be described by two questions: (1) which organizational terms could we measure and (2) how to do it? The project of the system of organizational terms includes answers to both questions.

Firstly, it is possible to measure only things as effects of

processes. Even when we try to measure a process, its parameters must concern a state of the world before and after when this process happens. This means that the parameters concern some kind of a resource which is being changed during this process. In team management this issue looks as it follows.

As it is shown in Fig. 2, when a team manager sets a goal (a team management process represented by Event 1.1 – setting 1.1), it is possible to measure features of goal 1.1 in content and time domains. If later (e.g. after describing a task – describing 1.1 and task 1.1) this team manager does the next setting of the same goal, he launches the next team management process. Then the features of this team management process are changed and represent the second version of this team management process (setting 1.2 and goal 1.2). The difference between features of goal 1.2 and goal 1.1. let do reasoning on the team management process which happened in this period of time. Such an approach to ontology of team management lets represent all such processes by standardized features vectors with data grouped in content and time domains [68].

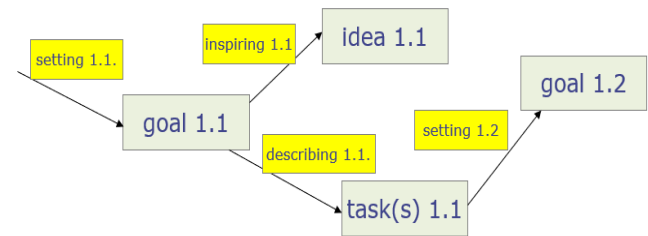


Fig. 2. The example of creating resources by processes in team management.

Secondly, if it is only possible to measure things (e.g. goal 1.1), there should be a special research tool which could let record the parameters of goal 1.1 keeping to the rule of minimum influence on a team manager. The solution is a research tool built-in a management tool, which a team manager uses during day-to-day work. In other words, when a manager does something (e.g. set a goal) with a certain tool, this tool should record the parameters of the goal during the managerial work (e.g. before and after setting). This approach partly based on a well-known method of time and motion study in management science [67].

In order to these assumptions of the system of organizational terms described above the innovative online management tools were designed and implemented. They are in TransistorsHead.com research platform which is a knowledge management system used to team management. In the Fig. 3 there is a dashboard of this KMS. Types of managerial actions recorded by this system means as it follows: (1) set goals (GOALS) (2) describe tasks (TASKS) (3) generate ideas (IDEAS) (4) specify ideas (SPECIFICATIONS) (5) create options (OPTIONS) (6) choose options (DECISIONS) (7) check motivation (MOTIVATION) (8) solve conflicts (CONFLICTS) (9) prepare meetings (MEETINGS) (10) explain problems (PROBLEMS).

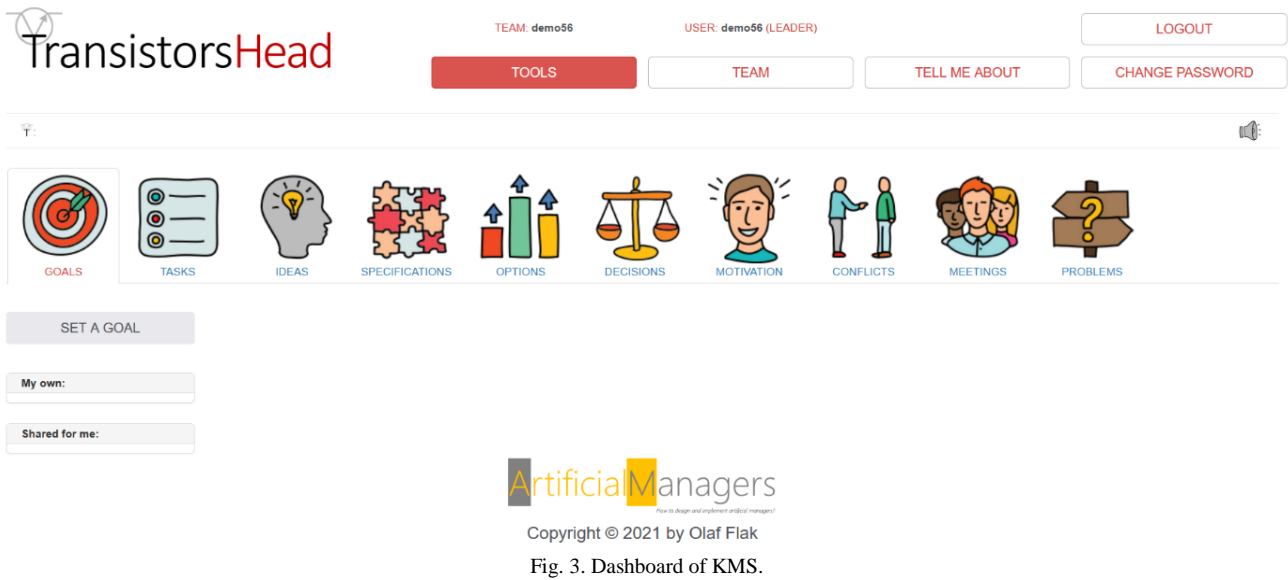


Fig. 3. Dashboard of KMS.

When virtual team members use online management tools of TransistorsHead.com, their managerial actions are being recorded in a sequence of time [65], which allows us to understand what are real activities of human managers and human team members [64] and estimate the activity of using KMS aimed at answering the research questions presented in Introduction.

A. Survey Questionnaires

Together with the knowledge management system called TransistorsHead.com we also used another methodology which was a survey questionnaire. It was a 20-question survey used to assess the subjective evaluation of effectiveness teamwork done by participants of the study. The questions pertained to various actions and behaviors that contributed to the final effectiveness and they were connected to the different online management tools in the knowledge management system (TransistorsHead.com).

The survey was divided into four parts: task performance (5 statements, e.g. “I completed my assignment thoroughly”), organizational citizenship behavior (6 statements, e.g. “I was effective at resolving conflicts between team members”), teamwork (4 statements, e.g. “I reacted to the needs of my teammates”), and creative behavior (5 statements). Table I shows the number of questions in several dimensions of teamwork effectiveness and names of the online management tools in TransistorsHead.com.

TABLE I: DIMENSIONS OF TEAMWORK IN A SUBJECTIVE EVALUATION AND NAMES OF TOOLS IN KMS

Dimension of teamwork effectiveness	Numbers of questions in the survey	Names of the online management tools in TransistorsHead.com (KMS)
creative behavior	5	IDEAS, SPECIFICATIONS
task performance	5	GOALS, TASKS
teamwork	4	PROBLEMS, MEETINGS
organizational citizenship behavior	6	CONFLICTS, MOTIVATION

Participants of the study rated their level of agreement with each statement using a seven-point Likert scale, with 7

meaning “strongly agree” and 1 meaning “strongly disagree”.

IV. RESULTS OF THE RESEARCH

A. Environment of the Study

The long-term observation by KMS was conducted from December 14, 2022 to January 14, 2023 among the students of management faculty of Jan Kochanowski University of Kielce, Poland. The study involved 26 participants in 5 groups - four groups had 5 participants, and one group had 6 participants. Participants in the long-term observation were given the task of preparing documentation of the program project on the YT channel in the Talent Show format. The task of the participants was as follows: formulate an organizing problem and solve this problem—propose a detailed format for the program and preparations for its implementation. The result of the study participants’ work was a pdf document containing a detailed description of the solution to the organizing problem, consisting of the following elements.

Firstly, participants used the knowledge management system, called TransistorsHead.com, described in Section 3, to work on the task. This KMS recorded their work in order to calculate their activity in using KMS during the project. Secondly, after completing the study, participants answered 20 questions in a survey on subjective evaluation of their team work in the fields of (1) creative behavior, (2) task performance, (3) teamwork, (4) organizational citizenship behavior. Based on this, we were able to estimate the relationship between using the KMS and there four aspects of teamwork effectiveness.

B. Relation between the Activity of Using KMS and Subjective Evaluation of Teamwork Effectiveness

The analysis of the results of the study, that is, the activity of using KMS for particular aspects of team effectiveness, was carried out based on 3 parameters. Two of them relate to activity of using KMS and these are: (a) time of work in KMS and (b) number of tool uses. Since the time of work was about a month and we recorded it second by second, in order to present the results in the same graph, we had to divide the

number of working seconds by 10000. We did the same with the number of tool uses—we divided the actual numbers by 100. The third parameter is (c) subjective evaluation of team effectiveness and its values, divided into 4 aspects of team effectiveness, were calculated based on surveys of participants after long-term observation. The range of subjective valuation is from 1 to 7.

Table II presents values of the parameters (a, b and c) for all aspect of teamwork effectiveness in 5 research groups. The same data was presented in Fig. 4. As we can read from the Table II and Fig. 4, all aspects of teamwork effectiveness are in different relations to the activity in KMS.



Fig. 4. Subjective evaluation, time of work in KMS (x 10000) and number of tool use (x 100) concerning creative behavior.

TABLE II: SUBJECTIVE EVALUATION, TIME OF WORK IN KMS (X 10000) AND NUMBER OF TOOL USE (X 100) FOR ALL THE TEAMS IN THE RESEARCH

aspect of teamwork effectiveness	subjective evaluation	time of work in KMS (x 10000) (in seconds)	number of tool use (x 100)
task performance	5,40	4,08	9,23
organizational citizenship behavior	5,83	1,45	5,87
teamwork	6,00	3,81	8,26
creative behavior	6,00	2,52	9,63

Firstly, creative behavior of the research groups was subjectively evaluated at 6.00 points. So, the participants felt that they were high efficient in this area. Meantime, they spend very little time using the online management tools in KMS focused on creativity (IDEAS and SPECIFICATIONS), but they used them many, many times. It seems that it is not clear what is a relation between activity of using KMS and their subjective evaluation of creative behavior.

Secondly, task performance was subjectively evaluated at 5,40 points, which means also a high level of effectiveness, however they spend most of their time working with tools in KMS called GOALS and TASKS. The average number of uses is also nearly the highest from all the tools in KMS. So, answering to it means that there is a quite strong relations between activities in using KMS and subjective effectiveness in the area of task performance.

Thirdly, as far as teamwork is concerned, the subjective assessment of effectiveness is the highest one—6.00 points. However, they spend quite a lot of time working in the tools called PROBLEMS and MEETINGS and the number of use was also quite high. On this foundation we can answer the third research question and claim that the activity of using KMS strongly related to evaluation of teamwork.

Fourthly, participants evaluated their organizational citizenship behavior on average at 5,83 points, but they did not use online management tools to many times in that area (in TransistorsHead.com—CONFLICTS and MOTIVATION). They also did not spend too much time on this activity. So, it is possible to answer the fourth research question that the relation between using KMS and evaluation of organizational citizenship behavior is very weak.

In addition, we present in Table III these parameters also for all the research groups separately. We can recognise big differences in all recorded parameters (time of work in KMS and number of tool uses) concerning all aspects of teamwork effectiveness (task performance, organizational citizen behavior, teamwork and creative behavior).

Such diverse results for individual groups show how much the phenomenon of team effectiveness is different in virtual teams. Each group creates its own organizational culture, which influences team effectiveness and its various aspects: task performance, organizational citizen behavior, teamwork and creative behavior. The parameters measured by online management tools in KMS (parameters a and b, recorded by TransistorsHead.com) and subjective evaluation (parameter c, measured by the survey) have different values for each team. Therefore, despite the given answers to the research questions based on all teams participating in the study, the answers to these questions could vary depending on the team studied.

TABLE III: SUBJECTIVE EVALUATION, TIME OF WORK IN KMS (X 10000) AND NUMBER OF TOOL USE (X 100) FOR INDIVIDUAL TEAMS IN THE RESEARCH

aspect of teamwork effectiveness	research group	subjective evaluation	time of work in KMS (x 10000)	number of tool use (x 100)
task performance	group 1	5,40	3,55	8,01
	group 2	4,80	8,46	18,51
	group 3	4,00	4,14	9,47
	group 4	6,00	1,82	3,36
	group 5	5,80	2,43	6,82
organizational citizenship behavior	group 1	5,83	1,22	8,82
	group 2	5,33	3,67	12,25
	group 3	3,17	0,43	1,02
	group 4	4,33	0,96	2,75
	group 5	4,17	0,97	4,53
teamwork	group 1	6,75	4,23	9,58
	group 2	6,00	6,26	14,52
	group 3	5,25	2,75	7,12
	group 4	7,00	2,26	3,20
	group 5	4,75	3,55	6,87
creative behavior	group 1	6,80	0,56	10,45
	group 2	5,00	3,12	14,02
	group 3	3,40	2,15	6,43
	group 4	6,20	4,41	9,36
	group 5	5,60	2,38	7,87

V. CONCLUSIONS

The aim of the paper was to solve the research problem concerning the level of activity in the use of knowledge management systems related to subjective evaluation of achieved effectiveness during teamwork in virtual teams. The research problem included 4 research questions. We compared the result of the activities in the KMS

(TransistorsHead.com) taken by 5 research groups to their subjective evaluation of their teamwork effectiveness. It appeared that (1) it is not clear what is a relation between activity of using KMS and their subjective evaluation of creative behavior, (2) there is a quite strong relations between activities in using KMS and subjective effectiveness in the area of task performance, (3) the activity of using KMS strongly related to evaluation of teamwork and (4) the relation between using KMS and evaluation of organizational citizenship behavior is very weak.

In the future we plan to analyze the data gathered by the KMS in more details and point out more correlations between the facts which occurred during the teamwork and the examined aspects of teamwork effectiveness.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

O. Flak conducted the research by the KMS (TransistorsHead.com) and surveys, analyzed the data gathered by KMS, described the answers to the research questions, edited the paper; A. Pyszka prepared the theoretical foundations of knowledge management systems and teamwork effectiveness, prepared the list of references; A. Pollak prepared the survey questionnaire, analyzed the data gathered by the survey; B. Kożusznik prepared the survey questionnaire, checked the methodological and psychological aspects the research; all authors had approved the final version.

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