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RESEARCH ARTICLE

Measuring and predicting teamwork quality in virtual project teams

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Abstract
More and more members of project organizations collaborate in virtual teams. Due to globalization and more recently driven by the impact of the Covid-19 pandemic, the number of virtual project team members grew significantly, and many leaders look for key factors which allow virtual teams to reach a higher level of Teamwork Quality. This article summarizes previous investigations to develop a measuring instrument for both Teamwork Quality and potential predictors. Based on a literature review a conceptual model with 30 salient items measuring ten latent predictors as well as one latent concept for Teamwork Quality has been developed and transformed into a survey. The questionnaire was shared online and completed by 211 members of virtual project teams. Afterwards an Explorative Factor Analysis as well as a Reliability Analysis have been performed to explore the structure of the items. The result suggested one dependent measure for Teamwork Quality in virtual project teams and three latent predictors. These factors have been included into a Structural Equation Model and have been supported by a Confirmatory Factor Analysis. The steps described led to three factors (Personal Commitment, Team Balance & Mutual Support, Result Orientation) that have an influence on the latent variable "Willingness to succeed".

Keywords
virtual project teams; project management; teamwork quality; remote collaboration; team performance.

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1. Introduction

Virtual teams are frequently used within many international companies for all project sizes (Gallego et al., 2021) and the total number of employees acting in global virtual teams grew by 40% between 2010 and 2018 (RW3-CultureWizard, 2018). Already in 2018 (two years before the Covid-19 pandemic started), roughly every sixth company worldwide has been fully remote, meaning there were no offices and all employees had the freedom to work from wherever they preferred (Owl Labs, 2018). Globalization of business as well as the desire for innovation were the main triggers for virtual teams (Adamovic, 2017) before the pandemic became the strongest driver and caused a radical breakthrough in 2020 (Wrycza & Maślankowski, 2020), which affected all industries and service sectors alike (Herath & Herath, 2020). A lot of organizations were forced to close operations (at least temporarily) or to modify their business models to adapt to the new pandemic environment (Carroll & Conboy, 2020). Especially when the lockdown(s) came, many employees, who were not required physically on site, were asked to take their most important workspace equipment with them and to start working from home (Klonek et al., 2022).

For many employees and their managers, the sudden change was challenging, as no playbooks were available before Covid-19, which described how to change to a fully virtual team within days (Mortensen & Hadley, 2020). On top of that, a lot of those responsible became nervous as they were concerned they would lose control when employees started to work from home (Lindner, 2020). Contrary to these expectations, the performance of employees who worked in co-located teams before the pandemic and who moved into home offices during the lockdown(s), was at least sufficient. This conclusion results out of surveys revealing that 64% of organizations plan to keep remote working long-term and one third wants to reduce their office footprint permanently (Eagle, 2020). Virtual collaboration would have increased anyway, but Covid-19 has highlighted the possibilities and accelerated the transition. It can be expected that this type of cooperation will further increase (Swart et al., 2022). Hence, it should be explored by which factors Teamwork Quality (TWQ) in virtual project organizations is influenced.

Several researchers investigated team collaboration and TWQ in general but most of them focused on co-located teams only (Almås, 2021; Alsharo et al., 2017; Aram & Morgan, 1976; Lurey & Raisinghani, 2001). Compared to the existing literature this paper aims to answer the question *Which factors predict Teamwork Quality in virtual project teams and how can they be measured?* It summarizes existing literature with regards to TWQ and virtual (project) teams in the following paragraph. The next section describes the Research Strategy followed by a paragraph summarizing the research findings. Finally, a discussion and a conclusion section close the article.

2. State of research

During the literature review the authors followed the recommended inclusion and exclusion criteria developed by Clark et al. (Clark et al., 2019).

Table 1. Literature Inclusion and Exclusion Criteria

Inclusion criterion	Description
Primary source	Literature collated and interpreted by authors directly
Relevant topic	Direct reference to research area
Literature hypothesis / proposition quality	Testable hypothesis or demonstrable proposition, which can be evaluated
Methodology quality	Research methodology included and applied
Data quality	Data is relevant and sources are traceable
Outcome quality	Evidence between gathered data and analysis results is transparent

Exclusion criterion	Description
Secondary source	Information can distort analysis
Irrelevant topic	Literature focuses on another topic or utilises the key words with another intention
Inadmissible quality	Untestable information and/or inadequate documentation
Unavailability	Literature was/is not available in data sources
Language duplication	Literature is a duplicate of other used literature

Scopus was the primary tool for the literature review and most of the sources were less than five years old (with the exception of some seminal papers which formed the foundation for the research paper). Journals and books were the preferred sources supplemented by online articles and other internet sources.

2.1. Teamwork quality

Working effectively in a team is one of the most important employee competencies nowadays (Kobushko et al., 2020). Furthermore, soft skills are vital, as they are the key for successful collaboration in project teams (Burba, 2017). Hoegl and Gemuenden (2001) defined TWQ as a measure of the quality of collaboration in teams that influences personal success as well as team performance (the latter one thereby differentiates between effectiveness and efficiency). Effectiveness describes the extent to which a project team meets expectations with regards to product quality, and efficiency refers to the degree to which the team meets project time and budget expectations (Lindsjørn et al., 2016).

Hoegl and Gemuenden (2001) also defined six facets of TWQ (Table 2) and claimed that behaviors of all these facets can be recognized when working with highly collaborative teams.

Table 2. Six facets of TWQ [20]

Facet	Description
Communication	Frequent, informal, direct, and open communication
Coordination	Activities within the team are well structured and synchronized
Balance of Member Contributions	Team members can bring in their full expertise
Mutual Support	All members of the team help and support each other in carrying out their tasks
Effort	Team members exert all efforts to the team's tasks
Cohesion	There is a team spirit, members are motivated to maintain the team

Aram and Morgan worked on team collaboration with focus on project teams in research and development laboratories. For this specific area they could not identify a direct link between interpersonal collaboration and performance of scientists and engineers, but they observed a relationship between the fulfilment of personal job needs and the performance level of team members (Aram & Morgan, 1976). Although their research was conducted more than 45 years ago, some of their survey questions are still valid and can be applied to studies related to virtual project teams.

Lurey and Raisinghani (2001) suggested that leaders should only add those people to their teams who are qualified for the job and Kobushko et al. (2020) indicated that a reward system could be implemented based on the results of a collective team task to improve Teamwork Quality. In addition, opportunities for personal growth are a strong motivator for those who perform well (Katzenbach & Smith, 2015). Moreover, the effect of trust on collaboration effectiveness has been confirmed by Cheng et al. (2016).

2.2. Virtual project teams

A team is a social system, which consists of three or more people who are part of an organization, work on a common task and see themselves / are seen as team members (Hoegl & Gemuenden, 2001). For a virtual project team a similar description applies with the additional aspect that the team is geographically dispersed, meets rarely in person and collaborates mainly via Information and Communication Technologies (ICT) to reach common goals (Dulebohn & Hoch, 2017; Kukytė, 2021). Such a team faces challenges which usually do not appear in co-located teams or the impact of these challenges is much greater in (semi-) virtual teams (Clark et al., 2019). In addition, a high team virtuality can have a negative impact on team performance (Liska, 2022) and it is more difficult to solve conflicts remotely (Saltman, 2020). Summing up, one can say that it is more challenging to lead a remote team than a co-located one (Hoch & Kozlowski, 2014).

Especially since the beginning of the pandemic the number of project team members who collaborate virtually grew considerably as companies were forced to ask their employees not to come to the office anymore (Newman & Ford, 2021). Most of these employees appreciated the request to work from home (Junk, 2020) although it was a new experience for more than half of them (Kamouri & Lister, 2020). From a career development perspective opinions are balanced, when it comes to work from home permanently (Behn, 2023). Nevertheless, 47% of company leaders, who have been interviewed by Gartner about their intentions regarding flexible working after Covid-19, answered that they will allow working remotely fulltime and an additional 35% plan to allow working remotely for at least some time (Gartner, 2020). These plans confirm on one hand that organizations profit from the deployment of virtual teams (Großer & Baumöl, 2017) and on the other hand it means that virtual teams will become a part of the company culture and young candidates will probably ask for remote working possibilities when they decide to join a company (Tamang, 2020).

Geographical dispersion, electronic dependence, national diversity and structural dynamism have been identified as the four characteristics of virtual teams (Gibson & Gibbs, 2006).

2.2.1 Geographical dispersion

Project teams are often geographically dispersed because of missing experts' knowledge on site or because of lower labor costs in other countries. International collaboration is no longer an exception and many companies do not even emphasize the "global" or "virtual" aspects anymore (Jimenez et al., 2017). O'Leary and Cummings defined the different characteristics of geographic dispersion, which are also called performance inhibitors of dispersed teams (O'Leary & Cummings, 2007). The first one is the spatial dimension, meaning how big the geographical distance is between team members. This characteristic reduces spontaneous communication within the team. Spontaneous social interactions in front of the coffee machine or in the break room are not happening anymore for example (Kohntopp & McCann, 2020).

Furthermore, there is the temporal dimension, which is challenging real-time problem-solving due to different time zones and no (or limited) overlapping work hours. The third dimension is called configurational dimension and takes into account the number of locations team members are spread across and how the membership is balanced (e.g., two involved locations with ten team members at one site and one team member at the other site). A strong imbalance can cause a decreasing awareness of the work status of team members who work isolated at a site.

2.2.2 Electronic dependence

In virtual teams the usage of electronic media is usually higher compared to co-located teams (Kirkman et al., 2004). Companies have to go through digital transformation in all business areas and digital collaboration is no longer an option, if working remotely (Fletcher & Griffiths, 2020). Besides their actual responsibility, leaders of virtual teams have to ensure that all challenges related to communication and technology get solved (Hacker et al., 2019).

2.2.3 National diversity

Companies recognize the increasing global competition (Rahman et al., 2018). Thus, to be able to take advantages of globalization and to compete against others, these companies have to adapt and to implement their own global organizational strategy (Ozguler, 2016). By national diversity Gibson and Gibbs mean the cultural differences within these multicultural organizations (Gibson & Gibbs, 2006). As the name suggests, these organizations bring together a diverse set of cultural backgrounds (Leonard, 2019). Culture can be described as "the collective programming of the mind which distinguishes the members of one human group from another" (Hofstede, 1981). It affects the attitude of each individual employee based on various behavioral conventions and artifacts as well as important geographical, ethnic, economic, and political influences (Abyad, 2017). This makes communication within global virtual teams more difficult (Liao, 2017). Hence, a high degree of multicultural competence is required by project managers who lead virtual teams (PMI, 2013) and particularly their tolerance and acceptance for diversity are important as they are responsible for employees from diverse cultures (Knap-Stefaniuk & Burkiewicz, 2020).

2.2.4 Structural dynamism

The arrangements in virtual project teams are often dynamic and team members must be flexible when it comes to their responsibilities and relationships with each other. Often, people join during a project while others leave the team when their tasks are done. A consequence of these dynamic structural arrangements is an increase of uncertainties (Gibson & Gibbs, 2006), which puts a high burden on managers who lead virtual project teams. Especially when it comes to virtual leadership avoiding uncertainties is essential and the exchange between team members needs to be fostered (Deloitte, 2020). Complex development tasks cannot just be broken down into work packages and be executed independently without collaboration of separated individuals (Hoegl et al., 2011).

2.3. Teamwork quality in virtual teams

Organizational leaders should not spend a vast amount of resources on more advanced technologies to improve the performance of virtual teams (Lurey & Raisinghani, 2001). It is more important to develop formal processes as well as a clear structure, and to agree on explicit primary objectives for the virtual teams to create a targeted collaboration.

Many people believe that knowledge sharing is associated with a loss of power but the research of Alsharo et al. (2017) proves that it positively influences the trust level and collaboration within virtual teams, which in turn significantly impacts upon their effectiveness. Social exchanges at the beginning of the collaboration help to generate trust (Jarvenpaa & Leidner, 1999), but as virtual teams usually collaborate remotely, there is a risk that the trust level decreases over time (Kauffmann & Carmi, 2017). In addition to trust in remote teams, the scope of virtual team management studies lies mainly on ICT and its significance for management, the leadership of remote teams as well as the effectiveness of virtual teams (Kukytė, 2021). Besides all principles mentioned, Hertel et al. point at the importance of sufficient performance feedback for each virtual team member (Hertel et al., 2005).

2.4. Conceptual model

The objective of this work is to identify factors and circumstances which influence TWQ in virtual project teams and to develop a measuring instrument for these in a second step. During the literature review many articles and other sources have been found which concentrate on TWQ, virtual teams in general or TWQ in virtual teams but no research documentation has been found, which describes TWQ in virtual project teams or concretely pinpoints how to assess the concept within surveys.

Thus, based on the findings within existing literature a conceptual model has been developed, which can be found in Figure 1.

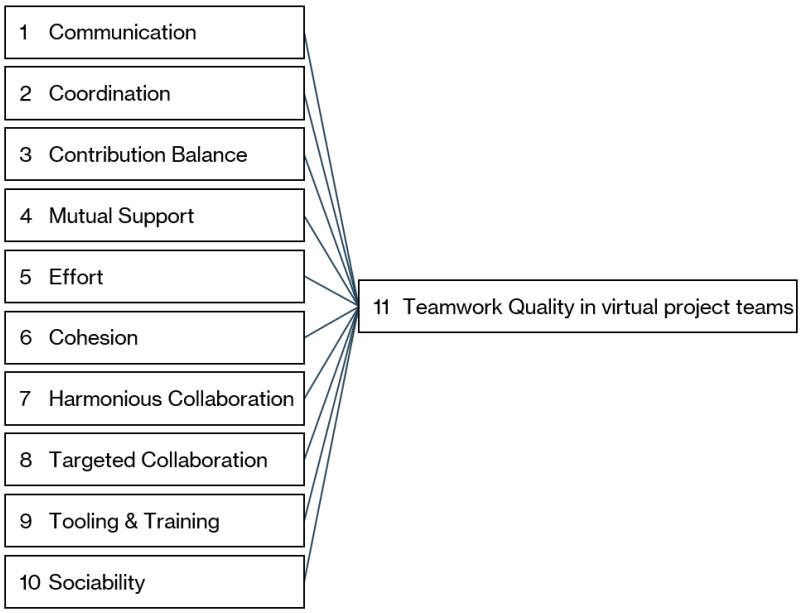

Fig. 1. Conceptual model

Notes: The model shows ten predictors as well as the dependent variable Teamwork Quality in virtual project teams. All variables are assessed as latent constructs through several manifest items. The representation is simplified within the model for parsimony.

The model consists of eleven different factors which are operationalized mainly based on previous literature. For each of the first ten factors (independent variables) three statements are formulated and used in an online survey (see section 3). The factors Communication (1), Coordination (2), Contribution Balance (3), Mutual Support (4), Effort (5) and Cohesion (6) are based on the construct of TWQ by Hoegl and Gemuenden (Hoegl & Gemuenden, 2001). The work done by Aram and Morgan in which they evaluated the role of project team collaboration in R&D performance (Aram & Morgan, 1976) is the foundation for the statements around Harmonious Collaboration (7). Lurey's and Raisinghani's article about best practices in virtual teams (Lurey & Raisinghani, 2001) provided three statements which are used for the eighth focus area called Targeted Collaboration, while the statements for Tooling and Training (9) come from Alsharo et al. who investigated the role of knowledge sharing and trust in virtual teams (Alsharo et al., 2017). For the area Sociability (10) input is given by a case study which investigated Teamwork Quality and Project Success in software engineering capstone courses at the university of Oslo (Almås, 2021).

To be able to measure the dependent variable Teamwork Quality as well, five additional statements were added to the survey. The first three address project time and budget compliance (Lurey & Raisinghani, 2001), as well as quality of teamwork during the project (Lindsjørn et al., 2016). They are based on statements the authors made in their surveys. The remaining two survey statements related to TWQ in virtual project teams concentrate on the overall satisfaction of stakeholders (Kobushko et al., 2020) and the opportunity to grow personally (Katzenbach & Smith, 2015). The latter one sees the personal growth as a result of delivering superior value while Kobushko et al. classify stakeholder satisfaction as a qualitative Key Performance Indicator.

3. Research strategy

The described conceptual model and a quantitative analysis, which is based on an online survey, are the foundation of this article. The survey used the items constructed above to test the developed model in terms of measurement and structure.

3.1. Choice of online survey

A quantitative online survey is chosen as the data gathering instrument since this methodological approach enables the identification and summary of characteristics of a large sample. In addition, the anonymity allows respondents to answer openly and honestly. Evans and Mathur gathered the major strengths of online surveys in 2005 and updated their findings a few years later (Evans & Mathur, 2018). Like Evans and Mathur, the authors of this article share the opinion that the global reach and the speed/timeliness are major strengths of online surveys which benefit from an increasing number of PC, tablet, and smartphone users as well as from internet access which more than half of the world population has available.

Like other survey methods, this approach has drawbacks, too. For example, online surveys can be perceived as junk mail and are often impersonal (Evans & Mathur, 2018). Nevertheless, the advantages outweigh the weaknesses for the purpose of this study which motivates the decision to use an online survey and to reduce the known risks to a minimum (perception as trustable mail, personalization).

3.2. Survey design (data collection instrument)

In total, the questionnaire consisted of 41 questions/statements, divided into three sections (Table 3). The first section contained six demographic questions (D1-D6) to learn more about the general background of the respondents. The second and third section were based on the conceptual model mentioned and entailed 30 statements (three per factor) about the independent variable (S1.1-S10.3) as well as five statements about the dependent variable (S11.1-S11.5).

Table 3. Overview of 41 questions/statements

#	Item (Demographic question)
D1	What is your age?
D2	How many years of working experience do you have in virtual teams?
D3	For which kind of industry do you work?
D4	How many countries are usually involved in the projects you support remotely?
D5	What kind of projects are usually managed remotely in your company? (multiple answers possible)
D6	What is the main reason for virtual project teams in your organization? (open question)

#	Item (Statement about independent variable on 5-point Likert scale)	Factor
S1.1	Project-relevant information was shared openly by all team members.	Communication
S1.2	The team members were happy with the timeliness in which they received information from other team members.	Communication
S1.3	The team members were happy with the usefulness of the information received from other team members.	Communication
S2.1	The work done on subtasks within the project was closely harmonized.	Coordination

#	Item (Statement about independent variable on 5-point Likert scale)	Factor
S2.2	There were clear and fully comprehended goals for subtasks within our team.	Coordination
S2.3	The goals for subtasks were accepted by all team members.	Coordination
S3.1	The team recognized the specific potentials (strengths and weaknesses) of individual team members.	Contribution Balance
S3.2	The team members were contributing to the achievement of the team's goals in accordance with their specific potential.	Contribution Balance
S3.3	Member contribution in our team was in balance.	Contribution Balance
S4.1	The team members helped and supported each other as best they could.	Mutual Support
S4.2	If conflicts came up, they were easily and quickly resolved.	Mutual Support
S4.3	Our team was able to reach consensus regarding important issues.	Mutual Support
S5.1	Every team member fully pushed the project.	Effort
S5.2	Every team member made the project their highest priority.	Effort
S5.3	Our team put much effort into the project.	Effort
S6.1	All members were fully integrated in our team.	Cohesion
S6.2	Our team was sticking together.	Cohesion
S6.3	The members of our team felt proud to be part of the team.	Cohesion
S7.1	When team members worked jointly on problems they tended to build on each other's ideas.	Harmonious Collaboration
S7.2	When several team members discussed an issue, it was all right to comment or ask questions about anything one did not understand.	Harmonious Collaboration
S7.3	After a disagreement over how the group should proceed everyone quickly picked up their part of the task activity.	Harmonious Collaboration
S8.1	Team members were selected based on their individual talents and abilities to contribute to the team.	Targeted Collaboration
S8.2	Team members regularly use phone and/or on-line computer conferences to share ideas.	Targeted Collaboration
S8.3	The team had an established process for making decisions.	Targeted Collaboration
S9.1	I have received training focused on performance improvement in virtual teams.	Tooling & Training
S9.2	My virtual team was equipped with adequate tools and technologies to perform our tasks (SharePoint, ...).	Tooling & Training
S9.3	The electronic methods (MS Teams, Zoom, ...) we used to communicate with each other were powerful.	Tooling & Training
S10.1	I felt comfortable in the virtual working environment.	Sociability
S10.2	The virtual working environment enabled me to get a good impression of my teammates.	Sociability
S10.3	The virtual working environment allowed spontaneous informal conversations.	Sociability

#	Item (Statement about dependent variable on 5-point Likert scale)
S11.1	When the team completed its work, it was generally on time.
S11.2	When the team completed its work, it was generally within the budget.
S11.3	I have been satisfied with the quality of teamwork during the project.
S11.4	The overall feedback from project stakeholders / clients was positive.
S11.5	I had the opportunity to personally grow during the project.

3.3. Sampling

The online survey was created in Microsoft Forms and shared via e-mail as well as social media (LinkedIn). Members of virtual project teams were asked to answer the first six demographic questions and to specify on a five-point Likert scale, how much they agree/disagree with the 35 statements. Within eight weeks 211 people participated in the online survey, which implies a 6:1 (211:35) participant-to-variable ratio. This number fulfils the requirements for a minimum sample size as more than 200 replies have been received and a participant-to-variable ratio of at least 5:1 has been reached (Howard, 2016).

The demographics of the sample turned out as shown in Table 4.

Table 4. Demographics of quantitative study (survey)

Question	Answers	Freq.	Percentage
1. Age	25-34	15	7.1
	35-44	92	43.6
	45-54	65	30.8
	55-64	39	18.5
	Total	*211*	*100.0*
2. Working experience in virtual teams	1-3 years	66	31.3
	4-6 years	43	20.4
	7-9 years	26	12.3
	10 years and more	76	36.0
	Total	*211*	*100.0*
3. Industry, participants work for	Aerospace	1	0.5
	Automotive	17	8.1
	Construction	9	4.3
	Education	6	2.8
	Electronics	24	11.4
	Energy	11	5.2
	Food & Beverage	3	1.4
	Government	4	1.9
	Health Care	3	1.4
	Hospitality	1	0.5
	Information Technology	27	12.8
	Manufacturing	55	26.1
	Marketing	8	3.8
	Transportation	5	2.4
	Others	37	17.5
	Total	*211*	*100.0*

Question	Answers	Freq.	Percentage
4. Amount of countries usually involved in projects	1-2	67	31.8
	3-4	85	40.3
	5 and more	59	28.0
	Total	*211*	*100.0*
5. Type of projects usually managed remotely in the company participant works for (multiple answers possible)	Administrative (e.g., new accounting system)	62	11.0
	Business & Organizational Change (e.g., M&A)	80	14.2
	Construction (e.g., building a road)	21	3.7
	Events (e.g., trade fair)	40	7.1
	Facility (e.g., building decommissioning)	8	1.4
	Maintenance Planning (e.g., of a critical machine)	27	4.8
	Product Development (e.g., sensor)	129	22.9
	Research (e.g., feasibility study)	75	13.3
	Software Development (e.g., mobile app)	93	16.5
	Others	28	5.0
	Total	*563*	*100.0*
6. Main reason for virtual project teams in participant's organization (open question)	Non-co-located teams	104	34.2
	Subject matter experts not available on site	53	17.4
	Travel reduction (e.g., less travel time/costs, Co2 emission)	44	14.5
	COVID-19 (e.g., travel restrictions)	39	12.8
	Project speed (e.g., meetings quicker arranged)	30	9.9
	Mobile working (e.g., home office)	15	4.9
	Global responsibilities (e.g., global customers)	14	4.6
	Others (e.g., lower salaries, digitalization, flexibility)	5	1.6
	Total	*304*	*100.0*

The age group 35-44 years has a high representation (almost 44%) compared to other age groups. A probable reason for this phenomenon is the need of higher education and working experience of employees joining project teams (Silvius & de Graaf, 2019), which would explain the relatively low amount of participants between 25 and 34 years. In addition, many participants replied to a social media campaign on LinkedIn which promoted the survey. Based on LinkedIn's potential advertising reach it is known that professionals who are 55 years and older are less active on LinkedIn compared to users between 35 and 54 years (Kemp, 2022). Almost 75% of all survey replies can be attributed to this latter age group.

The experience groups (based on time spent in virtual teams) can be split into three classes. More than one third (36%) of all participants works in virtual teams for more than ten years already. Roughly another third (32.7%) collaborates remotely between four to nine years and the last third (31.3%) started to work in virtual teams during the last three years. It can safely be assumed that Covid-19 is a key driver for this high number due to the change to mobile/home offices caused by the pandemic situation.

Most participants (26.1%) work for manufacturing companies, followed by IT- (12.8%) as well as electronics- (11.4%) companies and collaborate mainly remotely (40.3%) with 2-3 additional countries during their projects. Product- and Software development projects are conducted most often virtually (39.4%), followed by business & organizational change projects (14.2%) as well as research projects (13.3%).

When the survey participants were asked for the main reasons for virtual project organizations, 34.2% mentioned the global presence of the company, while 17.4% stated missing subject matter experts on site. Another 14.5% named travel restrictions (time/cost savings and reduction of CO2 emissions) and 12.8% declared Covid-19 and the lockdown(s) as main reasons. In general, demographics indicate a balanced sample without bias in any specific direction.

3.4. Analysis

The aim of this paper is twofold. First, to identify the factors and circumstances which influence Teamwork Quality in virtual project teams and second, to develop a measuring tool for the identified factors. To evaluate structural relations and to assess the quality of the measurement instrument, replies to the survey statements were changed into numeric values ranging from 1 to 5 (1 for strongly disagree, 5 for strongly agree). Next to descriptive analyses, an Explorative Factor Analysis (EFA) was carried out with SPSS (Version 29). First, it was done for all eleven concepts (ten independent and one dependent construct) individually to investigate if factors can be created out of the items suggested to belong to each concept. In a next step, identifying the underlying structure of the items of the independent variables, following the "intervalistic school" of Likert scales, was focused upon (Carifio & Perla, 2008). The purpose of the EFA is to group the independent variables which correlate the most into factors capturing common variance. The selected method for the EFA was Principal Axis Factoring and a Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy as well as Bartlett's Test of Sphericity were done. The minimum value for the Measure of Sampling Adequacy is 0.5 and variables with a lower value should be excluded from the EFA (Kaiser & Rice, 1974; Weiber & Mühlhaus, 2014). If the Bartlett's Test result is $p<0.05$, it is significant and means that a factor analysis can be carried out (Shrestha, 2021). Varimax was the chosen rotation method for the EFA.

While this analysis was a first step to explore the validity of the factors identified within the literature, a reliability analysis using Cronbach's Alpha was carried out alongside to check for internal consistency as well. Cronbach's Alpha should be 0.7 or higher to ensure a good reliability (Weiber & Mühlhaus, 2014).

In addition, a Confirmatory Factor Analysis (CFA) was done using a Structural Equation Model (SEM) in AMOS (Version 29). As a full SEM consists of both a measurement and a structural part, the CFA is employed first before correlating the resulting latent constructs with the dependent measure of TWQ. Most important criteria which were tested are the Root Mean Square Error of Approximation (RMSEA) (Hu & Bentler, 1999), CMIN/DF (Chi-square divided by Degrees of Freedom), and Baseline Comparisons like Normed Fit Index (NFI), Tucker-Lewis-Index (TLI) and Comparative Fit Index (CFI) (Weiber & Mühlhaus, 2014). They allow to evaluate how well a model fits. RMSEA should be ≤ 0.08, CMIN/DF should be ≤ 3.0 and NFI, TLI as well as CFI should be ≥ 0.9 (Weiber & Mühlhaus, 2014).

4. Findings

This section focuses on descriptive statistics of the statements presented as well as the results from EFA, CFA and the SEM.

4.1. Descriptive statistics

Mean and standard deviation of the 30 independent variables can be found in Table 5. Here, it can be seen that out of the statements regarding communication an open sharing of information (S1.1) scores highest with a mean of 4.05, while the other two statements, timing (S1.2) and usefulness (S1.3), rank lower.

Statement S8.2, which states that members of virtual project teams regularly use phones or online meetings to share ideas, reaches the highest mean score ($M = 4.20$) of the targeted collaboration factors. This suggests that members of virtual teams do not shy away from using these tools and that the available ICT satisfies employee's needs. On the other hand, the mean evaluation ($M = 2.64$) of received trainings focusing on performance improvement in virtual teams (S9.1) is ranked lowest out of all three items capturing training as well as out of all 30 statements presented.

Table 5. Mean and standard deviation for independent variables

#	Statement (Independent variable)	Mean	Std. Deviation
S1.1	Project-relevant information was shared openly by all team members.	4.05	0.692
S1.2	The team members were happy with the timeliness in which they received information from other team members.	3.82	0.730
S1.3	The team members were happy with the usefulness of the information received from other team members.	3.85	0.666
S2.1	The work done on subtasks within the project was closely harmonized.	3.63	0.803
S2.2	There were clear and fully comprehended goals for subtasks within our team.	3.70	0.737
S2.3	The goals for subtasks were accepted by all team members.	3.71	0.710
S3.1	The team recognized the specific potentials (strengths and weaknesses) of individual team members.	3.60	0.932
S3.2	The team members contributed to the achievement of the team's goals using their specific potential.	3.87	0.779
S3.3	Member contribution within our team was in balance.	3.43	0.888
S4.1	The team members helped and supported each other as best they could.	4.04	0.739
S4.2	If conflicts came up, they were easily and quickly resolved.	3.35	0.884
S4.3	Our team was able to reach a consensus regarding essential issues.	3.92	0.600
S5.1	Every team member fully pushed the project.	3.33	0.922
S5.2	Every team member made the project their highest priority.	3.09	0.884
S5.3	Our team put much effort into the project.	3.90	0.696
S6.1	All members were fully integrated in our team.	3.53	0.901
S6.2	Our team was sticking together.	3.61	0.794
S6.3	The members of our team felt proud to be part of the team.	3.63	0.797
S7.1	When team members worked jointly on problems, they tended to build on each other's ideas.	3.93	0.676
S7.2	When several team members discussed an issue, it was all right to comment or ask questions about anything one did not understand.	4.14	0.723
S7.3	After a disagreement over how the group should proceed, everyone quickly picked up their part of the task activity.	3.64	0.752
S8.1	Team members were selected based on their talents and abilities to contribute to the team.	3.54	1.006
S8.2	Team members regularly used phone and/or online computer conferences to share ideas.	4.20	0.800
S8.3	The team had an established process for making decisions.	3.51	0.907
S9.1	I have received training focused on performance improvement in virtual teams.	2.64	1.115
S9.2	My virtual team was equipped with adequate tools and technologies to perform our tasks (SharePoint, ...).	4.10	0.774
S9.3	The electronic methods (MS Teams, Zoom, ...) we used to communicate with each other were powerful.	4.19	0.707
S10.1	I felt comfortable in the virtual working environment.	3.97	0.864
S10.2	The virtual working environment enabled me to get a good impression of my teammates.	3.37	1.012
S10.3	The virtual working environment allowed spontaneous informal conversations.	3.26	1.255

A more appreciated mean value is the one for the comfort level in the virtual environment (S10.1). This statement belongs to the sociability dimension and reaches a mean of 3.97 which confirms that many members of virtual project teams feel comfortable in their current situation. Nevertheless, in terms of opportunities for informal conversations in the virtual working environment (S10.3) opinions differ, which causes the highest standard deviation (SD = 1.255) of the whole survey.

As far as the dependent variable is concerned (Table 6), the first statement (S11.1) gets the lowest mean value (M = 3.49) and has a standard deviation of 0.819, which indicates that many virtual projects are delayed.

Most positively evaluated is the opportunity to grow personally (S11.5) during the virtual projects (3.98).

Table 6. Mean and standard deviation for dependent variables

#	Statement (Dependent variable)	Mean	Std. Deviation
S11.1	When the team completed its work, it was generally on time.	3.49	0.819
S11.2	When the team completed its work, it was generally within the budget.	3.52	0.745
S11.3	I was satisfied with the quality of teamwork during the project.	3.77	0.773
S11.4	The overall feedback from project stakeholders / clients was positive.	3.86	0.710
S11.5	I had the opportunity to personally grow during the project.	3.98	0.807

4.2. Developing and testing the structure

To develop and test the reliability as well as the validity of the conceptual model, initially an EFA was performed to find factors underlying the 30 statements presented within the survey. Afterwards the internal consistency of items belonging to one common factor according to the EFA results was investigated using Cronbach's Alpha.

4.2.1 Explorative Factor Analysis

As mentioned in section 3.4, an EFA is done for all eleven concepts individually to explore if factors can be created out of the items suggested. Table 7 presents the results of the individual EFAs. In most cases the KMO lies between 0.6 and 0.7 which is named mediocre (Kaiser & Rice, 1974). For concept 9 the KMO is slightly below 0.6 and for concept 11 the value lies above 0.8, which Kaiser classifies as meritorious. The results of Bartlett's test of sphericity for all concepts are below $p < 0.001$ which means all concepts are correlated.

Table 7. Explorative Factor Analysis (Extraction Method: Principal Axis Factoring)

Concept	KMO	Bartlett's Sig.	Factors with Eigenvalue >1	Factor Ranking (Factor Matrix)
1 (S1.1 - S1.3)	0.675	<.001	1 (1.921)	1.3 (.746), 1.1 (.660), 1.2 (.631)
2 (S2.1 - S2.3)	0.673	<.001	1 (1.899)	2.2 (.721), 2.3 (.675), 2.1 (.618)
3 (S3.1 - S3.3)	0.645	<.001	1 (1.904)	3.2 (.834), 3.1 (.654), 3.3 (.540)
4 (S4.1 - S4.3)	0.630	<.001	1 (1.758)	4.2 (.786), 4.3 (.547), 4.1 (.527)
5 (S5.1 - S5.3)	0.656	<.001	1 (1.988)	5.1 (.799), 5.2 (.778), 5.3 (.539)
6 (S6.1 - S6.3)	0.635	<.001	1 (2.034)	6.2 (.950), 6.1 (.635), 6.3 (.593)
7 (S7.1 - S7.3)	0.666	<.001	1 (1.844)	7.3 (.697), 7.1 (.639), 7,2 (.613)
8 (S8.1 - S8.3)	0.603	<.001	1 (1.530)	8.2 (.639), 8.3 (.472), 8.1 (.442)
9 (S9.1 - S9.3)	0.574	<.001	1 (1.674)	9.1 (.723), 9.2 (.718), 9.1 (.316)
10 (S10.1 - S10.3)	0.679	<.001	1 (2.006)	10.2 (.812), 10.3 (.672), 10.1 (.647)
11 (S11.1 - S11.5)	0.806	<.001	1 (2.811)	11.3 (.767), 11.4 (.758), 11.1 (.736), 11.2 (.660), 11.5 (.423)

For each of the eleven concepts there is one factor with an Eigenvalue >1, which means all factors could be calculated as envisaged. The factor ranking shows the factor loadings, which underline the importance of each item for the respective factor (e.g., for the first factor, item 1.3 is ranked highest with a loading of 0.746 followed by 1.1 and 1.2).

4.2.2 Cronbach's Alpha

Also, Cronbach's Alpha is examined for each of the eleven concepts individually. Concepts 4, 7, 8 and 9 have a Cronbach's Alpha <0.7 which indicates that especially for the latter ones no internally consistent factors can be constructed. This impression is supported by low inter-item-correlations (see Table 8).

Table 8. Reliability analysis (Cronbach's Alpha for each concept)

Concept	Cronbach's Alpha	Inter Item Correlation
1 (S1.1 - S1.3)	0.717	0.416 - 0.493
2 (S2.1 - S2.3)	0.708	0.416 - 0.487
3 (S3.1 - S3.3)	0.703	0.352 - 0.546
4 (S4.1 - S4.3)	0.639	0.287 - 0.431
5 (S5.1 - S5.3)	0.744	0.419 - 0.622
6 (S6.1 - S6.3)	0.757	0.375 - 0.603
7 (S7.1 - S7.3)	0.686	0.391 - 0.446
8 (S8.1 - S8.3)	0.509	0.207 - 0.302
9 (S9.1 - S9.3)	0.541	0.227 - 0.520
10 (S10.1 - S10.3)	0.739	0.434 - 0.546
11 (S11.1 - S11.5)	0.796	0.218 - 0.625

Taken together, the preliminary EFA and Reliability analyses suggest that the concepts 1, 2, 3, 5, 6, 10 and 11 serve as reliable and valid measurement instruments. However, this implies that the conceptual model described in section 2.4 cannot be used as presented and needs to be optimized. For this purpose, further explorative analyses were done.

4.3. Validity check

After EFA and Cronbach's Alpha were carried out on concept level, both steps were repeated for the complete set of 30 independent items. The KMO measure of sampling adequacy is 0.892 and Bartlett's Test of Sphericity shows $p<0.001$ which means it is significant and an EFA for all variables can be carried out.

SPSS extracts seven factors, even though the seventh factor has an Eigenvalue of 1.005 only. Table 9 shows how the items load upon these seven different factors which are labeled Communication and Coordination (factor 1), Personal Commitment (factor 2), Team Balance and Mutual Support (factor 3), Result Orientation (factor 4), Social Fellowship (factor 5), Collaboration Equipment (factor 6) and Cohesion (factor 7).

As can be seen, seven factors representing possible predictors of TWQ arise. As the seventh factor includes one item only, it will be excluded from further confirmatory analyses.

Cronbach's Alpha for each identified factor lies between $\alpha= 0.731$ and $\alpha= 0.795$. For factor 6, a questionable reliability of $\alpha= 0.679$ results. Thus, a solution of five valid and reliable factors can be concluded after this exploratory stage.

Table 9. Rotated Factor Matrix

Factor	1	2	3	4	5	6	7
Factor 1: Communication & Coordination							
S1.1 - Project-relevant information was shared openly by all team members.	.503						
S1.2 - The team members were happy with the timeliness in which they received information from other team members.	.566						
S1.3 - The team members were happy with the usefulness of the information received from other team members.	.523						
S2.1 - The work done on subtasks within the project was closely harmonized.	.533						
S2.2 - There were clear and fully comprehended goals for subtasks within our team.	.517						
S2.3 - The goals for subtasks were accepted by all team members.	.402						
Factor 2: Personal Commitment							
S5.1 - Every team member fully pushed the project.		.625					
S5.2 - Every team member made the project their highest priority.		.819					
S5.3 - Our team put much effort into the project.		.367					
S6.1 - All members were fully integrated in our team.		.378					
S6.3 - The members of our team felt proud to be part of the team.		.372					
Factor 3: Team Balance & Mutual Support							
S3.1 - The team recognized the specific potentials (strengths and weaknesses) of individual team members.			.559				
S3.2 - The team members contributed to the achievement of the team's goals using their specific potential.			.504				
S3.3 - Member contribution within our team was in balance.			.432				
S4.1 - The team members helped and supported each other as best they could.			.382				
S4.2 - If conflicts came up, they were easily and quickly resolved.			.343				
S8.1 - Team members were selected based on their talents and abilities to contribute to the team.			.496				
Factor 4: Result Orientation							
S4.3 - Our team was able to reach a consensus regarding essential issues.				.389			
S7.1 - When team members worked jointly on problems, they tended to build on each other's ideas.				.600			
S7.2 - When several team members discussed an issue, it was all right to comment or ask questions about anything one did not understand.				.609			
S7.3 - After a disagreement over how the group should proceed, everyone quickly picked up their part of the task activity.				.490			

Factor	1	2	3	4	5	6	7
Factor 5: Social Fellowship							
S10.1 - I felt comfortable in the virtual working environment.					.604		
S10.2 - The virtual working environment enabled me to get a good impression of my teammates.					.687		
S10.3 - The virtual working environment allowed spontaneous informal conversations.					.635		
Factor 6: Collaboration Equipment							
S8.2 - Team members regularly used phone and/or online computer conferences to share ideas.						.481	
S9.2 - My virtual team was equipped with adequate tools and technologies to perform our tasks (SharePoint, ...).						.720	
S9.3 - The electronic methods (MS Teams, Zoom, ...) we used to communicate with each other were powerful.						.648	
Factor 7: Cohesion							
S6.2 - Our team was sticking together.							.789
No assignment to a specific factor (as loading too small)							
S8.3 - The team had an established process for making decisions.							
S9.1 - I have received training focused on performance improvement in virtual teams.							

4.4. Confirmatory Factor Analysis

As EFA and Cronbach's Alpha do not take errors of measurement into consideration (Weiber & Mühlhaus, 2014), a SEM was built in AMOS and a CFA was done to confirm the five factors obtained in section 4.3.

To build up the measurement part of the SEM stepwise, all latent factors are tested separately first. This enables the detection of factors which might influence the model fit of the CFA negatively in advance.

Factor 1 is not able to fulfil the model fit requirements. Even after adding two item-correlations none of the fit criteria can be fulfilled. Also factor 5 and 6 struggle to reach the expected thresholds. Factor 2 (Personal Commitment), factor 3 (Team Balance & Mutual Support) and factor 4 (Result Orientation) on the other hand show sufficient fit indices. For these three factors, all loadings are significant, too. Taking these three latent factors as basis, a measurement model is constructed. The resulting measurement is depicted in Figure 2.

The final model consists of the mentioned three factors (F2, F3, F4) plus their items and their associated errors of measurement (E1-E15). Some of the item-correlations suggested by AMOS are implemented (depending on the meaningfulness of the proposal, content wise) and can be found in the SEM above (curved arrows).
As there is a multicollinearity between the three latent factors, they were merged into a higher-order latent construct. This latent variable is called "Willingness to succeed" as it mirrors the statements of factor 2, 3 and 4. All three latent factors load significantly upon this construct and fit measures pinpoint towards a suitable measurement model. Within the full SEM a path relating the factor "Willingness to succeed" to TWQ is suggested.

CMIN/DF for the complete SEM is 1.745 while 0.06 is the value for RMSEA, meaning both requirements are fulfilled (see section 3.4). Two of the Baseline Comparison Indices meet the prerequisite of ≥0.9 (TLI is 0.903 and CFI is 0.917), while NFI is a bit lower but close (0.828).

Finally, a reliability analysis is added for the newly constructed higher order latent construct "Willingness to succeed". This analysis confirms a good internal consistency (α= 0.795).

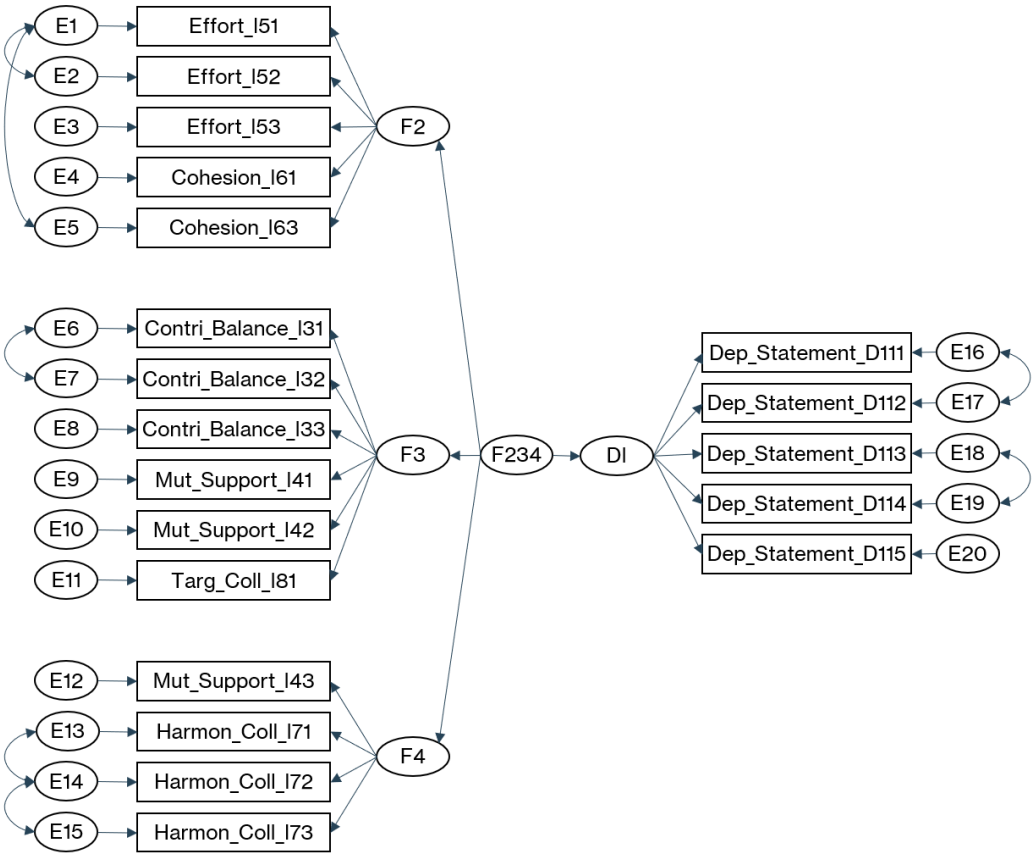

Fig. 2. Structural Equation Model

4.5. The three factors which affect TWQ in virtual teams

As mentioned within the previous section, there are three factors which provide good results in the EFA, reliability analysis and CFA. The first one is labelled "*Personal Commitment*". It relates to the operational readiness of the project team members and how much they identify themselves with the team and the project. Model Fit values can be found in Table 10.

The second factor is called "*Team Balance & Mutual Support*" and captures the right composition of the team, considering individual strengths and weaknesses. Furthermore, team members should support each other, and everyone should be given the opportunity to make their contribution.

Factor 3 stands for "*Result Orientation*". As the title indicates, the focus rests upon goal-oriented collaboration (finding consensus, being open to other people's ideas, expressing honest opinions, etc.).

In turn, these three factors have an influence on the "*Willingness to succeed*". If, for example there is a high personal commitment or a high result orientation in the team, then the willingness to succeed is higher as well. And ultimately, the higher the willingness to succeed, the higher the TWQ.

Table 10. Model Fit Values

	CMIN/DF	NFI	TLI	CFI	RMSEA
Threshold Value	<3.0	≥0.9	≥0.9	≥0.9	<0.08
Confirmed Factor 1: Personal Commitment	1.273	0.979	0.990	0.995	0.036
Confirmed Factor 2: Team Balance & Mutual Support	1.204	0.962	0.989	0.993	0.031
Confirmed Factor 3: Result Orientation	0.192	0.998	1.031	1.000	0.000
Confirmed higher-order latent variable "Willingness to succeed"	1.745	0.828	0.903	0.917	0.060

5. Discussion

The purpose of this paper was the identification of factors affecting TWQ in virtual project teams as well as the exploration of their measurement. Summarizing the main findings of this paper, the conducted research discovered three factors, namely Personal Commitment, Team Balance and Mutual Support as well as Result Orientation, that are valid and reliable and that, taken together, capture the "Willingness to succeed" which in turn affects TWQ in the described virtual environment.

The results emphasize the importance of Personal Commitment to the project and the virtual project team. From co-located teams it is already known, that a high project commitment positively influences team member motivation to spend all available efforts on the project (Buvik & Tvedt, 2017). Hence, it should be fostered and used as a leverage for project teams and successful project results (Tremblay et al., 2015). Due to the identified importance of personal commitment towards the virtual project (team) it could make sense to extend important goals and values for co-located to virtual project teams. These could for instance be the provision of a clear project vision or the emphasis on how the project contributes to the prosperity of the company (Lee, 2021).

Amongst others the second factor focusses on Team Balance, which stands for a balanced team composition on one hand and for a balanced team member contribution on the other hand. The first point is ensured by paying attention to qualifications when selecting team members (Lurey & Raisinghani, 2001). Related to the second point, it should be the aim of every organization to motivate team members to share knowledge and experiences with the team, but in addition, it needs to be ensured that contribution is in balance (Hoegl & Gemuenden, 2001). Besides Team Balance the second factor also takes Mutual Support into account. Samuel and Mathew pointed at the importance of Mutual Support for work performance among co-located team members already (Samuel & Matthew, 2021) and the research carried out here confirms the significance for virtual project teams, too.

The importance of "Result Orientation" as an additional key factor is no surprise, as project teams have clear goals (e.g. related to quality, time and cost) in their project mandate, which is approved by senior management (PMI, 2013). If results are delivered as expected in the project mandate, the project is considered a success (Zid et al., 2020). This applies to all projects and does not depend on whether the teams are co-located or working remotely.

Despite literature pointing towards additional relevant predictors within the context of TWQ, represented by the ten constructs pictured within the conceptual model, the analyses of this paper could not verify their reliability and validity. Given that many authors focusing on TWQ have done so without checking the validity of their measurement tools, this paper provides a novel contribution to future work within this research field. The research aims of identifying relevant predictors and developing a valid measurement tool have thus been met. Scholars and companies focusing on TWQ should hence use the manifest items related to TWQ, Personal Commitment, Team Balance and Mutual Support as well as Result Orientation developed here to assess TWQ and influencing factors.

6. Conclusion

Virtual project teams offer advantages like the ability to include experts from other regions or countries, to allow productivity around the clock seven days per week, to reduce environmental impact and costs due to less travel, and to share knowledge globally and across organizational borders (Dulebohn & Hoch, 2017). On the other hand, it is more difficult to build up and to keep the level of trust and engagement within virtual project teams, as the team members meet rarely and communicate mainly through ICT. Therefore, the aim of this paper was to answer the question *Which factors predict Teamwork Quality in virtual project teams and how can they be measured?* An EFA based on an online survey has been conducted, followed by a Reliability Analysis and CFA to develop a measuring tool for TWQ in virtual project teams and to investigate which influencing factors companies should focus upon, if their project teams are not co-located.

Even though the topic of this paper is of current interest and fulfils the academic requirements, a survey with any sample always has limitations with regards to reliability. It should be mentioned that it is not possible to clearly retrace the exact background of the survey participants, and under which conditions they work, as it was an open questionnaire for people working remotely in project teams. Therefore, participants might interpret the same statement differently or define key terms such as "trust" in a different way. It should also be pointed out that all items were collected using a Likert scale with the same scaling, which can lead to method bias (DeVellis & Thorpe, 2021). It is therefore recommended for future studies to use different survey instruments or a variation to prove whether the results hold up.

However, this work represents a good basis and can be a motivator for researchers to carry out more targeted investigations with focus on further testing of the three identified factors, perhaps with explicit attention on specific cultures, leadership styles or project types.

The contribution of this paper is that it delivers empirical data related to TWQ in virtual project teams and that it closes a gap as no research has been carried out with focus on these two variables. Now, leaders are capable to maximize the "Willingness to succeed" and consequently they are able to positively influence Teamwork Quality in practice. Thanks to the developed measuring tool the three identified factors can be tracked and, by using trends, even be forecasted.

Declarations

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