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Moments of Stress in the Virtual Classroom - How Do Future Vocational Teachers Experience Stress Through 360° Classroom Videos in Virtual Reality?

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Moments of Stress in the Virtual Classroom - How Do Future Vocational Teachers Experience Stress Through 360° Classroom Videos in Virtual Reality?

ABSTRACT: To deal with challenging situations and stress in the classroom, future vocational teachers could benefit from training with 360° classroom videos in virtual reality in advance of being confronted with reality at school. The present study attempts a first step into measuring psychophysiological stress responses in form of Moments of Stress of future vocational teachers while experiencing 360° classroom videos and completing the task to act as teachers in the given situations. Participants acted as teachers within the 360° classroom videos in virtual reality while their gaze and reaction were recorded, and psychophysiological data was tracked with a sensor. Moments of Stress were calculated, and a qualitative analysis of Moments of Stress occurrence was performed. The explorative results show that all participants (N =16) show stress reactions with a pattern of stress occurrence during intended and scripted classroom stressors such as student misbehaviour or teacher centred situations. The virtual training environment thus provides a tool for stress measurement in initial teacher training. It can be used to train and possibly prevent stress during difficult classroom situations through use in university seminars as it provides a protected space for initial practical teacher training. These findings provide a first approach to the application of 360° video in VR in university teacher training because perceived stress during teaching is one factor that contributes to higher levels of illness and burn-out related symptoms in teachers. Further research on the application of virtual teacher training for stress reduction and a positive impact on practical training is needed to broaden the understanding of its benefits and downsides.

Keywords: Stress, 360° Videos, Virtual Reality, Classroom Situation, Vocational Teacher Education

Moments of Stress im virtuellen Klassenzimmer - Wie erleben zukünftige Lehrpersonen Stress durch 360°-Unterrichtsvideos in Virtual Reality?

ZUSAMMENFASSUNG: Um mit herausfordernden Situationen und Stress im Unterricht umzugehen, könnten angehende Berufsschullehrpersonen von einem Training mit 360°-Unterrichtsvideos in Virtual Reality profitieren, bevor sie mit der Realität in der Schule konfrontiert werden. Die vorliegende Studie unternimmt einen ersten, explorativen Schritt zur Messung der psychophysiologischen Stressreaktionen in Form von Stressmomenten von angehenden Berufsschullehrpersonen, während sie 360°-Unterrichtsvideos erleben und als Lehrperson handeln. Das Testsetting besteht aus fünf kurzen Unterrichtsvideos, in denen die Teilnehmenden als Lehrpersonen (z. B. verbal) innerhalb der 360°-Videos in Virtual Reality agierten, während ihr Blick and ihre Reaktion aufgezeichnet and psychophysiologische Daten (Hauttemperatur, elektrodermale Aktivität, Herzfrequenz) durch einen tragbaren Sensor aufgezeichnet wurden. Die Sensordaten wurden verwendet, um Stressmomente zu ermitteln and es wurde eine qualitative Analyse des Auftretens von Stressmomenten durchgeführt. Die Ergebnisse zeigen, dass alle Teilnehmende (N =16) Stressreaktionen mit einem Muster des Stressauftretens bei beabsichtigten Stressoren im Unterrichtsvideo wie störende Schüler:innen, Fehlverhalten and Schwierigkeiten bei Übungen zeigen. Diese Ergebnisse bieten einen ersten Ansatz für mögliche Anwendungen von VR in der Lehrpersonenbildung, da der wahrgenommene Stress während des Unterrichts ein Faktor ist, der zu höheren Krankheitsraten

und Burn-out-Symptomen beiträgt. Außerdem könnten die Abbrecherquoten in der ersten und zweiten Phase der Ausbildung in Deutschland reduziert werden, wenn realistische Trainingsszenarien präventiv eingesetzt werden. Weitere Forschungen zur Anwendung der virtuellen Lehrerausbildung zur Stressreduzierung und zur positiven Auswirkung auf die praktische Ausbildung sind erforderlich, um das Verständnis für ihre Vor- und Nachteile zu erweitern.

Schlüsselwörter: Stress, 360° Videos, Virtual Reality, virtuelle Unterrichtssituationen, berufliche Lehrpersonenbildung

1 Introduction

In the course of the digital transformation, the development of digital technologies to train and develop competences of teachers has gained enormous importance (König et al. 2020; Tondeur et al. 2021). Through digital learning settings, future teachers have the opportunity to use technology for adaptive and individualised learning processes (Starkey 2020). The use of technology in form of videos or virtual reality (VR) can support the professionalisation of future teachers (Major & Watson 2018; Mystakidis et al. 2021). One proven option is training with instructional videos of classroom situations to ensure growth in situation-specific skills and action-related pedagogical knowledge (Kramer et al. 2017; Stürmer et al. 2015; Cattaneo & Boldrini 2017; Michalsky 2021). Interactive use of video content positively influences preservice teachers' motivation and engagement (Syring et al. 2015; André et al. 2023). Researchers (Kunz & Zinn 2022; Richter et al. 2022; Stavroulia & Lanitis 2017; Walshe & Driver 2019) go one technological step further and use VR technology to train (future) teachers. One area that VR can be used in for training is the confrontation with everyday yet challenging situations in the classroom that might trigger emotions, especially stress, in teachers (Huang et al. 2022; Bardach et al. 2023). Although emotions are an integral part of a teacher's work and have an impact on their behaviour and motivation as well as on the efficacy of teaching, the empirical basis is yet very thin (Frenzel et al. 2021). One reason for this could be the difficulty of operationalising emotions in the real classroom within an experimental setting. VR technology poses the possibility of creating realistic teaching situations that give future teachers the feeling of being in the classroom. The potentially high immersion can create an experience of presence (Cadet & Chainay 2020), whereby a wide range of emotions from real lessons can also be experienced and operationalised in VR. In contrast to real environments, emotions in virtual environments are controllable and easier to capture. For the measurement of emotions, which includes stress, objective methods such as psychophysiological measurement procedures can be used besides self-reported psychological stress perception. Research on teacher stress in the majority uses measures of self-reported stress (Harmsen et al. 2018; McCarthy et al. 2016; Iacolino et al. 2023) while more recent studies begin to incorporate psychophysiological data for an objective or outside measurement of physiological stress reactions during classroom settings due to its easier availability because of technological developments (Huang et al. 2022; Ritvanen et al. 2003; Junker et al. 2021; Junker 2023; Wettstein et al. 2021). Findings indicate, that psychological measures are able to associate physical stress reactions in teachers with typically stressful classroom situations such as low student engagement (Junker 2023), or level of disruption (Bardach et al. 2023). At the same time, theories of occupational stress emphasize the important role of physiological stress reactions at the workplace for understanding and consequently counteracting the consequences of stress at work (Demerouti et al. 2001; Huang et al. 2022; Meurs & Perrewé 2011).

One approach for training and observing the emotions experienced by novice teachers in the classroom is the presentation of teaching situations via 360° videos in VR and the simultaneous recording of stress reactions using psychophysiological measurement methods. Findings in this area could hold great potential for the professionalisation of future teachers regarding the training for challenging situations and possibly preventing stress associated illnesses in teachers (Embse et al. 2019; Bottiani et al. 2019). Virtual simulations of classroom situations have become more accessible and popular in research and education (McGarr 2021). Therefore, it is of interest to expose preservice teachers to challenging classroom situations in VR which include well-known stressors (e.g. disruptions, low student engagement) during training and measure the psychophysiological stress reactions to be able to make assumptions on the usefulness of the technology in terms of its closeness to real-life characteristics for teacher training. This means, that the combination of VR technology as an established but extended form of case-learning in teacher education with objective stress measurement provides new insights into the possible benefits of case-learning of classroom situations (e.g. aspects of professional vision). Thus, the question arises, to what extent the feelings experienced in real situations can also be experienced in VR and to what extent they are reflected in psychophysiological data while using VR for training reflective teaching practise. To investigate this, broad empirical research with different teaching situations is necessary. The present work ventures a first and explorative step into this direction.

In the present study, psychophysiological measurement methods are used to investigate the extent to which virtual learning environments realised through 360° videos in VR are suitable for confronting challenging teaching situations in the context of professionalising teachers. For this purpose, 360° videos of simulated classroom situations were created and shown to students of vocational and technical education with a head-mounted display (HMD) with the task for participants to react as teacher to the given situation. Both, the field of vision of the test subjects and their behaviour, were recorded for the evaluation of the data. The psychophysiological reactions were recorded and analysed using a sensor wristband.

2 Theoretical Background and Research

Emotions play an important role in the work of teachers (Frevert & Wulf 2012). The profession is generally described as stressful, and international studies show that teachers have a comparatively high proportion of people with burnout symptoms (Harmsen et al. 2018; Heus & Diekstra 2010; Bottiani et al. 2019). Since the "Potsdam Teacher Study" by Saarschmidt and colleagues (Schaarschmidt & Kieschke 2007), the topic has also received greater attention in the German-speaking society and academia. Teachers regularly must deal with challenging situations that may be associated with stress, anger, and frustration. In addition, teacher shortage is a concern for the German public vocational school system at the moment and attrition of sufficient new teachers after the retirement of the baby boomer generation poses a challenge to politics and institutions of teacher education (Seeliger & Håkansson Lindqvist 2023). Therefore, it is very important to promote the emotional intelligence of teachers in general and especially of young teachers f to be able to stay healthy on the job despite stressful classroom situations. By using different methods and innovative technologies, teachers can be sensitised to recognise their own emotions and the emotions of their students (Nissim & Weissblueth 2017; Herman et al. 2020). In this context, VR technology has the potential to provide future teachers with comprehensive teaching experiences. Through the face-to-face experience provided through VR environments, teaching can be experienced quite realistically. This could allow teachers to train their behaviour for stressful situations in advance without the impact of a real classroom (Huang et al. 2022; Bardach et al. 2023).

Wettstein and colleagues state regarding stress response and measurement, that „self-reports do not provide reliable data on biological stress responses. It is often challenging to interpret biological processes adequately […], and biological stress measurements are not always consistent with subjective stress perception" (Wettstein et al. 2021, p. 4). They suggest measuring and understanding teachers' psychobiological stress responses to disruptions in the classroom to conceptualise a theory for counteracting the negative effects the stress can have for teachers as well as students (ibid.).

This work provides a first insight into the possibilities of objectively measuring stress of future teacher while being exposed to reality-like classroom situations via 360° videos in VR. In the following, a brief introduction to the topic of VR is given and different types of virtual environments are described with a focus on the 360° videos in VR used in the study. Subsequently, a definition of stress and teacher stress is provided, and the possibilities of measuring stress are discussed.

2.1 Virtual Reality

Virtual reality is defined as computer-generated simulation of an environment in which users can interact with the environment in real-time and usually wearing some sort of HMD (Rauschnabel et al. 2022; Dörner et al. 2019). VR as a technology is in the context of teaching and learning associated with advantages regarding experiencing presence or emotional involvement (Gold & Windscheid 2020; Ramalho & Chambel 2013; Visch et al. 2010; Zinn & Ariali 2020). Researchers are intensively exploring VR and trying to add an extra dimension to teaching through the immersive experience provided by the technologies (Radianti et al. 2020). Recent developments in visualisation and interaction as well as availability of hardware and software make VR increasingly attractive for education and in specific also for teacher education (McGarr 2021; Hamilton et al. 2021). The latest head-mounted displays (HMDs) can engage the user in a VR environment in such a way that they feel present in an artificial world while being affordable at the same time (Yang et al. 2023; Moulders et al. 2020). This feeling is described as immersion and is fundamentally studied in the context of VR (Jennett et al. 2008; Moulders et al. 2020; Dörner et al. 2019).

To implement virtual learning and training environments, semi-immersive VR technology (e.g. 3 degrees of freedom via headtracking) is often used due to the generally cheap availability and good mobility of the devices (Ariali & Zinn 2020). With low-budget HMDs, entire classes or groups of students can engage with the virtual environment simultaneously. However, there are limited interaction possibilities (e.g. through head movements) and there is usually lower image quality in such environments. In the context of this study, 360° videos of classroom situations were scripted and recorded to be perceived via HMDs in VR. In this case, the only "real" interaction the user has, is head movement within the videos. Further interaction possibilities were created by carefully scripting the videos to cause users' reactions to be perceived as realistic as possible. Nevertheless, the lack of an appropriate and synchronous reaction of the audience within the video to the actions of the users in 360° videos can lead to irritation (Kunz & Zinn 2022). Therefore, there are reasons to believe that these limitations of 360° videos may affect their potential as a tool for training public speaking and addressing social anxiety (Barreda-Ángeles et al. 2020). However, there is also research evidence that 360° video applications (without user interactivity and avatars) can be effective in the treatment of social anxiety disorders (Stupar-Rutenfrans et al. 2017). The approach adopted in this study is based on the following rationale: If 360° videos in VR generate realistic reactions in future teachers, then the emotional state of the users should be influenced by the behaviour of the students in the classroom. The disruptive behaviour and disregard for the cues should lead to stress reactions in the video viewers.

2.2 Description of Stress

Stress is an automatic response of the body to various internal and external stimuli, consisting of psychophysiological and psychological (i.e. cognitive, affective, and behavioural) components (Everly & Lating 2019). Selye defined stress as "nonspecific response of the body to any demand upon it" (Selye 1974) cited in Schmidt et al. 2018). Stress is considered an unpleasant emotional state that people experience in situations that are perceived as very challenging or physically threatening (Lee et al. 2004), (Villarejo et al. 2012). A distinction must be made regarding the occurrence of stress in acute or chronic form. Acute stress refers to a temporary event, whereas chronic stress occurs due to prolonged and recurring demands of everyday life (Hemming 2015). It is generally associated with the action of the sympathetic nervous system (SNS) (Everly & Lating 2019). The SNS causes psychophysiological changes in the body, such as changes in heart rate, sweat gland activity and skin temperature (Everly & Lating 2019). Therefore, psychophysiological signals, including galvanic skin response and skin temperature, related to these activities can provide information about ANS activity (Cho et al. 2017; Seoane et al. 2014) and are considered reliable indicators of stress (Karthikeyan et al. 2013). This psychobiological representation of stress is particularly useful for research aimed at localising specific extrinsic stressors at specific time points. The increasing availability of low-cost and sophisticated measurement systems creates the basis for new research ideas to answer fundamental questions in emotion research (Wilhelm & Grossman 2010). The use of new technologies raises the question of the extent to which an activating effect is present and how this can be recorded. The measurement of psychophysiological parameters to determine the activation state appears promising for this.

Various psychophysiological parameters and parameter combinations can be used to objectively detect stress (Zangróniz et al. 2017). Previous approaches show that combining several psychophysiological signals does not guarantee the highest possible accuracy. However, most researchers have used galvanic skin response, mainly in combination with heart rate and skin temperature (Kyriakou et al. 2019). Kyriakou et al. (2019) developed and validated a rule-based algorithm to detect so-called moments of stress (MOS) based on galvanic skin response (also EDA) and skin temperature of the test subjects, using wearables for gold standard stress detection in real-life situations. This algorithm thus seems applicable for investigating the stress response of preservice teachers in VR classroom settings as the VR is supposed to portray a classroom setting which is as close as possible to reality while still offering the comparability of a test setting between different test subjects which is impossible to achieve in real classroom settings.

2.3 Stress-Recognition with Wearable Sensors

Psychophysiological measurements in everyday contexts are now realised with modern wearables that can record and store various signals from the body (electrodermal activity, temperature, heart rate, etc.). These signals reflect different cognitive and emotional processes that can be useful to understand how the user is thinking and feeling at a given moment. For example, an increase in electrodermal activity (EDA) has been associated with emotional arousal, cognitive effort, or stress (Leiner et al. 2012; Bailey 2017). Heart rate or heart rate variability reflects parasympathetic nerve activity associated with attentional focus and emotional regulation, and the electromyogram of specific facial muscles is useful for representing the hedonic valence of emotions experienced by a user (Leiner et al. 2012).

A significant facilitation for the recording of psychophysiological signals is the use of new sensor possibilities. In particular, wearable biosensors allow continuous recording of psychophysiological data with high temporal resolution and can be used for basic research, clinical applications or for daily routines in real-life situations (Schmidt et al. 2018). They do not require individuals to report on their current condition and are less disruptive as individuals can go about their normal routines. The rapid development of high-performance sensor technology has led to small and flexible wearable biosensors that form the basis for ubiquitous sensing. These biosensors can be valuable tools for detecting emotional or stress activation as they provide high quality data that is accurate, complete, relevant, timely, detailed, appropriately presented and contains adequate contextual information to support a decision-making process. However, the use of wearable biosensors in real-world experiments poses several challenges in terms of reliable and useful emotion recognition measurements. First, the sampling frequency should be sufficient to map the signal correctly. Second, proper placement of the sensor is critical to avoid ambiguity and accurately capture the psychophysiological signal. Thirdly, even if the sensor is placed correctly, the raw psychophysiological signals usually have many small fluctuations caused by the oscillations of the psychophysiological state of the human body. These fluctuations are inevitably recorded. Therefore, filtering the raw sensor signal is an essential task to eliminate the noise to ensure stress detection with high accuracy. Finally, it is not possible for researchers to control environmental factors in real studies. Consequently, isolating the effects of a stimulus is challenging. Despite all these challenges, a considerable number of studies have attempted to detect stress using wearable psychophysiological sensors, as is the case in this study.

In this study, an Empatica E4 wristband (Empatica Inc. 2020) was used to measure psychophysiological attributes of the subjects before and during the virtual phase. The following psychophysiological data were collected and analysed from the participants: EDA, ST and HR. To identify moments or intervals of stress from the collected data, the application of algorithms is required. An algorithm by Kyriakou et al. (Kyriakou et al. 2019) , which can be used to identify moments of stress (MOS) from EDA and ST data is described below (4.3 Measures and Instruments).

2.4 State of Research Teacher Stress

One of the most commonly used models to describe stress in the context of teachers and teacher education is the *Model of Teacher Stress* by Kyriacou and Sutcliffe (1978). Before conceptualising a framework for further research on teacher stress Kyriacou and Sutcliffe conducted a review on the main sources and manifestation of teacher stress while stating that the „need for careful empirical research using experimental designs, to investigate the specific factors implicated in teacher stress and the interrelations between such factors“ (Kyriacou & Sutcliffe 1977), p. 205). Main sources of teacher stress are for example teacher-pupil relationships, overload, poor human relations among staff, inadequacies of school buildings and equipment, teacher training, large classes, feelings of inadequacy as a teacher, status of the profession in society, difficult students, time pressure, interruptions and clerical duties, dealing with difficult pupils as well as general heterogeneity (ibid.).

After conducting this review on “occupational stress amongst teachers“ (Kyriacou & Sutcliffe 1978, p. 1) it was stated that teacher stress was on the rise. The model consisting of eight interconnected aspects was then constructed to conduct research on the topic based on a common ground definition as well as based on the study of occupational stress in general. In the model teacher stress is described

> „as a response of negative affect (such as anger or depression) by a teacher usually accompanied by potentially pathogenic psychophysiological and biochemical changes (such as increased heart rate […] resulting from aspects of the teacher’s job and mediated by the perception that the demands made upon the teacher constitute a threat to his (sic.) self-esteem or well-being and by coping mechanisms activated to reduce the perceived threat (Kyriacou & Sutcliffe 1978, p. 2).

The model distinguishes between potential (1) and actual stressors (3) of individual teachers leading to teacher stress (5) which is only the result if a potential stressor is perceived by teachers to be a threat to their self-esteem or well-being during a process of appraisal (2). This appraisal of stressors depends also on their individual characteristics (7) while the perception of lack of control seems to be a necessary condition for the occurrence of stress (Averill 1973; Kyriacou & Sutcliffe

1978). Depending on whether potential stressors are appraised to be actual stressors depending on the individual teacher characteristics, coping mechanisms (4) are used to deal with them. Teacher stress (5) results as negative affects response correlates when individuals are not able to cope with certain actual stressors. The response correlates can be behavioural, psychophysiological (e.g. high blood pressure, elevated heart rate) or psychological which then may lead to psychosomatic as well as psychophysiological chronic symptoms (mental ill health, coronary heart diseases (Kyriacou & Sutcliffe 1978)). Another level of this particular model of teacher stress is the incorporation of „feedback loops“ (ibid.). For example, it is possible that an actual stressor can be reduced to a potential stressor through using successful coping strategies.

The topic of teacher stress has become relevant to researchers who are for example interested in the actual stress of teachers in comparison to other professions (Ritvanen et al. 2003) teacher stress in connection with teacher health (Gluschkoff et al. 2016), or in connection with teacher characteristics (Bardach et al. 2023).

Ritvanen and colleagues measured and surveyed (n = 26) high school teachers (full-time and part-time) as well as gardeners (n = 12) and rescue workers (n = 13) in comparison over one year with four repeated measurements of psychophysiological data (Ritvanen et al. 2003). The data consists of questionnaires (job conditions, well-being, psychosomatic symptoms), perceived stress (visual analogue scale), neuroendocrine reactivity, electromyography of the trapezius muscle as well as blood pressure and heart rate (Ritvanen et al. 2003). The results show that full-time teachers show similar levels of stress on all days of measurements while stress is reduced during summer holidays. There is a significant decrease in psychosomatic symptoms, static muscle tension, blood pressure, perceived strain, and epinephrine level. As a conclusion Ritvanen et al. state that „[m]ore emphasis should be given to prevent psychophysiological stress among teachers as well as to develop stress coping methods, and part-time working systems to facilitate work ability of aging teachers“ (Ritvanen et al. 2003, p. 255).

McCarthy et al. (2016) assessed teacher appraisals and stress in the classroom. They use the CARD-tool (Classroom Appraisal of Resources and Demands) for assessing the teachers' risk for stress because appraisals are seen as key determinant of stress. Moderate effects for associations between CARD and job satisfaction and job commitment, burnout, resources for stress prevention, and challenging student demands were found (McCarthy et al. 2016).

Another study investigates the connection between perceived stress causes, stress responses, observed teaching behaviour and attrition of beginning teachers (N = 143). They use a questionnaire on Experience and Evaluation of Work-BT and structural equation modelling and show that perceived negative pupil aspects can be positively related to stress responses, perceived tension, discontent, and negative emotions (Harmsen et al. 2018). The authors attempt to provide options for more professional support for beginning teachers.

Through a review, the importance of a psychobiological approach to teacher stress is attempted in opposite to purely self-reported measurements by a psychobiological ambulatory assessment (AA) (Wettstein et al. 2021). They argue that classroom disruptions are a primary stress factor and early detection of teachers' health status is important for acting preventively.

Huang et al. (2022) compare physical and psychological stress reactions of preservice teachers in a VR classroom depending on the class size. They measure the psychophysiological stress reactions of the subjects (n = 65) through the heart rate as well as psychological stress reactions through self-reported acute stress immediately after the VR experiment. The results showed that both, average heart rate (psychophysiological stress) and subjective stress ratings (psychological stress) were significantly higher with the bigger class (Huang et al. 2022).

Westphal and colleagues (2024) used immersive VR teaching scenarios to research the connection between I-talk in written reflections on their own teaching in connection with stress during the actual teaching in a VR environment. Based on previous findings, I-talk or “self-focused attention” relates to stronger negative emotionality and in teaching reflection is related to negative classroom situations. Findings of a test setting with preservice teachers (N =59) show, that the use of the first-person singular pronouns (I, me, my) are a predictor of physiological stress reactions.

Klusmann and colleagues investigate teacher stress by assessing teachers’ (N = 1102) emotional exhaustion with the Maslach Burnout Inventory (Maslach et al. 1996) and students‘ achievement in mathematics with a standardized competencies test in order to show a negative relation of stress (in form of emotional exhaustion) and students’ achievements (Klusmann et al. 2016). A statistically significant association between teachers’ emotional exhaustion and students’ achievements could be shown. It was also shown that class composition (e. g. of language minority students) moderates the association between both aspects. Classes with higher numbers of language minority students show stronger associations between teachers’ exhaustion and students’ tests scores (Klusmann et al. 2016).

Junker and colleagues investigate the frequency and intensity of known classroom stressors (low student engagement and motivation, negative teacher-student relationship and interactions, teacher-centred activities) by tracking (N = 40) teachers’ heart rates during a lesson (Junker et al. 2021). Using multilevel regression analysis, the authors predicted the teachers’ heart rate depending on different classroom stressors. They could show that low engagement and motivation on the students’ side and teacher centred activities predict an increase of the teachers’ HR while still finding individual differences between the teachers (Junker et al. 2021).

Another study with focus on teacher burnout caused by work stress focuses on the role of recovery as mediating mechanism between teacher stress an burnout (Gluschkoff et al. 2016). Teachers (n = 76) at Finnish primary schools completed surveys on burnout using the Maslach Burnout Inventory, on work stress by conventionalising the effort-reward imbalance model (ERI), and on recovery with the Recovery Experience Questionnaire and Jenkins Sleep Problems Scale. The result of a multiple linear regression show that high ERI is associated with burnout and reduced professional efficacy (Gluschkoff et al. 2016).

Another study focused on the recording of HR and self-reports of perceived stress during two working days of (N = 35) teachers at the beginning of the school year using gender as modulator of the variables (Serrano et al. 2008). HR and perceived stress were higher during the working days and when interacting with students and both variables increased at the end of the school year (Serrano et al. 2008).

Maué and colleagues try to identify different types of trainee teachers’ stress and work experience profiles in Germany (Maué et al. 2023). One aim is to detect differences in the profiles regarding dropout rate during teacher training and regarding the perceived relationship between teacher trainees and their mentors.

Voss and Kunter (2020) take a closer look at the “reality shock” of beginning teachers during their first years at school based teacher induction. 163 mathematics teachers participated in the study for three points of measurement. A significant decrease in constructivist beliefs we found as well as an inverted U-shaped change of the emotional exhaustion of the teacher. The exhaustion can be related to stress.

In general, it can be stated, that research on teacher stress spans across a wide range of methods, research foci (causes for stress, stress measurement, stress recovery) as well as disciplines (e.g. medicine, psychology, educational science). Thus, teacher stress as one form of occupational stress is a topic of interest for research initial teacher training as well as further education of teachers to prevent drop-out, burnout and negative learning outcomes for students.

2.5 Motivation for the Study

Based on the outlined theory and research behind the use of 360° video in VR in teacher training and teacher stress, the application of VR poses the opportunity to experience presence or emotional involvement in reality-like classroom situations. In the context of case-based learning for classroom interactions in teacher training, 360 ° video in VR should be researched with the question of how realistic the situation is experienced by its users thus possibly allowing a transfer of trained action-related competences in the classroom. So far, no research with focus on stress-experience in connection with 360° videos in VR (with its reduced interaction possibilities in comparison to fully immersive VR) could be found. Gaining insights into the benefits of the use of technology can be attempted by, on the one hand, retrospectively asking participants after the VR experience through questionnaires with technology-use related questions. This has been done by researchers and shown high scores for perceived presence and immersion (Kunz & Zinn 2022). On the other hand, if the training situation in VR is close to or resembles as real-life classroom situation to a certain extent, emotions as a response to challenging classroom situations should be detectable. Thus, if 360° videos in VR generate realistic reactions in future teachers, the emotional state of the users should be influenced by the behaviour of the students in the classroom. Disruptive behaviour and disregard for the cues as well as teacher centred situations should lead to stress reactions in the video viewers. At the same time, a different level of teaching experience could play a role at how high the stress experience and hence how many Moments of Stress could be detected This appears to be of interest, because training possibilities for action-related knowledge of pre-service teachers is mostly reserved to internships and professional training after the university degree. However, during these training possibilities, there are a lot of overlapping factors besides teaching (e.g. the internship setting, strains of being watched and graded during teaching, the real consequences resulting from one’s actions with real students). The present study aims to explore, whether the 360° classroom situations in VR can be used to train pre-service teachers for stressful teaching situations. This is attempted by objectively measuring psychophysiological stress responses of the subjects in the form of MOS to determine the applicability of the training environment for initial teacher training at the university.

3 Research Questions

Based on the current state of research, further investigation in the field of teacher stress in connection with realistic teacher training situations in VR seems indicated because teacher education and training strive to help future educators to prepare for challenging situations and a reality shock while acting professional (Westphal et al. 2024; Bardach et al. 2023; Voss & Kunter 2020). To find out whether 360° classroom videos in VR are a suitable training tool for preparing for real life classroom situations within a protected space, it is of interest to also investigate the psychophysiological indicators of stress that occur during teacher training sessions in the virtual 360° classroom situations. Two aspects appear to be of specific interest in this context. Firstly, the question if pre-service teachers with more teaching experience (or experience at all) react differently to the stressors within the classroom scenes than those without any experience. Previous studies on perceived stress of beginning teachers showed a significant reduction of stress after the first year of teaching (Voss & Kunter 2020). Secondly, previous research identified various sources of teacher stress as explicit stressors such as teacher-centred situations or student misbehaviour (Junker et al. 2021). Therefore, an analysis of detected stress reactions regarding the quality of the stressor seems indicated, to get a more nuanced picture of the stress reactions (or patterns) of test subjects within the VR classroom. To do so and based on previous research in the field of teacher stress and virtual classroom scenarios (using psychophysiological measures and virtual simulations), which show that while experiencing fully immersive VR teaching scenarios, pre-service teachers experience stress in association with stress-inducing events such as disruptive student behaviour or teacher-centres situations (Bardach et al. 2023; Huang et al. 2022; Junker 2023), the following research questions are proposed:

RQ 1 How does stress differ between participants regarding their teaching experience?

RQ 2 How do stress patterns differ regarding the different classroom scenes and thus different stressors?

4 Method

The following chapter describes the methodological procedure for data collection and processing within this mixed-methods approach. A description of the sample (4.1 Participants) is followed by a description of materials and equipment used (4.2), followed by measures and instruments (4.3) and finally a description of the study procedures and classroom scenes (4.4) and data processing (4.5).

4.1 Participants

The sample consists of altogether N = 16 participants who are students in a university degree in vocational technical education or STEM for a teaching degree at the University of Stuttgart. The participants were recruited via information in university courses about the possibility of participating in the study as part of the course work due to the close connection between course content (focus on dealing with heterogeneity in the classroom) and the study’s focus on classroom situations in VR.

The average age of the participants is 25.81 years (SD = 4.98, Min. = 22, Max. = 38) and 7 of them had previous practical teaching experience. Practical teaching experience means a mandatory internship of six weeks (bachelor’s level) or four weeks (master’s level) at a vocational school, that the participants either already completed or were completing during the semester. Previous teaching experience should be taken into consideration as a possible moderating factor of the stress responses. Research showed that students with teaching experience rated virtual teaching environments as less useful and perceived less presence during teaching sessions in VR (Kunz & Zinn 2022). Most participants (n = 11) were enrolled in a master’s level course of studies in vocation technical education or STEM education, while 5 participants were Bachelors’ level students in vocational technical or STEM education. All participants were invited to participate in the test setting once for approximately 45 minutes each.

4.2 Material and Equipment

The participants watched and reacted to five different short classroom scenes (*Test Scene, Scene 1*, *Scene 2*, *Scene 3*, *Scene 4*) via HMD (Oculus Go and Headphones or Meta Quest 2). The content of each scene is briefly described in section *4.4.1 360° Classroom Scenes*.

The 360° classroom videos were shot with university students working at the Department for Vocational Education focused on Teaching Technology at the University of Stuttgart as actors. A script was written beforehand trying to capture typical, every day like challenging classroom situations at a vocational school according to experience of the authors, teachers and literature on effective teaching and classroom management (Sabornie & Espelage 2023; Grub et al. 2020). The script was written and revised according to feedback given by two experienced teachers of vocational education and according to practical constraints of the facilities and participants (actors) involved.

4.3 Measures and Instruments

The participants' psychophysiological (stress) reactions were measured during the video watching and reacting with the E4-Empatica wristband (Empatica Inc. 2021). The wristband has sensors which measure blood volume pulse (BVP for heart rate), EDA (for changes in electrical properties of the skin), 3-axis accelerometer, and infrared thermopile (for ST or skin temperature) (Empatica E4 Wristband). The collected data was analysed using the Moments of Stress (MOS) Algorithm (Kyriakou et al. 2019) which is described in detail in section *4.3.2*. The MOS-data is then analysed descriptively to provide a detailed quantitative description of the small sample size.

4.3.1 Psychophysiological Signals

The galvanic skin response (GSR), also called skin conductance (SC) or electrodermal activity (EDA), is a biomarker of the activation of the sympathetic nervous system and is considered one of the most sensitive and valid markers of emotional arousal (Christopoulos et al. 2019; Everly & Lating 2019). When emotional arousal is high, sweat secretion is strongly activated. Increased emotional arousal triggers significant sweat secretion, which can be accurately and easily measured with an EDA sensor on the hands and feet (Fathullah & Willis 2018). EDA is the most used physical response system in psychophysiological studies. The reason for this lies primarily in its relatively simple measurability, low cost and comparatively clear correlation with some key psychological phenomena. These include activation, attention, information processing and emotional reactions (Dawson et al. 2007). A particular advantage of the EDA over other psychophysiological measures is its comparatively valid indication of the activity of the sympathetic nervous (SNS) through skin conductance, specifically via eccrine sweat gland activity (van der Mee et al. 2021). EDA can thus track cognitive and emotional processes influenced by media particularly in response to negative stimuli (Lang et al. 1996). However, a study by Codispoti et al. showed that positive and negative film stimuli lead to similar SCLs (Codispoti et al. 2008). Thus, the valence of the emotional response does not seem to play a role in EDA, which is why it is associated with emotional arousal regardless of valence (Potter & Bolls 2012). Therefore, the respective electrodermal response must always be interpreted in relation to the respective stimulus or experimental design (Ravaja 2004). The measurement of EDA is therefore only suitable for explorative designs to a limited extent.

Skin temperature (ST), typically ranging from 32°C to 35°C (Quazi et al. 2012), can be easily and reliably measured using a temperature sensor in contact with the skin (Alberdi et al. 2016), and is extensively utilized in emotion recognition research. However, there is uncertainty about the effects of stress on skin temperature. Some studies confirm that skin temperature increases in the presence of stress (Kaklauskas 2015), while other studies find that skin temperature decreases under stress (Cho et al. 2017; Hui & Sherratt 2018; Zhang et al. 2016).

Heart Rate (HR) is a widely recognized marker of psychophysiological stress reactions, with research highlighting its significance (Huang et al. 2022; Bodie 2010) Elevated HR has been observed in high-stress work environments (Galy et al. 2012; Huang et al. 2022), and first indicators suggests a similar trend among teachers during classroom activities (Serrano et al. 2008; Ritvanen et al. 2003; Junker et al. 2021).

4.3.2 Description of the Moments of Stress Algorithm

Kyriakou et al. (Kyriakou et al. 2019) developed an algorithm to detect moments of stress (MOS) in real/life situations based on five rules applied to psychophysiological data (EDA and ST) collected through a wearable sensor wristband. Each rule has associated critical values for three degrees of fulfilment: complete fulfilment (condition for score 1), partial fulfilment (condition for score 0.5) and no fulfilment (condition for score 0). The algorithm is currently described as a "gold standard" for detecting MOS in psychophysiological data as response to stressors (Kyriakou et al. 2019).

Tab. 1: Description of the five rules for detecting moments of stress with psychophysiological data according to and adapted from Kyriakou and colleagues (Kyriakou et al. 2019).

Rule	Detected Signal and Feature	Value: 1 Condition	Value: 0.5 Condition	Value: 0 Condition
1	EDA Increase time (t)	$[EDA_t : EDA_{t+n}]' > 0$ where $2 \leq n \leq 5$	$[EDA_t : EDA_{t+n}]' > 0$ where $5 < n \leq 8$	$[EDA_t : EDA_{t+n}]' > 0$ where $n < 2$ and $n > 8$
2	ST Decrease (T)	$[T_{t+3}: T_{t+m}]' < 0$ where $m > 3$	$[T_{t+2}: T_{t+m}]' < 0$ where $5 \leq m \leq 6$	$[T_{t+3}: T_{t+m}]' < 0$ where $m < 3$
3	EDA Rising time (t)	$1 \leq t_{peak} - t_{onset} \leq 5$	$5 < t_{peak} - t_{onset} \leq 15$	$t_{peak} - t_{onset} > 15$
4	EDA Response slope	$\frac{EDA_{peak} - EDA_{onset}}{t_{EDA_{peak}} - t_{EDA_{onset}}} \geq 10°$	$\frac{EDA_{peak} - EDA_{onset}}{t_{EDA_{peak}} - t_{EDA_{onset}}} \geq 8°$	$\frac{EDA_{peak} - EDA_{onset}}{t_{EDA_{peak}} - t_{EDA_{onset}}} < 8°$
5	Time difference (t) between MOSi and MOSi+1	$t_{MOS_{i+1}} - t_{MOS_i} \leq 10$ s	-	$t_{MOS_{i+1}} - t_{MOS_i} > 10$ s

The first rule of the algorithm concerns the duration of increase of the EDA (EDA Increase) and assigns the score 1 if it increases from two to five seconds, score 0.5 if it increases from five to eight seconds and score 0 if it increases from zero to two or for more than eight seconds (Kyriakou et al. 2019).

The second rule concerns the decrease of skin temperature (ST Decrease) and assigns the three different scores depending on the delay after EDA Increase and the duration of the decrease of the skin temperature. Score 1 is assigned for ST Decrease three seconds after EDA Increase and a duration of more than three seconds. Score 0.5 is assigned for ST Decrease two seconds after EDA Increase and a duration between five and six seconds. Score 0 is assigned for ST Decrease three seconds after EDA Increase and a duration of more less than three seconds (Kyriakou et al. 2019).

The third rule concerns the EDA Rising Time which means the time difference between a local minimum and local maximum or measures EDA values. A score of 1 is assigned for a value from one to five seconds. A score of 0.5 is assigned for a value from five to fifteen seconds and a score of 0 is assigned for a value of more than fifteen seconds (Kyriakou et al. 2019).

The fourth rule is called EDA Response Slope, and its features are the degrees of slope which means that a score of 1 is assigned the ratio between amplitude and rising time is equal to or bigger than ten degrees. The score of 0.5 is assigned for a ratio that is equal to or bigger that eight degrees and the score of 0 is assigned for a ratio smaller than eight degrees (Kyriakou et al. 2019).
The fifth and last rule called MOS Duration only assigns the scores 1 and 0. The score of 1 is assigned for a duration equal to or smaller than ten seconds. If the MOS has a duration of more than ten seconds the score of zero is assigned (Kyriakou et al. 2019).

The signals obtained are recorded at 4 Hz or 1 Hz. To obtain one value per second for the 4 Hz data, the average of the four values is calculated which makes it possible to compare the signals in the frequency range. The algorithm evaluates the rules and assigns a score (0, 0.5 and 1) at 1 Hz intervals and then multiplies the scores by the weight of each rule. The total score (TS) for one second is calculated as follows: $TS = \Sigma(sc * wn)$ (Kyriakou et al. 2019).

Here *sc* is the score assigned to the rule and *wn* is the associated weight of the rules and Σwn equals 100. A TS score of 100 is maximum when all rules are scored as "1" and therefore, $0 \leq TS \leq 100$. They defined 75 as the critical score (CS) to identify MOS. The algorithm thus works as a binary classifier if TS is greater than CS, a MOS is detected and the value "1" is assigned to the second. The accuracy of MOS detection is 84 % (Kyriakou et al. 2019).

The described algorithm for detecting MOS is intended to bridge the gap between stress detection in controlled laboratory settings with pre-defined stressors towards detecting stress in a real-world environment. In our case, detecting stress in reality-like classroom setting experience via 360° videos in VR also addresses this dichotomy of stress-measurement because the algorithm is here used in a laboratory-like setting with the possibility and intent to use it in real classroom situations. As a first step, it makes sense to test for suitability of the algorithm in the test situation to identify future possibilities of use.

4.4 Procedures and 360° Classroom Scenes

In the following section, the content of the different classroom scenes and intended stressors is described (*4.4.1*), followed by a brief description of the procedures (*4.4.2*) of the study.

4.4.1 360° Classroom Scenes and Stressors

The five different 360° classroom scenes in VR are embedded in shorter introductory 360° videos which are set in the same room as the actual scenes only without students. The introductory videos for the scenes give a narrated context of the following classroom situation (e.g. “You are the teacher in a small afternoon class at a vocational school. The class starts right after lunch break and the students were supposed to hand in their maths homework before the beginning of the lesson. Please start the lesson as if you were the teacher.”). After each classroom scene there is a reflection scene which is also set in the same classroom. The first video gives an introduction and context to the test setting and the upcoming videos and consist of the task. The general setting is a vocational school with a small class with students that need additional lessons and training in the afternoon. The lesson is basic maths revision (simple fractions) and the participant watching the videos is the only teacher in the room, which means the participants are positioned as the teacher in the 360° classroom video in VR and there is no other person acting as teacher. The students in the room have name plates in front of them.

All participants have a background in vocational technical or STEM education and therefore all participants have sufficient knowledge about the content of the classroom scene (here: simple fractions) through their course of studies as well as they need basic mathematics for their individual subjects like mechanical engineering, physics, electrical engineering, etc.

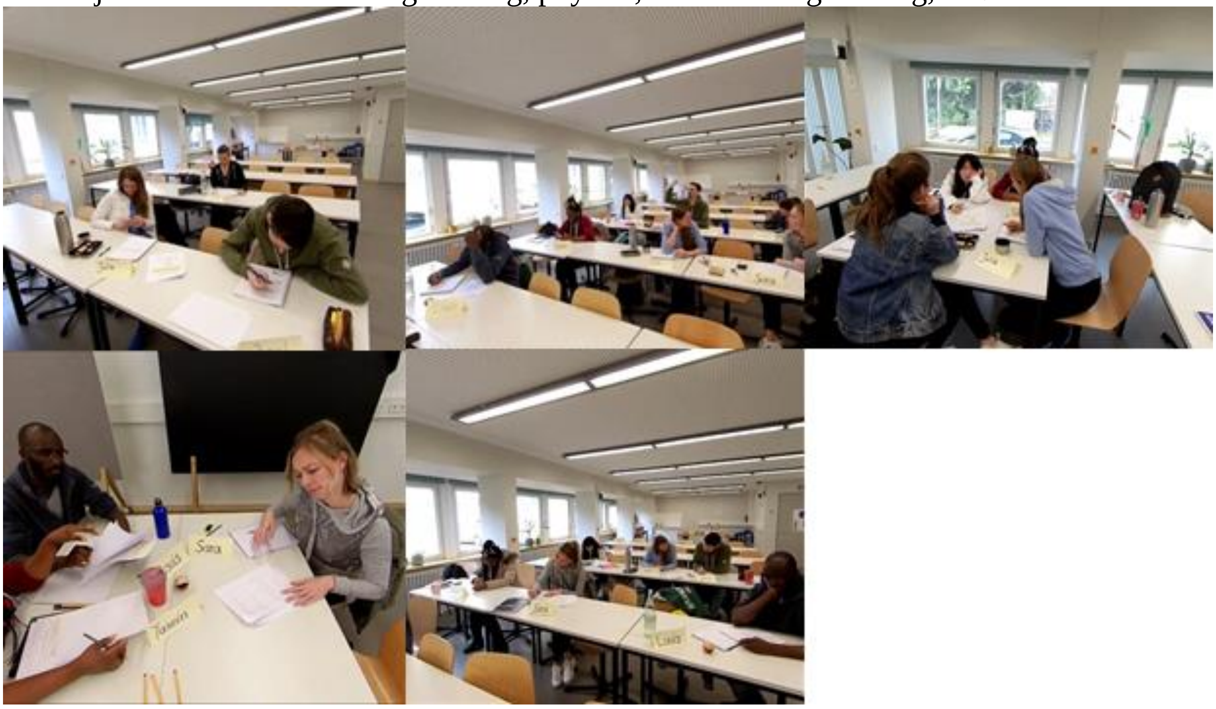

Fig. 1: Screenshots from the five different classroom scenes. From top left to bottom right: Test Scene, Scene 1, Scene 2, Scene 3, Scene 4 (own images).

The contents of the classroom scenes were scripted based on typical challenging classroom situations according to research on teacher stress such as low student engagement and motivation, student misbehaviour, or teacher-centred activities (Junker et al. 2021; Huang et al. 2022). The scripted scenes were discussed with three experienced teachers (n = 3) in the field of vocational and technical education and adapted according to the experts' feedback. A pilot trial of the classroom scenes with student research assistants working at the department was conducted after the videos were recorded. Feedback from the pilot study was incorporated into the final testing sequence such as giving clearer instructions in the introductory videos and help with orientation in the virtual classroom. In addition, during the pilot session, all classroom situations were comprehended in the intended way by the participants which indicates that the scripting and intention of the scenes developed with experts were transferred into the video scenarios.

The following section depicts a brief description of the content of all classroom scenes which include all intended and possible causes of stress (stressors) of the scenes according to research findings could cause stress in teachers (disruptive student behaviour, low student engagement and motivation, teacher-centred situations). Each scene contains 4 intended stressors. The stressors are categorized into two categories depending on the one side whether they cause a mainly teacher-cantered reaction, meaning that the situation is not necessarily problematic or caused by misbehaviour but mainly need a teacher to act for the class to continue (e. g. answer a student's question or ask for the homework). Or on the other side whether the stressor is based on student misbehav-

iour of some sort (e. g. disruptive behaviour). Research findings suggest that teacher-centred situations cause higher levels of stress in the classroom as well as student misbehaviour (Junker et al. 2021). All other MOS which do not occur with a stressor are categorized as category *z* to indicate stressors which appear not in relation to intended stressors (e. g. at the beginning of the video or at the end, when the video stops).
Test Scene: The scene contains a short scenario in an extra training course in the afternoon for three students who are supposed to solve maths exercises individually. One student (Julia) in the front row in the left (see figure 1 top left) openly tells the teacher and everyone else that she is done with the exercises and that these exercises are simple (*stressor 1)*. She then goes on and asks the other two in the room, if they are not done yet because the tasks are very easy (*stressor 2*). She keeps asking the other two students why they are not done yet because the exercises are far too simple (*stressor 3*). Then she goes on and tells them part of the solution and then turns to her smartphone because she says she is bored (*stressor 4*).
Scene 1: The scene is set right at the beginning of lesson right after lunch break of a small group of seven students in a special training class for students with learning deficits at a vocational school. When the bell rings to initiate the lesson, two students are still standing at the side of the classroom having a loud conversation about last weekend's events (*stressor 1*). After some time, they all sit down but keep talking (*stressor 2*). One student in the back keeps eating and lets the teacher know that she put her maths homework on the table (*stressor 3*). Two students from the back start teasing one student in the front row (Louis) and throw paper balls at him calling his name (*stressor 4*).
Scene 2: The scene is set in the same classroom with the same group of seven students but now they are split into two groups for a group work (stressor 1). The left group shows no signs of problems and works calmly together in a concentrated manner. The right group of three does not work together (*stressor 2*). Louis tries to get the group work started but the other two opposite him just ignore him and work together excluding him (*stressor 3*). After that Louis is frustrated and does not want to work in the group anymore (*stressor 4*).
Scene 3: It is a group work setting with one group on the left that is cooperating very well. The group on the right consisting of three people is unsure of how to start the exercise and thinks about splitting up the individual tasks (*stressor 1*). After a moment of rereading the task one student decides for the rest who should do which exercise after which another student disagrees with him (*stressor 2*), and they continue a discussion in a different and unintelligible language (*stressor 3*) which Sara does not understand and is excluded from (*stressor 4*).
Scene 4: The last scene is set in the same classroom with the same seven students completing revision tasks on their own. One student has problems with the exercises and then raises his hand (*stressor 1*) and asks the teacher for help with the task (*stressor 2*). After that, two students in the back start talking about the student and making fun of him (*stressor 3*). The student in the front reacts angrily towards them (*stressor 4*).

4.4.2 Procedures

Before watching the 360° classroom videos in VR and reacting to them as a teacher, the participants were thoroughly instructed about the technology in use (HMD Oculus Go or Meta Quest 2) and the navigation of the videos as well as their rights while participating in the study and afterwards. All participants gave written consent to participate and to data collection. The E4-Empatica wristband was put on the participants' wrists in advance of the test session to calibrate a baseline. When the video-session was started an event was marked via a button on the E4-wristband to enable a mapping of the measured psychophysiological data with the participants' collected video data (they were videotaped while watching the videos and reacting to them). The participants altogether watched 17 short videos (ranging from 19 seconds to 1 minute and 56 seconds) including introductory videos, reflexion videos and an outro. The core of the video-sessions consists of 5 classroom-scene consisting of the described *Test Scene* and four following classroom scenes (*Scene 1-4*) (described in section *4.4.1*) with an average length of 01:38 minutes (min. = 01:16, max. = 01:56). The participants were instructed to react like a teacher (e.g. verbally) to the different classroom scenes while experiencing the situation from a first-person perspective via HMDs. After watching all five scenes and reflecting upon their own reaction verbally after each video, the participants ended the videos session and filled out an online survey on aspects of technology acceptance, immersion, and presence as well as open format questions on usability for teacher training and potential for improvement of the video's scenarios. The test-sessions lasted between 30 and 45 min including an introduction, written consent for participation, calibration of the wearable sensor device watching videos and reacting to them, verbal reflexion of each video sequence and subsequent completion of the survey.

4.5 Data Processing and Statistical Analysis

The MOS-Algorithm (Kyriakou et al. 2019) was adapted to our data structure and applied for processing the psychophysiological data (EDA and ST). The program was executed on Python 3.11.3 using the packages *NumPy* (Harris et al. 2020) and *Pandas* (McKinney 2010). The MOS were quantified with respect to the corresponding scene and/or action of the participants at the moment of the occurrence of the MOS using the Software Mangold Interact and Data View (Mangold International GmbH 2023). We connected the psychophysiological data (EDA and ST) as well as the detected MOS to the collected video data. In detail this means, that the video material of each participant consists of two separate videos which were synchronised. The first video shows the outside perspective of the participant including the verbal reactions (see Fig. 2 middle). The second video recorded the perspective of the participant through the HMD which also includes the head movements and the focus each participant chose in the scene (see Fig. 2 right). The synchronised videos were then mapped to the collected psychophysiological data and MOS data. This was possible via time stamps and event markers in the psychophysiological data and the corresponding videos. For each participant, the synchronised videos and data were then used to ascribe a MOS to the specific situation within each scene and thus corresponding stressor due to its occurrence at the same time. This way, we can associate each MOS with the event (e. g. stressor, beginning of scene) within the classroom scene and the corresponding reaction of the participant (e. g. the active verbal response to the students).

Average HRs were calculated for each MOS and compared to average baseline HRs before the testing using the Mann-Whitney U Test of mean values. This was done in order to see if other methods of stress detection used in research provides comparable results with the collected data (Huang et al. 2022). Other studies only used HR as indicator for stress in teachers. The HR evaluation was performed in R 4.3.1 using the package *dplyr* (Wickham et al. 2023) for data preparation. The Mann-Whitney U Test was used to compare the data of HR of individuals before testing (baseline) and during a MOS to determine, if significant differences between both HR values could be detected. The test was chosen because normal distribution of the HR values could not be assumed and due to the small sample size ($N = 16$) a non-parametric test is the more robust option (McKnight & Najab 2010).

A descriptive analysis of the detected MOS was conducted such as statistical testing for correlations with related constructs such as if previous teaching experience in real life had any impact.

To further answer RQ 1 and RQ 2 the MOS were analysed qualitatively depending on the subgroup (with/ without teaching experience) and depending on which stressor the MOS appears in association with. This was done to gain more detailed insights into the occurrence of MOS in connection with other variables such as previous classroom experience and concrete stressor/scene because teaching experience can be seen as moderating variable for perceived stress in the classroom.

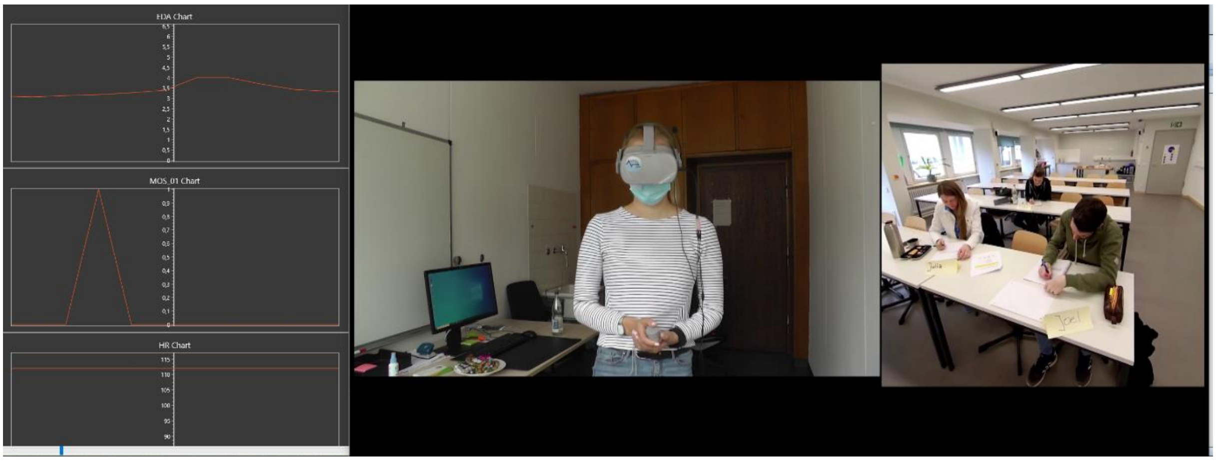

Fig. 2: Analysis of psychophysiological data of a participant experiencing a MOS detected by the algorithm and visualised and synchronised via Mangold Data View (left) synchronised with the recording of a participant watching the Test Scene (middle) and recording of the HMD of each participant (right) (own images).

5 Results

In the following, the results of the data analysis of the collected psychophysiological data are reported in correspondence with the afore mentioned research questions. Following the descriptive results of all measured MOS, the analysis of MOS-patterns in relation to subgroups with/without experience (RQ 1) and in correlation with stressors is described (RQ 2).

5.1 Descriptive Results

All individuals showed MOS while watching or reacting to the 360° classroom video sequences with a total of N = 63 MOS over all 16 participants. The average amount of all MOS per scene is 12.60 (Min = 10, Max = 15, SD = 2.93) (see Tab. 2). The average amount MOS per participants across all scenes is 3.94 (Min = 1, Max = 9, SD = 2.49). This indicates that that the algorithm is in general sensitive to detection of psychophysiological correlates of stress-inducing events during VR classroom sessions.

The detected MOS were categorised into *active* and *passive* depending on the participants' behaviour during the MOS occurrence. *Active* meaning that the participants were either actively moving their body, gesturing and or verbally reacting to the different classroom stressors. *Passive* meaning that the participants showed no movement, gesturing and or verbal reactions during the MOS. More MOS were detected in the active category (n = 36) compared to the passive category (n = 27). The scene with most MOS is *Scene 1* (n = 15) followed by the *Test Scene* (n = 14) and *Scene 2* (n = 14). The other two scenes show less MOS (*Scene 4:* n = 12, *Scene 3:* n = 10). This shows that on the one hand technological effects need to be considered as well as a novelty effect during the *Test Scene* and *Scene 1* because of the relatively higher number of MOS in comparison to the last scenes even though the number of intended stressors and length of scene are the same or close to the same across scenes.

On average, the participants spent 1389 seconds in the test scenario (wearing the HMD and watching the intro scenes, scenes and reflection scenes) (Min = 1201, Max = 1737, SD = 125). The difference in duration between the participants mainly results from the different amount of reflection time as participants are not restricted in how long they should reflect upon each previous classroom situation. The classroom scenes are all the same length between participants. All classroom scenes together have a duration of 477 seconds (Min = 76, Max = 116, SD = 14.81). This means that the experience of classroom scenarios is in general comparable in between test subjects and difference in participation time in VR stem from introductory videos or reflection which is not part of the stress measurement. Thus, the detected MOS across all test subjects indicate a comparability of the use of the VR technology with different test subjects.

Tab. 2: Detected MOS during classroom scenes

	MOS 16 Participants	**MOS 5 Scenes**	**Active Scenes**	**Passive Scenes**	**Test Scene Participants**	**Scene 1 Participants**	**Scene 2 Participants**	**Scene 3 Participants**	**Scene 4 Participants**
Mean	3.94	12.60	7.20	5.40	1.40	1.36	1.56	1.25	1.67
Median	3.50	14.00	6.00	4.00	1.00	1.00	2.00	1.00	1.50
SD	2.45	2.15	2.14	2.65	.49	.48	.50	.43	.75
Var.	6.60	5.80	5.70	8.80	.27	.25	.28	.21	.67
Min.	1.00	10.00	6.00	2.00	1.00	1.00	1.00	1.00	1.00
Max.	9.00	15.00	11.00	9.00	2.00	2.00	2.00	2.00	3.00
Sum	63.00	63.00	36.00	27.00	14.00	15.00	14.00	10.00	10.00

To cross-validate the detected MOS, the average HR of all participants was calculated for the baseline HR before the test setting and for each MOS event that occurred. The average HR for the MOS was calculated by taking the average HR during the 25 seconds during the occurred MOS according to the MOS algorithm. The average HR values of the baseline were compared with the average HR during the MOS using a Mann-Whitney-U test. Out of the 63 Mann-Whitney-U tests for alle MOS during the classroom scenes, most of them, 51%, is positively significant (n = 32), while only 8% (n = 5) of those with a positive difference in average HR are not significant. This means that the mean HR during the experienced MOS is significantly higher than the mean baseline before the test setting. There are also some results which show a negative significant difference in HR with 30% (n = 19) and 11% (n = 7) which show a non-significant negative HR difference. This means that the baseline HR was higher that the HR during the MOS (appendix tab. 5 and 6).

Tab. 3: Detected MOS in total and according to scenes corresponding to participants (N = 16), cross-validated MOS via Mann-Whitney-U-Test of HR difference in brackets. * Indicates participants with previous classroom experience.

Partici-pant	MOS Scenes	Test Scene	Scene 1	Scene 2	Scene 3	Scene 4
P1	9(7)	2(2)	1(1)	2(1)	1(1)	3(2)
P2	1(0)	0	1(0)	0	0	0
P3	1(0)	1(0)	0	0	0	0
P4	5(4)	0	2(2)	0	2(2)	1(0)
P5	4(3)	0	1(1)	2(1)	1(1)	0
P6	4(4)	1(1)	1(1)	2(2)	0	0
P7	7(2)	2(1)	1(0)	2(0)	1(0)	1(1)
P8	2(0)	0	1(0)	0	1(0)	0
P9	3(3)	0	1(1)	0	0	2(2)
P10*	1(1)	0	0	1(1)	0	0
P11*	4(4)	2(2)	1(1)	1(1)	0	0
P12*	8(4)	2(2)	2(1)	1(0)	1(0)	2(1)
P13*	6(4)	1(1)	2(0)	2(2)	0	1(1)
P14*	4(2)	1(0)	1(1)	0	2(1)	0
P15*	1(1)	1(1)	0	0	0	0
P16*	3(0)	1(0)	0	1(0)	1(0)	0

5.2 Detected MOS and Teaching Experience (RQ 1)

The number of MOS detected within the group without classroom experience (n = 9, P1-P9) accumulated to a total of n = 36 during the classroom scenes (see Tab. 3). The group with classroom experience (n = 7, P10-P16) experienced n = 27 during the classroom scenes. This results in an average MOS of 3.86 for the more experienced group and 4.00 for the beginner group. A group difference cannot be calculated for this sample size due to the low statistical power. Further research to determine a difference between novices and more experience future teachers is indicated.

5.2.1 Analysis of MOS and Teaching Experience: Test Scene

The subgroup with teaching experience is responsible for n = 8 of the n =14 MOS in total of the Test Scene. Out of these n = 2 are active MOS and n = 6 passive MOS at the beginning.
The subgroup without teaching experience is responsible for n = 6 (of the n = 15 MOS). Three of these occur at the beginning of the scene, when the student tells everyone that she finished the task (n = 3, passive). Three of them are active MOS (n = 3 active).

5.2.2 Analysis of MOS and Teaching Experience: Scene 1

The subgroup with teaching experience is responsible for n = 6 of the n =15 MOS in total of Scene 1. Out of these n = 4 are active MOS and n = 2 passive MOS at the beginning.
The subgroup without teaching experience is responsible for n = 9 MOS out of which n = 2 are passive MOS and n = 7 active.

5.2.3 Analysis of MOS and Teaching Experience: Scene 2

The subgroup with teaching experience is responsible for n = 6 of the n =14 MOS in total of Scene 2. Out of these n = 4 are active MOS and n = 2 passive MOS during the scene.
The subgroup without teaching experience is responsible for n = 8 MOS of which n = 3 are active and n = 5 are passive MOS.

5.2.4 Analysis of MOS and Teaching Experience: Scene 3

The subgroup with teaching experience is responsible for n = 4 of the n = 10 MOS in total of Scene 3. All of them are active MOS.
The subgroup without teaching experience is responsible for n = 6 of the MOS with n = 2 passive MOS and n = 4 active MOS.

5.2.5 Analysis of MOS and Teaching Experience: Scene 4

The subgroup with teaching experience is responsible for n = 3 of the n = 10 MOS in total of Scene 4. Out of these n = 2 are active MOS and n = 1 is a passive MOS at the beginning.
The subgroup without teaching experience is responsible for n = 7 MOS with n = 3 passive and n = 4 active MOS.

5.2.6 Summary of the Analysis of MOS and Teaching Experience

More MOS were detected in the group without classroom experience. Altogether, the MOS appear to be distributed without a specific pattern. A very slight tendency could be seen in the Test Scene in which the more group with experience showed comparably more MOS and especially more passive MOS than in later scenes. The novelty of the technology, the beginning of the test setting as well as the effect of getting used to the scenes needs to be considered.
The group without experience shows a tendency to show more active MOS.
All of these findings have to be seen with regard to the small sample size which only allows explorative

5.3 Analysis of MOS Patterns and Stressors (RQ 2)

In the following section, a qualitative analysis of MOS Patterns will be attempted with focus on the different scenes and thus different stressors of the video scenario (*5.2.1 - 5.2.5*). The description of each scene consists of stress patterns differing regarding the different classroom scenes and thus four different stressors and tasks for the subjects (e. g. quality of the stressors such as teacher centred or disruptive student behaviour) and active or passive MOS of test subjects (see Tab. 4).

5.3.1 Qualitative Analysis of MOS Patterns and Stressors: Test Scene

In total there are n = 14 MOS during the *Test Scene*. Participants reacted actively verbal (n = 5) or were passively observing the scene (n = 9). The active MOS (n =5) occurred while reacting and interacting with the one student in the scene that was distracting the others during a task (n = 3 stressor 2, student misbehaviour) or when the student takes up the phone (n = 1 stressor 4; n = 1 stressor 3, both student misbehaviour). The nine passive MOS either occurred right at the beginning of the scene (n = 4) when the participants oriented themselves in the virtual classroom (stressor z) or while observing the student who was distracting the others (n = 5) (n stressor 1).
Overall, it can be stated that passive MOS occurred either at the beginning of the scene when the participant gets freshly confronted with the situation and task to act as teacher in the classroom or during the actual stressors. All active MOS occurred during one of the described stressors.

5.3.2 Qualitative Analysis of MOS Patterns and Stressors: Scene 1

In total n = 15 MOS occurred during *Scene 1*. Out of these, n = 11 occurred while participants verbally, actively reacted to classroom situation they were in. Most of the active MOS occurred at the beginning of the scene (n = 6) when participants asked the students to calm down, sit down, and get ready to start the lesson (stressor 1, teacher centred). Three MOS (n =3) occurred when two students distracted one other student in the front and the participants intervened (stressor 4, student misbehaviour). Finally, two MOS (n = 2) occurred when the participants askes the students directly for their maths homework towards the end of the classroom scene after one student tells the teacher about having handed in the homework already (stressor 3, teacher centred). The four passive MOS (n = 4) during *Scene 1* occurred right at the beginning of the scene (n = 2, stressor z), in the middle of the scene (n = 1, stressor z) and at the very end of the scene (n = 1 stressor z). All active MOS occurred during one of the described stressors. Passive MOS occur either right at the beginning or the end of the scene.

5.3.3 Qualitative Analysis of MOS Patterns and Stressors: Scene 2

Half of the n = 14 MOS that occurred during *Scene 2*, occurred during the active reaction of the participants (n = 7). Six MOS (n = 6) during interaction with the group of students on the right (stressor 3, student misbehaviour), one MOS (n = 1) while switching between the two group tables of students (stressor 1, teacher centred) and one at the very end of the scene, when the video ends and the participant needs to navigate with the controller (stressor z).
The other half of the MOS (n = 7) occurred during passive watching of the two group tables in the scene seemingly unsure which groups needs help (n = 3 stressor 1) and observing the table on the right hands side (n = 4) (stressor 2).
All active MOS occurred during one of the described stressors.

5.3.4 Qualitative Analysis of MOS Patterns and Stressors: Scene 3

Of the n = 10 MOS detected during *Scene 3*, n = 8 occurred during active reactions of the participants and n = 2 passive MOS while observing the group table on the right-hand side (stressor 1, teacher centred). Most MOS occurred during participants' interaction with the group on the right in which two students switch from German to another language during group work (n =6) (stressor

3, student misbehaviour), one participant asks the person conducting the study on which group in the scene to focus on (n = 1) (stressor z).
The active MOS occur either during the provided stressors or when struggling with the video navigation to repeat the videos.

5.3.5 Qualitative Analysis of MOS Patterns and Stressors: Scene 4

Of the n = 10 MOS detected during *Scene 4*, n = 6 occurred during active reactions of the participants. Of those, n = 3 occurred while actively responding to the student Louis' question about the maths task (stressor 2, teacher centred) and n = 2 during intervention after another student makes a bad comment about student Louis' question (stressor 3, student misbehaviour). One Person (n =1) has a MOS at the end of the scene and asks the person conducting the study if they may repeat the sequence (stressor z). The n = 4 passive MOS occurred during the beginning of the scene (n = 2) and while observing the class at work before the first stressor occurs (n = 2).
Most active MOS occur during the stressor sections of scene.

5.3.6 Summary of Qualitative Analysis of MOS Patterns and Stressors

With respect to RQ 2, it can be stated that a pattern of stressors during the different classroom scenes can be qualitatively described by the occurrence of the following categories: *student misbehaviour* caused MOS in n = 26 (n = 4 of these passive, n = 22 active) cases, *teacher-centred activities* caused MOS in n = 22 (n = 10 of these passive; n = 12 active) cases, and stressor *z* (*did not occur with a scripted stressor*) caused MOS in n = 11 cases.

Tab. 4: Stressors according to scene, content and category of stressors

Scene	**Stressor**	**Content**	**Category**	**MOS active/passive**
Test	1	student is done with task and tells teacher	teacher centred	5/passive
Test	2	student disturbs classmates	student misbehaviour	3/active
Test	3	student disturbs and mocks classmates	student misbehaviour	1/active
Test	4	student tells classmates solution and uses phone	student misbehaviour	1/active
1	1	students do not sit down for class to begin	teacher centred	6/active
1	2	students keep talking	student misbehaviour	
1	3	student tells teacher about homework	teacher centred	2/active
1	4	one student is teased and bullied by two others	student misbehaviour	3/active
2	1	two groups working but one has a problem	teacher centred	1/active; 3/passive
2	2	group at the right does not cooperate	student misbehaviour	4/passive
2	3	student excluded from work at the right group	student misbehaviour	6/ active
2	4	student is frustrated and refuses to work	student misbehaviour	
3	1	unclear what to do for the groupwork	teacher centred	2/ passive
3	2	students in group disagree on how to do the task	teacher centred	
3	3	two group members speak in another language	student misbehaviour	6/ active
3	4	student does not understand and is excluded	student misbehaviour	

4	1	student raises hand to ask teacher a question	teacher centred	
4	2	student asks teacher about the revision tasks	teacher centred	3/ active
4	3	students at the back laugh about question	student misbehaviour	2/ active
4	4	mocked student reacts angrily	student misbehaviour	

6 Discussion, Limitations, Conclusion and Further Research

In the following section, the results will be discussed to answer the research questions (6.1) followed by the limitation of the current study (6.2) to then draw a conclusion and bring up implicated further research on the topic (6.3).

6.1 Discussion of Results

Firstly, the results of the descriptive analysis of MOS are discussed, followed by a discussion of the MOS of different subgroups (RQ 1) and the qualitative patterns of MOS occurrence (RQ 2). After analysing the data, it can be stated, that the 360° classroom videos in VR cause MOS with every participant during the study even though there is a range of MOS occurrence between the individuals. It can be stated that psychophysiological data of stress-inducing events could be found in the data after applying the MOS algorithm (Kyriakou et al. 2019). This means, that the participants experienced situations of emotional arousal like real life situations as the algorithm has been developed to reliably measure real moments of stress by combining sensor data of EDA and ST via the E4-Empatica wearable.

To answer RQ 1, the MOS of complete novice teachers training students and students with previous classroom experience were compared but no notable differences could be found between the groups with respect to the amount of MOS detected overall and for the individual classroom scenes. This could indicate that the 360° classroom situations in VR are challenging independent of previous experience. It should also be mentioned that all the participants are still enrolled in a university course and none of them are teachers yet so the experience they might have, is not comparable to that of an experienced teacher.

To answer RQ 2, the MOS during the classroom scenes were analysed qualitatively with respect to the concrete situations (stressors) during which they occurred and the concrete reactions the participants showed while experiencing MOS. For the first scene (called *Test Scene*) the participants show more MOS during passive watching of the situation (n = 9) than during active reaction and interaction with the students in classroom (n = 5). The MOS occur either when the participants react to the student who disturbs the rest of the group or while getting acquainted with the classroom situation (stressor 1) at the beginning when they "arrive” in the scene. This could mean, that participants are still holding back reactions due to the novelty of the situation and the given information that the scene was going to be a test scene. They could be more concerned with the actual task and getting to know the test setting as well as preparing for the following scenes. Nevertheless,

The second situation (*Scene 1*) has more MOS during active reaction of participants to the students in the room (n = 11) than while passively observing or getting to know the room and situation (n = 4). Active MOS occur almost exclusively during central interactions of the students which are worth to notice and intended to be stressors such as the two students who do not sit down after class starts, the students distracting the student in the front or the lack of turned in maths homework. This indicates that MOS occur when the participants might realise the necessity of their own reaction as teacher within the situation and this causes emotional arousal which can be detected as MOS.

The third situation (*Scene 2*) presents a new difficulty to the participants as there are two group tables with students working together and the participants need to decide which table they should pay attention to. Only the group on the right hand's side has difficulties with the task and voices the problems our loud. Several MOS (n = 5) occur when participants try to make the group on the right work together despite problems with the task and with each other. Several MOS (n = 4) occur while just watching the group on the right and several times there are MOS when people are moving between the groups from left to right (n = 3) seemingly unsure or still evaluating which side needs their attention. This indicates again that the participants are mostly aware of the task to find out which group needs help and that they seem to be able to determine it.

The fourth situation (*Scene 3*) is set with the same two groups of students sitting at two different group tables. Again, the group on the right is discussing the task and disagreeing on how to do it while the group in the left is working quietly and does not appear to have any trouble with the task or each other. Out of the n = 10 MOS that occur during this scene, n = 6 are during active reactions of the participants to the group on the right which switches from German to another language that part of the group does not seem to understand. The other n = 2 passive MOS also occur when the participants are watching the group on the right. This shows that if a MOS was detected during *Scene 3*, they almost exclusively are associated with the challenging situation of noticing that the group on the right has difficulties with the task and with working on it together. Therefore, the occurrence of MOS is in accordance with the intended stressors of the scene and show the emotional arousal of participants caused by the classroom situation.

The last situation (*Scene 4*) brings the participants back to the whole class setting with students facing the front and teacher and working on revision tasks individually. Out of the n = 10 MOS that occur in total, n = 5 occur while reacting to the situation between one student in the front with difficulties mastering the tasks and one student in the back negatively reacting to the student in the front. This situation is the crucial moment of the last scene and main stressor because a teacher should, firstly react to the question of the student in the front and then accordingly react to the student in the back making fun of the student in the front publicly. The occurrence of MOS in connection with this stressor once again points at the possibility to cause emotional challenging situations of teaching or dealing with students through 360° classroom videos in VR.

Following research on stress detection in simulated VR classrooms (Huang et al. 2022), which used the comparison between average HR baseline and average HR in a VR classroom as only indicator to detect stress, we used the average heart rate during each MOS of the scenes in comparison to cross-validate the MOS which could be detected by the algorithm. More than half of all measured MOS during the scenes could be cross validated by a significant HR difference. The other, non-significant or negatively significant, HR difference needs to be addressed. Because the algorithm for MOS detection does not use HR but only uses EDA and ST, the results are still possible and plausible. HR has been seen as less reliable measure to detect psychophysiological stress responses and since the measurement is conducted by only one sensor for HR in opposite to two sensors (EDA and ST), there could be inaccuracies of measurement of the HR. Also, the cross-validation results differ strongly between the 16 participants (e. g. some no MOS could be cross-validated for certain participants and most MOS for others). This might indicate measurement problems of the HR values during baseline measurement and/or test setting. The HR could be less reliable as the sensor in rare cases occasionally stopped recording data while all other sensors still recorded. Another explanation could be that the baseline measurement took place in the minutes right before entering the 360° VR classroom setting. Participants might have already been on a higher level of arousal due to the unknown upcoming task as they knew already that they would participate in a study. This could then indicate that that the positively significant differences in HR suggest especially challenging and stressful MOS during the test setting. Finally, the cross-validation via HR difference was attempted to test out different methods of stress detection using wearable sensors to calibrate for further research. In this case it can be stated that HR difference itself does not seem to be as reliable as the MOS algorithm (Kyriakou et al. 2019)Therefore, the more complex measure of HR variability should be looked into for further research.

Overall and in accordance with previous research on teacher stress, the findings show measured stress during stressors such as classroom disruptions like Wettstein and colleagues who see this as a primary stress factor and emphasise the importance of counteracting stress as preventative health measure. This goes along with findings by Klusmann and colleagues who specifically pointed out the stressor of class composition (e. g. of language minority students) where classes with higher numbers of language minority students show stronger associations between teachers' exhaustion and students' tests scores (Klusmann et al. 2016). Furthermore, Junker and colleagues investigate the frequency and intensity of known classroom stressors (low student engagement and motivation, negative teacher-student relationship and interactions, teacher-centred activities) by tracking teachers' heart rates during a lesson. In parallel to our results of MOS detected during the stressors in the classroom scenes, they could show that low engagement and motivation on the students' side and teacher centred activities predict an increase of the teachers' HR (Junker et al. 2021).

The results indicate that MOS experienced during 360° VR-classroom scenes could be seen as an extension of early teacher training practices because well-known stressors such as classroom disruptions or teacher-centred activities induced stress with all participants of the study.

While there could not be found any evidence that previous classroom experience had an impact on stress experience of the subjects, the small sample size as well as still relatively reduced experience (few weeks of internship) might be an important factor. Bigger studies with larger and more divers samples of pre-service teachers should thus be conducted.

6.2 Limitations

The biggest factor of limitations is the small sample size which needs to be kept in mind when interpreting statistical analysis and their statistical power. Therefore, the results of the small sample size (N = 16) should be seen in the light of their exploratory nature and as a first step into researching objectively measured teacher stress in virtual 360° classroom situations. With the results of this study, further research with bigger sample sizes should be attempted to confirm the suitability of the educational technology in use for teacher training with respect to teacher stress and health.

Another factor of limitations is the possible novelty effect of the 360° classroom situations in VR which might inherently cause stress by just experiencing it. This needs to be kept in mind even though the results show that more MOS occur during the actual classroom situations than between in the intro or reflection scenes even though the classroom scenes only make up a small part of the overall time of the test setting timewise.

Another factor of limitations that needs to be mentioned is, that no cross-validation of stress was conducted through participants' self-reported stress (Harmsen et al. 2018; Ritvanen et al. 2003; Junker 2023). Studies also use objective measures as well as self-reports to gain insights into the participants subjectively experienced stress. Even though this would have been interesting, previous research shows mixed results with respect to benefits and disadvantages of both measures of stress (Goyal et al. 2016; Carneiro et al. 2019). Additionally, subjective self-reports were not used in this study for reasons of research economy as the test-setting is already quite long and extensive as it is.

Another limitation that should be mentioned, is, that it is not possible to compare the results of the virtual 360° classroom to real life classroom situations yet, because no data has been collected to measure MOS though using the same method and algorithm in a real-life situation. This concerns every attempt if imitating real-life situations ins order to somehow close or narrow the theory-practice gap in teacher education. This is why it is important to note that VR training of classroom situations should never be seen as a substitute for real classroom experiences. Rather should it be seen as a more realistic extension of traditional case-based work in teacher education.

6.3 Conclusion and Further Research

This work tried to venture a first step into the direction of stress detection in simulated 360° VR classroom situations. Future teachers and students of vocational and technical education were immersed in virtual classroom situations with the task to act like teachers. Altogether in can be stated, that several MOS could be detected for every participant of the study during the classroom situations. Most MOS were measured during the actual teaching scenarios of the five different classroom scenes and most of them were timewise associated with relevant classroom situations (stressors) that were built into the stages scenes to be noticed by the participants.

These finding should be seen within the context of the technology enhanced learning and the growing importance of educational technologies in use for initial teacher training at the university (source). The 360° classroom videos in VR can be helpful in order to bridge the theory-practise divide as well as bring a higher level of authenticity and individualisation to university teacher education (McGarr 2021; Starkey 2020). The use of technology in form of videos or VR is just one option of training with videos of classroom situations to ensure growth in situation-specific skills and action-related pedagogical knowledge (Kramer et al. 2017; Stürmer et al. 2015; Cattaneo & Boldrini 2017; Michalsky 2021). An additional benefit poses the finding that interactive use of video content positively influences preservice teachers' motivation and engagement (Syring et al. 2015; André et al. 2023).

For further research, these findings build a foundation to look more closely into the role of stressful situations during teacher education and training also through using virtual classroom environments in order to help softening a reality-shock at school (Huang et al. 2022). In order to gain a more systematic insight into the ways the technology can be used to reduce or counteract stress in pre-service teachers, university courses should be developed to implement and use the 360° VR-classroom scenes for training practical knowledge about teaching and at the same time to closely monitor the development of stress in students of the course of, for example one semester. This could then also mitigate the implications of the small sample size with its reduced diversity regarding participants background (e. g. including other teacher training courses outside of vocational and technical education).

Based on the findings, the following hypotheses should be researched in order the validate the first explorative findings: if teaching experience is a predictor for less MOS during stressors, more experienced teachers should experience less MOS in a VR test setting after sufficient time to get used to the technology itself. Furthermore, it would be interesting to see if similar MOS can be detected in real classroom situations. Besides real classroom situations it could also be interesting to look at the MOS of more experienced teachers as comparison to the two subgroups.

Another interesting field for further research could be to adapt further stressors that were found in research on teacher stress to incorporate a more comprehensive learning experience for future teachers.

Altogether, teacher education could benefit of a more nuanced understanding of the psychophysiological stress reactions novice teachers and university student teachers experience during their first attempts of teaching in class to help future teacher to overcome obstacles during their teacher training and to become more resilient for the profession. Especially because an initial “reality shock” during the first years of teaching is very common and demands resources from you teachers which they should be able to use in other ways for their teaching (Voss & Kunter 2020). “Hence, the reliance on VR in the present study helped to overcome significant limitations of prior research in (teacher) stress by balancing the teaching tasks with the precision afforded by experimental control thus combining the best from both worlds.” (Bardach et al. 2023). Finally, 360° classroom situations in VR could be used to help future teachers to make first, reality-like attempts of teaching a class in protected place while experiencing realistic stress without having an impact on real students and their learning.

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Contribution Statement

Katharina Kunz developed the virtual environment, conceptualised and performed the study, wrote the original draft and final draft of the manuscript and conducted the statistical analysis.

Marcus Brändle performed statistical testing and contributed to the first draft of the manuscript.

Bernd Zinn supervised the project, contributed to the interpretation of the result and reviewed and edited the revised manuscript.

Sunita Hirsch contributed to review and editing of the original manuscript.

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Appendix

Tab. 5: Results of Man-Whitney-U tests according to scene (*Test Scene*, *Scene 1*, *Scene 2*) and participant (TP), Annotation: [1]not significant, [2]negatively significant

TP	**U-Test:** ***Test Scene***	**TP**	**U-Test:** ***Scene 1***	**TP**	**U-Test:** ***Scene 2***
P1	U = 0, p-value < .001	**P1**	U = 991, p-value < .001	**P1**	U = 2491, p-value <.01
P1	U = 0, p-value < .001	**P2**	U = 7621.5, p-value = .89[1]	**P1**	U = 2917, p-value = .09[1]
P3	U = 5490, p-value = .03[1]	**P4**	U = 0, p-value < .001	**P5**	U = 1025.5, p-value < .001
P6	U = 0, p-value < .001	**P4**	U = 0, p-value < .001	**P5**	U = 4890.5, p-value = .67[1]
P7	U = 12121, p-value < .001	**P5**	U = 899, p-value < .001	**P6**	U = 0, p-value < .001
P7	U = 1923, p-value < .001	**P6**	U = 793.5, p-value < .001	**P6**	U = 0, p-value < .001
P11	U = 0, p-value < .001	**P7**	U = 12871, p-value < .001[2]	**P7**	U = 10935, p-value < .001[2]
P11	U = 0, p-value <.001	**P8**	U = 26737, p-value < .001[2]	**P7**	U = 9134.5, p-value < .01[2]
P12	U = 1768, p-value < .001	**P9**	U = 2807.5, p-value < .001	**P10**	U = 0, p-value < .001
P12	U = 2915, p-value < .001	**P11**	U = 417, p-value < .001	**P11**	U = 1402, p-value = .01
P13	U = 2320, p-value < .001	**P12**	U = 4476.5, p-value = .13[1]	**P12**	U = 9153.5, p-value < .001[2]
P14	U = 22117, p-value < .001[2]	**P12**	U = 4104.5, p-value = .03	**P13**	U = 2262, p-value < .001
P15	U = 4.5, p-value < .001	**P13**	U = 29813, p-value < .001[2]	**P13**	U = 2314.5, p-value < .001
P16	W = 25750, p-value < .001[2]	**P13**	U = 23380, p-value < .001[2]	**P16**	W = 23620, p-value < .001[2]
		P14	U = 8080, p-value = .01		

Tab. 6: Results of Mann-Whitney-U tests according to scene (*Scene 3*, *Scene 4*) and participant (TP)
Annotation: [1]not significant, [2]negatively significant

TP	**U-Test: *Scene 3***	**TP**	**U-Test: *Scene 4***
P1	U = 184, p-value < .001	**P1**	U = 2358, p-value < .01
P4	U = 0, p-value < .001	**P1**	U = 1900, p-value < .001
P4	U = 0, p-value < .001	**P1**	U = 5306, p-value < .001[2]
P6	U = 0, p-value < .001	**P4**	U = 3918, p-value < .001[2]
P7	U = 13664, p-value < .001	**P7**	U = 248.5, p-value < .001
P8	U = 31550, p-value < .001[2]	**P9**	U = 1665, p-value <.001
P12	U = 7193.5, p-value < .01 [2]	**P9**	U = 1433, p-value < .001
P14	U = 5391.5, p-value < .001	**P12**	U = 7875, p-value < .001[2]
P14	U = 11703, p-value = .72[1]	**P12**	U = 2903, p-value < .001
P16	U = 22053, p-value < .001[2]	**P13**	U = 411, p-value < 2.2e-16

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