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Research Article

"I'm sweating!": A physiological investigation of a pedagogy of practice

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Significant attention to practice-based teacher education centers on providing teacher candidates with opportunities to rehearse the distinct practices of the profession. Grounded within practice-based teacher education, this study focuses on the physiological responses of teacher candidates in a clinical simulation learning environment. We examine a convenience sample of teacher candidates' engaging in a series of six simulations that approximate some of the challenging situations and practices of teaching in secondary (grades 7-12) schools. As teacher candidates engage, we measure their heart rate and physical activity outputs within individual – and across the series of – simulations to better understand physiological response patterns within a practice-based learning environment. Data indicate statistically significant differences between the number of verbal triggers in each simulation and the measurements of heart rate and physical activity counts. Data also indicate statistically significant declines in physiological measures as the series of clinical simulations occurs across the one-semester timeframe. This study contributes to practice-based educator preparation in its examination of teacher learning through scaffolded simulation experiences. Advancing beyond teachers' self-perceptions of stress, measures of teacher candidates' physiological responses highlight a unique lens on instructional practices and sequenced pedagogical development in a clinical learning environment.

Keywords: Clinical practice; Simulation; Teacher education

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1. Introduction

Advancing teacher education and novice teacher development beyond traditional 'sink or swim' comparisons (Casey et al., 2013; Howe, 2006; Varah et al., 1986) requires systematic approaches to the specific practices and situations of the profession. In recent years, significant attention has returned to practice-based teacher education (Zeichner, 2013) as a means to front-load, control for, and provide teacher candidates [TCs] with opportunities to experience and rehearse the distinct practices of the profession (Ball et al., 2009; Forzani, 2014; Lampert & Graziani, 2009). This study is grounded within practice-based teacher education, yet the focus is not on novice teachers' professional practices, structures, or outcomes. Instead, the purpose of this study is to examine the physiological responses of TCs in a practice-based learning environment, guided by the research question: *What are teacher candidates' physiological responses within the clinical simulation learning environment?*

The research team investigated TCs' physiological responses across a series of six clinical simulations that approximate some of the challenging situations of teaching in secondary (grades 7-12) schools. To outline this study and its outcomes, this manuscript begins with a review of teacher stress literature, and the diffusion of the simulation concept from medical education to teacher education. Next, the manuscript

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describes the design and implementation of six clinical simulations, outlining the physiological variables that were examined as TCs (n=28) engaged in the simulations. Discussion of the resulting data centers on links between TC stress and didactical foci, with implications focusing on practice-based teacher education structures.

2. Literature Review

2.1. Teacher Stress

When novice teachers (i.e., induction years 1-3) begin their licensed practice in schools, they experience a variety of unknowns – new content to master, new professional identities to embody, new peer-groups and faculty colleagues to communicate with, and diverse K-12 student groups with whom to engage. These professional unknowns are disequilibrating, surfacing the uncertainties of practice – either distinct circumstances or ambiguous situations where path(s) are uncertain – and resulting in stress (Hargreaves, 2000, 2001; Shulman, 2005).

The research literature on teachers' physiological responses has manifest through studies of teacher anxiety, stress, burnout, attrition, and retention. As documented in Guglielmi and Tatrow's (1998) now-historical meta-analysis of forty studies on teacher stress (between 1965 – 1997), past studies of teacher stress have focused on teachers as a broad group, and the systemic causes or impact of their stress through common methodological approaches. In particular, Guglielmi and Tatrow (1998) note a large number of teacher stress studies rely heavily on teachers' self-assessments of levels of stress, complete with the known subjective nature of self-report methodologies. Largely due to a reliance on subjective methodologies and an absence of theoretically driven studies in their comprehensive review, Guglielmi and Tatrow (1998) note that "…the study of teacher stress and burnout appears to be still in its infancy, and it lags far behind the parent occupational stress literature" (p. 82).

Since that meta-analysis, additional research on teacher stress (e.g., Bakker & Schaufeli, 2006; Brouwers & Tomic, 1999; Hakanen et al., 2006; Lambert et al., 2009) has followed similar lines of inquiry and methodological patterns, reinforcing the trends noted and critiqued by Guglielmi and Tatrow (1998), but also focusing more on specific groups of teachers. For example, Geng et al. (2016) studied 310 total preservice teachers' (159 undergraduate; 151 graduate) stress levels using a perceived stress scale to assess uncontrollable or unpredictable life events, supported by an additional in-house questionnaire that focused on field placement workload and teacher candidate opinions. Their findings show increased levels of graduate preservice teacher stress, associated with fewer opportunities to rehearse instructional practices and develop teacher identity. Similarly, Collie et al. (2012) examined through survey 664 teachers' perceptions of school climate and social-emotional learning and the potential impact on teacher stress and efficacy. Their findings center on teachers' perceptions of student behavior and motivation, and the self-reported impact on stress. Fives et al. (2007) examine the feared outcome – teacher "burnout" – and how early it might manifest in novice teachers. Their study of novice teacher stress and early signs of burnout suggests that teacher educators focus less on reducing stressors for teacher candidates and instead guide teacher candidates through mastery and vicarious learning experiences outlined by Bandura (1997) to enhance efficacy and identity-building.

As we consider more recent scholarship on teacher stress, we do so through the meta-analytic lens on teacher stress that Guglielmi and Tatrow (1998) construct, and the avenues for future research they suggest. In particular, Guglielmi and Tatrow (1998) emphasize that the literature on teacher stress has not accounted for the variety of instructional responsibilities teachers embody, noting that the "type of teacher" variable (p. 66) (e.g., 1st grade Elementary teacher; 11th grade Chemistry teacher; 8th grade Vocational Education teacher) must be interrogated to a much greater degree. Encouragingly, we see recent literature (e.g., Geng et al., 2016; Ji et al., 2022) that makes this distinction in the study design. Another key variable – that of the *type of stressful situation* – is addressed in the teacher stress literature from a systemic perspective, where researchers consistently examine chronic stress is association with the long-term effects of teacher burnout and attrition. Guglielmi and Tatrow (1998) caution against this association between stress and burnout, yet the methodological choices in some of the more recent literature continue to examine associations between these two variables (e.g., Fives et al., 2007; Flook et al., 2013; Hakanen et al., 2006).

Our study responds to the critiques of the research literature in two ways. First, we do not look across the broader teacher career span; instead, we specifically investigate the *pre-service* 'type of teacher' and the stress responses that TCs exhibit. Second, we do *not* look at TC stress systemically, with a broad review of stress in their student teaching or clinical practica. Instead, we examine TCs' stress responses within very distinct teaching situations – as TCs interact with an overworked parent who doesn't say much in conference, to a worried single dad, to a verbally aggressive student, to a paraprofessional colleague with years of seniority, and others. We take the position that understanding teacher stress means drilling down closer to distinct points of practice and examining how TCs engage in those didactical/pedagogical situations. We suggest that how one navigates specific professional stressors offers a sharper portrait of disposition and practice, with implications for what leads TCs to engage with and respond effectively to the stressors of induction-stage, licensed practice.

Guglielmi and Tatrow (1998) also note the challenges of self-report data, aligned with common concerns about perceptions-based data collection approaches (Chan, 2010). Past teacher stress studies have examined stress broadly, and the past self-report, perceptions-based approaches are understandable, given the many different contexts associated with classroom teaching. That is, different classrooms present different teachers with distinct situations at different times and intervals. These differences, and teachers' perceptions of them, present a methodological quagmire, where controlling for and studying teachers' stress responses across broad, varying classroom contexts is complex at best. In our study, we utilize a clinical simulation process to place distinct boundaries on the type of stressful situation, and collect data through independent instrumentation, sharpening the methodological lenses through which we study TCs' physiological responses. For example, while past studies might inquire about teachers perceived stress responses with *challenging students* in general, one portion of our study focuses on TCs' physiological stress responses as they engage with a specific student issuing a verbal threat. To fully explicate the clinical simulation process and how we study TCs stress responses across multiple situations, we shift to the medical education origins of clinical simulations, their diffusion to educator preparation, and their specific role in this study.

"Everything else gets fuzzy…"

In the early 1960's, medical educators began designing medical simulations to enhance the preparation of physician candidates (Barrows & Abrahmson, 1964). Medical simulations occur between a physician candidate and a standardized patient – carefully-trained actors who present a specific medical case and its distinct medical symptoms and communicate questions/concerns to physician candidates in a standard, consistent manner (Barrows, 1987, 1993, 2000; Barrows & Abrahmson, 1964). Engaging one-to-one with the standardized patient, each physician candidate is challenged to synthesize medical knowledge, diagnostic assessments, and interpersonal skills in real-time to construct a regimen of treatment or medical plan of action. Today, simulations are universally employed in U.S. medical schools to both teach and assess physician candidates on the knowledge, skills, and dispositions necessary for licensed practice (Coplan et al., 2008; Hauer et al., 2005; Islam & Zyphur, 2007).

In 2007, Syracuse University faculty partnered with State University of New York [SUNY] Upstate Medical University to diffuse the medical simulation concept to the field of educator preparation. Early simulations situated TCs in one-to-one simulations with standardized parents, students, and paraprofessionals. Each of these earliest simulations centered on how TCs attend to difference, inclusion, and support of all students in the classroom (Dotger, 2010; Dotger et al., 2008; Dotger & Ashby, 2010; Dotger & Smith, 2009). For example, one simulation examines how TCs engage with a standardized mother, who reports evidence of her son's physical harassment and bullying on school grounds because peers "think he is gay". TCs are challenged to carefully document the reported situation, but to also engage with discretion in response the parent's concern that it not appear like "mom coming to the rescue". As the simulation concept diffused within Syracuse University and to other partnering universities, additional scholars began examining how simulations can be used to situate TCs in content-specific contexts. For example, one such simulation places mathematics TCs in one-to-one simulations with a standardized student who is struggling to solve for "X" in an algebraic equation (Njoroge, 2017). Still, other simulations focus specifically on inequality within K-12 schools, situating TCs within simulated contexts that challenge them to identify and navigate circumstances that inequitably position one person (or group) ahead of another (Self, 2016), or that hold great impact on individuals and communities (e.g., students committing self-harm; parents questioning the teaching of evolutionary biology) (Dotger et al., 2010).

Clinical simulations reflect the tenets of situated cognition (Brown et al., 1989; Lave & Wenger, 1991), where professionals construct meaning *in situ*. Embodying the tenet that "learning and cognition…are fundamentally situated" (Brown et al., 1989, p. 32), simulations provide the professional situations that ground TCs' meaning making and support knowledge growth. The professional situations and contexts reflected in simulations support communities of (instructional) practice (Lave & Wenger, 1991), giving TCs chances to engage in specific (simulated) situations, while also actively engaging with their emerging identities as the *teacher* and the cultural considerations and responsibilities that communities of teachers hold toward each other, as well as to parents, students, and their school communities. Further, engaging and constructing meaning through clinical simulations directly aligns with the body of scholarship on practice-based teacher education (Zeichner, 2013), where scholars study the distinct practices used in K-12 classrooms and which pedagogies (e.g., simulations) can support TCs' experiences with and improvement upon these practices. Clinical simulations serve as "approximations of practice" (Grossman et al., 2009, p. 2076), where TCs engage within very carefully designed environments that place boundaries on the TCs' experiences. Like other approximations of practice (e.g., Lampert & Graziani, 2009), simulations are intentionally bounded to focus on a specific aspect of teaching, learning, or student support, and by their very nature, do not represent fully contextualized classroom teaching. Simulations are not designed to supplant professional practice in schools and classrooms. Instead, like medical education's use of standardized patients, standardized individuals are utilized in educator preparation simulations to approximate for TCs what they might not otherwise experience through traditional field placements in fully contextualized K-12 classrooms. By offering each TC in a cohort the opportunities to practice engaging in specific situations, simulations provide a pedagogical common denominator to the TC community – a professional situation in which each TC can engage, practice, analyze, and reflect.

Across nineteen years and four research-intensive university contexts, 125 different simulations have been implemented over 6,300 times with pre-service teachers, school counselors, and school leaders. Studies of TCs' experiences in single and across series of simulations demonstrate the capacity of simulations to shape novice teacher identity (Dotger & Smith, 2009), ethical and reflective dispositions (Dotger, 2010), and specific instructional practices in science and mathematics contexts (Dotger et al., 2015; Dotger et al., 2018; Shaughnessy & Boerst, 2018a). Through simulations, we have a replicable lens into how TCs navigate the terrain, or emotional geographies (Hargreaves, 2000), between school, home, and other professionals (Cil & Dotger, 2017), and the degree to which TCs enact policies and practices taught through traditional coursework (Dotger & Ashby, 2010; Self, 2016; Shaughnessy & Boerst, 2018b).

While these past studies used simulations to investigate different research questions, the participating preservice school professionals within these studies and others consistently self-reported the same anecdotal data strands, which serve as the primary impetus for this study. As they emerged from simulations, participants often reported tunnel vision, where a sole focus on the standardized individual across the table means that "…everything else (in the simulation room) gets fuzzy…". Simulation participants routinely reported increased physical movement (i.e., hands-wringing or overuse), perspiration, and anxiety prior to and during specific simulations. Participants commonly referenced their own physiological responses to particular questions or challenges from a (standardized) parent or student. For example, one TC said, "When she (standardized mother) asked me what I knew about autism, I froze. My heart was racing; I was drawing a blank".

The frequency and regularity of such anecdotal data fostered conversations with Exercise Science colleagues who specialize in measuring heart rate and physical activity. Collectively, we began to ask questions about TCs' physiological responses in specific, and across multiple, clinical simulations. One meta-question emerged, asking *What are teacher candidates' physiological responses within the clinical simulation learning environment?* From that guiding question, two sub-questions emerged to guide our data collection and analysis:

RQ 1) How does stress manifest within teacher candidates during a series of six simulations, as measured by physical activity (PA) and heart rate (HR)?

RQ 2) Do teacher candidates show evidence of physiological acclimation across a series of six simulations?

3. Methodology

3.1. Research Design & Simulation Overview

Building from these research questions, this quantitative study utilized a repeated-measures design. TCs were assessed on the same variables (heart rate, heart rate variance, and physical activity) as they engaged with the different conditions presented to them in six different simulations across a fifteen-week semester. This subset of simulations was designed between 2007-2009 and implemented with more than 2,800 TCs prior to this specific study[2]. By design, each simulation in this study situated TCs in one-to-one, face-to-face interactions with standardized students, parents, or colleagues. Each simulation challenged TCs to engage

[2]Dotger and Chandler-Olcott (2022) provides extensive detail on simulation iterative design framework, data collection, and implementation procedures.

with standardized individuals who verbally presented to each TC questions, concerns, and data related to inclusion, equity, and difference in classroom contexts. Due to space limitations, we do not provide an in-depth review of each of the six simulations. Of note, we do specify the didactical focal points – namely professional communication skills, data collection/documentation, and situational responsiveness – that TCs experience in and across these six simulations. Table 1 provides an overview of the simulations and the challenges within each, and Dotger and Chandler-Olcott (2022) gives an extensive account of the design parameters for the standardized individuals and verbal triggers in each simulation.

Each simulation consists of two protocols – one for the TC and one for the standardized individual [SI]. Each TC Protocol gives appropriate background information, describing the particular classroom or school context and providing appropriate data. Some TC Protocols give extensive background context and data, such that the TC knows exactly why s/he will soon engage with this parent, student, or colleague. In similar fashion, though, other TC Protocols for other simulations provide very little background context or data. This also intentionally approximates the situations teachers sometimes encounter, where they must engage with a parent, colleague, or student without knowing the full backstory, or without access to all evidence and perspectives. Most importantly, TC Protocols in no way script, direct, or otherwise narrate what TCs say and do in any simulation. Instead, TCs are charged to utilize the information in the TC Protocol, their professional training, and their "best professional judgment" when engaging in any simulation.

In direct contrast to the TC Protocols, the Standardized Individual Protocols for any given simulation very intentionally script and direct the SI in the simulation. The design rationale stems from the two original purposes of simulations – (1) to situate each TC in authentic interactions where they can engage, synthesize, and practice their knowledge, skills, and dispositions, and (2) to provide all TCs with a shared set of (simulated) experiences through which they can collectively examine their potentially different approaches to the same professional challenges. One week prior to any given simulation, the SIs are trained to enact verbal/non-verbal triggers – exact questions, information, context, and/or non-verbal mannerisms. For example, the third simulation in this study situates TCs in front of the standardized student *Casey Butler*. Four actors (age 18+) from a nearby College of Visual & Performing Arts are recruited to portray the 16-year-old *Casey*, and are carefully trained on the verbal triggers for this simulation. Through deliberate rehearsal, all four actors learn to sit defensively with arms crossed, scowling, and say to each TC in simulation, "They'd better stop talking *%$! about me, or I'm gonna take care of this myself!" This specific trigger – along with other verbal and non-verbal cues – constitute the heart of the *Casey Butler* SI Protocol. Resulting from approximately two hours of SI training per simulation, the end result is a small cohort of carefully rehearsed actors who enact *Casey Butler* in a consistent, standard manner as they engage with multiple TCs.[3]

3.2. Participants & Clinical Setting

This study is based on a convenience sample, where participants in this study were TCs enrolled in a *Foundations of Education* course at Syracuse University [SU], a large research-intensive university in the northern United States. This course represented one of three core education courses, populated by sophomore- and junior-year students engaged in undergraduate teacher preparation courses of study. As students in the course, TCs were required to engage in six different clinical simulations, aligned with programmatic requirements of SU's School of Education. TCs' engagement in this study of physiological responses in simulations, though, was distinctly separated (SU IRB protocol #15-198) from their required engagement in the simulations as a learning experience. Because this study included the collection of physiological data, an additional SUNY Upstate Medical University [UMU] IRB protocol (#811459-3) was followed to ensure the ethical collection and analysis of medical data. Twenty-eight of thirty-two TCs consented to participate. The only distinction between participants and non-participants was the collection of physiological (i.e., heart rate and physical activity) data using the procedures and instruments described below.

TCs engaged in simulations within UMU's Clinical Skills Center, a twenty-two-room medical simulation facility. Each simulation room is a medical exam room, complete with exam table and typical medical equipment. However, these simulation exam rooms contain multi-angle cameras and microphones embedded in the ceiling. For this study in particular, and like all other SU simulations implemented in this facility, the medical exam table is moved to the corner, and a simple table-and-chair arrangement occupies

[3] Dotger and Chander-Olcott (2022) provides extensive detail on the design of TC and SI Protocols, as well as detail on exact SI recruitment and training procedures.

(Insert Table 1 Here)

the simulation room. Thus, when SU TCs engage with standardized parents, students, or colleagues, they are essentially situated in a small office environment, but one that is audio/video-enabled for later review of simulation data. This study differed from past practice only in that consenting TCs wore specific instruments designed to collect physiological data.

3.3. Data Collection

We used two instruments to collect physical activity [PA] and heart rate [HR] data. ActiGraph Link accelerometers were used to gather PA data, with dimensions 3.5 x 3.5 x 1 cm and weight of 14 grams. Each accelerometer fits in a wristband, closely resembles a traditional wristwatch, and has multiple sensors. For this study, we utilized the accelerometer to gather physical activity data (up to 100 Hz at a range of ± 8 G), while also relying on its ability to sync to external devices via Bluetooth technology. To collect HR data, we used Polar H7 heart rate chest straps. Importantly, this HR instrument gathers data at the same time interval as the accelerometer, and syncs to and stores data within the accelerometer, allowing us to download and catalogue the resulting Physical Activity and heart rate data together in an Excel file for the individual TC and the six simulations s/he engaged in.

Data collection procedures were implemented in exactly the same manner across the sequence of six simulations. One week prior to each of the six simulations, TCs were given electronic access to the TC Protocol for the upcoming simulation. Regardless of whether they consented to participate in this specific study of physiological response patterns, all TCs reported to UMU's Clinical Skills Center approximately fifteen minutes prior to their scheduled simulation with an SI. Consenting TCs reported to a designated room, where we had arranged all study instrumentation and documentation. Two members of the research team provided each TC with the two instruments (Polar H7 & ActiGraph Link), with verbal instructions on how to apply the heart rate monitor in a nearby restroom. Upon application, each TC was checked by a research team member, ensuring that the HR and PA monitors were synced to each other and actively collecting data. The screen of the accelerometer was covered so TCs could not see the physiological information in real-time during the simulation.

Once TCs were equipped with the two instruments, they were situated outside of individual simulation rooms, and upon prompt, they logged into computer stations. Doing so activated their respective data accounts on UMU's closed loop server and also activated the audio-visual recording equipment in each simulation room. The TCs were verbally reminded that upon entry to their respective simulation rooms, they would experience three minutes of wait time, giving the TCs' time to acclimate. At the exact three-minute mark, a knock at the door would indicate that each SI had arrived to engage with the TC. With this final logistical reminder in place, the TCs entered their respective simulation rooms. This moment of entry for each TC was recorded by a research team member. Importantly, while all TCs entered their respective simulation rooms at exactly the same moment, and all waited exactly three minutes, they could each exit their respective simulations when they determined professionally appropriate. Thus, the research team recorded the same "entry" time for the TCs, but each TC had a different "exit" time from the simulation room. As TCs concluded their individual simulated interactions, they exited by the same door, a research team member documented this exit time, and the TCs were guided to a small-group debriefing room. TCs were encouraged to remove the two instruments during this transition from simulation to debriefing, as we were not collecting any physiological data beyond the time marker of TCs' exit from their simulation rooms. Instruments were returned, cleaned, and downloaded for later analysis.

3.4. Data Analysis

Each TC's participation in each of the six simulations resulted in a combined raw data file of both PA and HR data for that given simulation. The first step in the analytic process was converting the raw data into fifteen-second epoch Excel files. Data were categorized by participant and simulation. Data were processed to generate a graphic representation of both the HR and PA data in the initial analysis of the 168 simulated interactions (i.e., 28 participants X 6 simulations). Initial graphic representations were used to determine the number of stress responses for PA and HR independently (defined in this study as an elevation of PA or HR usually followed by a peak but not necessarily a decrease) for each participant at each simulation. The elevations were determined on an individual basis and did not have to cross a pre-determined threshold to be counted. Two graduate student researchers initially identified the stress response elevations and a senior researcher verified them and made the decision on classification. The number of detected stress responses were aggregated by simulation. Elevations for both HR and PA at the very beginning and end of the data collection period were ignored because they were associated with the TCs' navigation into and exit from the simulation room.

Physical Activity data peaks were calculated for each TC in each simulation. Descriptive statistics were then calculated across the cohort to provide a mean PA rate in each of the six simulations. We analyzed the PA data in comparison to a count of the number of verbal triggers delivered in each of the six simulations, testing for a relationship between the number of verbal triggers in a simulation and the average number of PA peaks in that same simulation. The heart rate data showed rates in three different time periods – (1) after instruments were applied, (2) during the three-minute waiting period in the simulation room, and (3) during the simulation itself. Our analysis focused only on the HR data captured during the simulation itself. We analyzed the fifteen-second interval HR data and calculated a mean HR for each TC in each of the six simulations. Then, we examined HR data across the cohort for each of the six simulations, resulting in descriptive statistics for each simulation.

4. Findings

This study focused on TCs' stress responses within the practice-based learning environment of clinical simulations. Two research questions guided our data collection and analysis; we organized our findings in accordance with each research question.

4.1. How does stress manifest within teacher candidates during a series of six simulations, as measured by physical activity and heart rate?

Our examination of this research question focused on assessments of TC physical activity and heart rate, as measures of stress in potential response to the verbal triggers in each simulation. First, we conducted paired-sample *t*-tests, examining whether there was a statistically significant relationship between the average number of PA peaks and verbal triggers for each of the six simulations (see Table 2). These tests reflect statistically significant differences in the number of verbal triggers in each simulation, and the average number of physical activity peaks for Burton (1), Butler (3), and Smithers (6) simulations. These tests further reflect no statistically significant difference between the number of verbal triggers and average number of physical activity peaks for the Bolden (2), Wilson (4), and Meyers (5) simulations. We further conducted paired-sample correlation tests, to determine if there were correlations between the number of activity peaks and the number of triggers. Our correlation tests reflect no statistically significant correlations between these two variables (not shown in Table 2). Shifting to the HR variable, we also conducted paired-sample *t*-tests, examining whether there was a statistically significant relationship between the average number of heart rate spikes and the verbal triggers for each of the six simulations (see Table 2). These tests reflect statistically significant differences in the number of verbal triggers and the average number of heart rate spikes for each simulation. Additional paired-sample correlation tests showed only one statistically significant correlation ($p < .016$) for the fifth simulation (Meyers), while all other tests reflected no statistically significant correlation between the two variables (not shown in Table 2). These findings suggest that we cannot directly link the verbal triggers in each simulation to a measured stress response.

Table 2
Paired-sample t-tests for Physical Activity and Heart Rate for SIMs 1-6

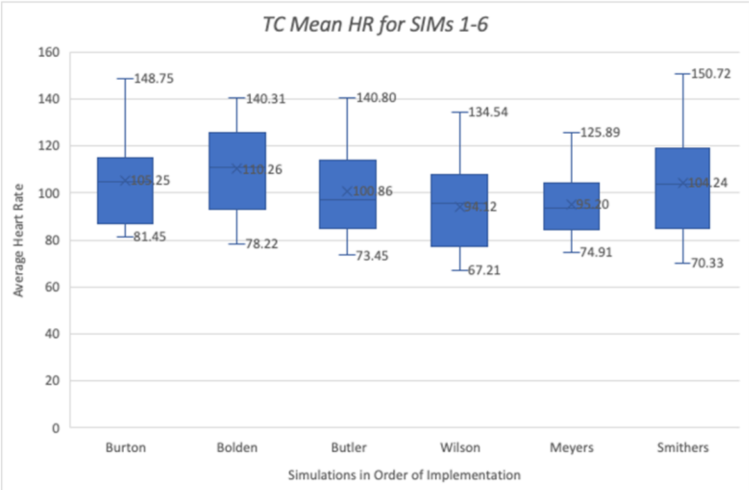
Peaks/SIM Triggers	*Mean Difference*	*SD*	*t*	*p*
PA Peaks				
PA Peaks - SIM 1	−1.24	1.95	−2.914	.009
PA Peaks - SIM 2	−0.69	1.93	−1.825	.08
PA Peaks - SIM 3	−1.23	2.64	−2.375	.026
PA Peaks - SIM 4	−0.33	2.06	−0.842	.407
PA Peaks - SIM 5	−0.59	2.26	−1.226	.234
PA Peaks - SIM 6	−2.96	2.67	−5.772	<.001
HR Spikes				
HR Spikes - SIM 1	−3.47	1.55	−8.65	<.001
HR Spikes - SIM 2	−2.00	1.66	−4.497	.001
HR Spikes - SIM 3	−1.40	1.35	−4.01	.001
HR Spikes - SIM 4	−1.44	1.58	−3.715	.002
HR Spikes - SIM 5	−1.76	2.22	−3.273	.005
HR Spikes - SIM 6	−4.10	2.23	−8.401	<.001

4.2. Do teacher candidates show evidence of physiological acclimation across a series of six simulations?

Our second research question was drawn directly from regular, but anecdotal, data observed across the nearly two decades that we have embedded multiple simulations within the *Foundations of Education* course. Typically, TCs are very nervous for their first simulation, but report "settling into" the challenge that each new, and unknown, simulation presents every two weeks in the semester. That is, anecdotal, self-reported data suggest TCs acclimate to the idea that they will encounter professional unknowns each time they engage in a simulation. Still, these data were anecdotal, and we sought to more deliberately examine their stress markers for quantifiable signs of physiological acclimation.

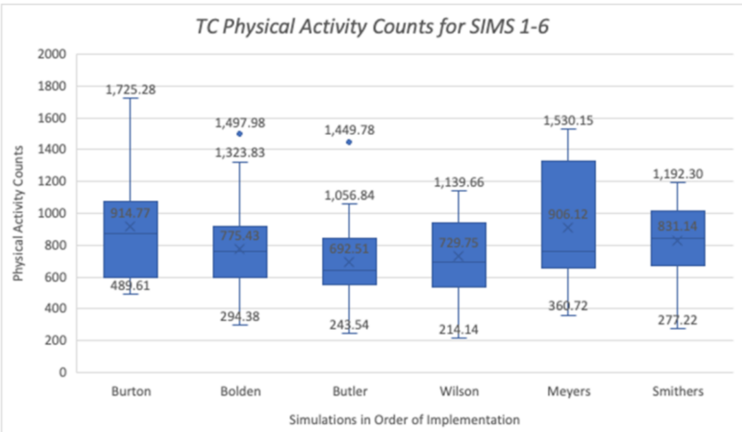
Figure 1 shows box & whisker plots of the TC's mean HR data, as well as quartile and outlier data, beginning with the first simulation (Jennifer Burton) on the left, and ending with the sixth and final simulation (Jim Smithers) on the right. Mean HR data show an initial uptick, between the first and second simulations, then a gradual decline between the second and fifth simulations, before a mean increase for the final simulation.

Figure 1
TC Mean HR for SIMs 1-6 (from left to right)



Just as we examined heart rate output across the six simulations, we also examined patterns of physical activity (PA) across the broader learning experience. Figure 2 shows box & whisker plots of the TC's mean PA data, as well as quartile and outlier data, beginning with the first simulation (Jennifer Burton) on the left, and ending with the sixth and final simulation (Jim Smithers) on the right.

Figure 2
TC PA Counts for SIMs 1-6 (from left to right)



In Figure 2, we see TCs exhibit physical activity levels at approximately the same for their first and sixth simulations, with a decline in PA levels from their initial peak for the second, third, and fourth simulations. The fifth simulation, where they engage with a standardized colleague, shows a broader range of PA counts across the sample, but a mean value (906.12) approximate to the first simulation mean.

While we can discern some evidence of declining mean HR and PA values, we wanted to know if these declines held statistical significance. We examined the relationship between mean HR values for each simulation, performing pairwise comparisons to test for statistically significant differences in the mean HR values of the six different simulations, and repeated this same pairwise comparison for mean PA values. Table 3 summarizes this output.

Table 3
Pairwise comparisons of mean HR and PA values

Simulation / Paired simulation	*Sig.*	*Sig.*
0rder of simulation	*HR*	*PA*
Burton (1)		
Bolden (2)	.301	.021
Butler (3)	.273	.044
Wilson (4)	.024	.018
Meyers (5)	.031	.806
Bolden (2)		
Burton (1)	.301	.021
Butler (3)	.047	.915
Wilson (4)	.015	.447
Meyers (5)	.024	.128
Smithers (6)	.359	.137
Butler (3)		
Burton (1)	.273	.044
Bolden (2)	.047	.915
Wilson (4)	.213	.351
Meyers (5)	.19	.163
Smithers (6)	.525	.261
Wilson (4)		
Burton (1)	.024	.018
Bolden (2)	.015	.447
Butler (3)	.213	.351
Meyers (5)	.766	.015
Smithers (6)	.055	.068
Meyers (5)		
Burton (1)	.031	.806
Bolden (2)	.024	.128
Butler (3)	.19	.163
Wilson (4)	.766	.015
Smithers (6)	.131	.873
Smithers (6)		
Burton (1)	.797	.732
Bolden (2)	.359	.137
Butler (3)	.525	.261
Wilson (4)	.055	.068
Meyers (5)	.131	.873

Although the box-and-whisker plots provide a holistic overview of a decline in mean HR and PA, these pairwise comparison data allow us to look more closely at whether those declining HR and PA mean values hold statistical significance. There were statistically significant declines in mean HR between the very first simulation (Burton) and the fourth and fifth simulations (Wilson; Meyers). Because the mean HR elevated in the second (Bolden) simulation, there were statistically significant differences between the second simulation, compared to the third, fourth, and fifth simulations. These statistically significant mean declines reflect the broader declining pattern outlined by the above box-and-whisker plots. Similarly, there were statistically significant declines in mean PA between the first simulation (Burton) and the second, third, and fourth simulations. Of note, there is a statistically significant increase in PA values between the first simulation, and the fifth simulation (Meyers), which is the only simulation where TCs engage with a standardized colleague.

5. Discussion

This study focuses on TCs' physiological responses in multiple clinical simulations. By design, each simulation reflects a distinct problem-of-practice in K-12 school contexts. While novel, the examination of TCs' physiological responses in and across multiple simulations is important only in its broader contribution to how TCs learn and develop the professional practices they will soon utilize in daily K-12 school service. With the simulation serving as a distinct approximation of practice (Grossman et al., 2009), this study of TCs' physiological responses contributes to the broader emergence of practice-based teacher education (Zeichner, 2013).

To frame our discussion of these data on stress within a distinct learning environment, we turn to Lee Shulman, past President of the Carnegie Foundation for the Advancement of Teaching, as he highlights one's physiological responses to specific learning environments. In a 2005 speech, Shulman outlined the tenets of signature pedagogies – those instructional approaches that are unique to the preparation of lawyers, doctors, engineers, and the clergy. Shulman (2005) argued that within the preparation of each respective group of professionals, there exist distinct "signature pedagogies" specific to that profession. While unique to each professional preparation context, Shulman suggested all share three cross-professional pedagogical tenets – as pedagogies of uncertainty, engagement, and formation. Shulman (2005) emphasizes that the signature pedagogies we use to prepare professionals change the rules of learning, shifting the learner beyond traditionally passive roles toward "accountable talk" (Shulman, 2005), where the learner's actions, statements, and decisions are visible, the learner is held accountable to peers and instructors, and vulnerability is introduced into the learning environment. Shulman (2005) argues that when learners who are accustomed to remaining invisible or withdrawn in the face of pedagogical challenges are placed in learning environments where they become visible, accountable, and vulnerable, the emotional intensity of classroom interaction inevitably increases. Such pedagogical situations involve risk, unpredictability, and anxiety. However, anxiety should not necessarily be understood as detrimental to learning. Rather, a moderate level of anxiety may be adaptive, as it can enhance learners' attention and vigilance. The central pedagogical challenge, therefore, is to create learning environments that are sufficiently risky to promote engagement and learning, yet not so threatening that they become paralyzing for students (Shulman, 2005).

Our first point of discussion focuses on the stress levels represented in the simulated learning environment. If it is "good to be a little anxious" in order to learn (Shulman, 2005), then how anxious are TCs when they engage in simulations that situate them as professionals? As noted in Figure 1, data from this study reflect different stress values for different simulations. Acknowledging that a 'typical' heart rate for an adult (18 years +) depends on a variety of age, environment, health-related factors, the average heart rate for an adult is 60-100 beats per minute (bpm) (American Heart Association, 2020). Through this lens, we see mean HR values in these data that are above average, suggesting physiological focus on the professional situation at hand. The box-and-whisker display, though, adds another consideration, allowing us to see the broad range of individual TC HR values across the six simulations. For example, in the first simulation, individual TC HR values ranged from 81.45 bpm to 148.75 bpm. Thus, Shulman's conceptual question comes into sharp relief. For the collective cohort, our data reflect that TCs are "a little anxious", with an average rate of 105.25 bpm. Sharpening the lens, though, we might reasonably ask if our data show that the simulation experiences challenged some individual TCs enough, or potentially challenged other TCs beyond the point of educative anxiety and toward levels that may be considered paralytic. If we accept the notion that there are common bpm thresholds that support weight loss and cardiac conditioning in health-focused environments, might we apply a similar concept to that of simulated learning environments, to further test Shulman's (2005) assertion of "creat(ing) an environment that is simultaneously risky but not paralytic"? Might there by a common bpm threshold that supports action and decision-making in simulated learning environments?

It is this last question that links TCs' physiological responses in simulation to the broader intent of the simulations themselves – that is, to prepare novice teachers to navigate a range of challenging professional experiences. Looking closely at Figure 1, we see an increase in the mean HR from the first to second simulation. These physiological data are notable when you consider the pedagogical requirements at the heart of these initial two simulations. In the first simulation, TCs initiate the interaction with the standardized parent, have plenty of academic and behavioral data to share, and – as seen for the past nineteen years with this simulation – tend to verbally dominate their first interaction with a standardized parent, Jennifer Burton. Importantly, though, the second simulation is initiated by a standardized parent (Donald Bolden), and the TCs only have background information on the strong academic performance of the student in question. As Mr. Bolden shares concerns for his daughter's emotional crisis, the unknowns and the serious nature of this situation emerge. We suggest that the HR data for these two simulations point to greater TC uncertainty in professional interaction skills, and in their novice fluency in responding to either acute moments of adolescent development or acute situational complexity. Notably, the sixth simulation is unique in both situational complexity and in the need for exact professional interaction skills. Faced with the angry father, Jim Smithers, who demands an alternative text and advocates loudly that the teacher censor a whole-class reading, the TCs are challenged to balance thoughtful communication and clear situational decision-making while sitting face-to-face with an abrupt parent. We affix the clear increase in TC HR values here to the increased challenges on TCs situational "know how" related to calls for censorship and to their ability to professionally communicate clear decisions in a hostile environment.

Our second point of discussion centers on rehearsing (some of) the practices of the profession, and the accompanying physiological response patterns. Scholarship on the high-leverage practices of teaching – including engaging with parents, communicating with students in crisis, and collaborating with colleagues (Ball & Forzani, 2009; Forzani, 2014) – calls for rehearsals of these practices (Grossman et al., 2009; Lampert & Graziani, 2009). In this study, TCs engaged with parents who struggle to balance parenting with work, who are worried for the well-being of their kids, and who are angry at school decisions. TCs also engaged with a verbally aggressive student and a colleague who envisions classroom structures differently. That is, all six simulations represent TC rehearsals with specific practices of teaching. The TCs' rehearsals of practice show evidence of both distinct rises in HR for particular simulations and also show evidence of a decline in mean HR as the series of simulations progressed.

Consider again Figure 1, which shows TCs' HR values are approximately the same for the first and last simulations, with respective means of 105.25 (Burton) and 104.24 (Smithers). At a cursory glance, one might interpret the relatively unchanged mean HR values for simulations 1 & 6 to suggest that TCs showed no signs of physiological acclimation across the simulation series. To really understand what happened in those simulations, though, one must return to Table 1 to review the verbal triggers issued by the standardized parents in the first and sixth simulations. In the first simulation, Jennifer Burton is unaware of her son's off-task behavior in school, inquires what she can do to help, and shares that she struggles at times as a single mother. This standardized mother presents as tired, but engaged and supportive. In sharp contrast, the sixth simulation presents Jim Smithers as an aggressive father who loudly demands an alternative reading for his daughter, before shifting his focus to broader censorship of a school-approved reading, an interrogation of the teacher's ethical stance, and a final indication that he will be taking his concerns to the school principal. He presents in simulation as condescending, patriarchal, and verbally aggressive. These two simulations are remarkably different in context and professional challenge – yet they reflect virtually the same mean HR values. There is no statistically significant difference in HR values for the first and last simulations, and we interpret the quantitative and qualitative data to suggest that TCs' did acclimate across the broader series of simulations. An angry, condescending, demanding father in the final simulation did not cause TCs any greater stress responses than those reflected in the first simulation with a sincere mother who wants to help her son.

In the first simulation with Jennifer Burton, TCs were entering a new (simulation) environment, but were entering into a conversation that they had initiated and for which they had all of the student performance data. In contrast, the second simulation with Donald Bolden was parent-initiated, and the TCs knew only that Mr. Bolden had some concerns he wanted to share. When engaging in conference with Mr. Bolden, which they did not initiate and for which they do not have data to rely on and prepare from, TCs' mean HR values spiked to the highest values across the entire six-simulation sequence. As the simulation series progressed to simulations three, four, and five, TCs engaged with the verbally aggressive student Casey Butler, the concerned mother Ashley Wilson who reports on-campus physical assault, and the paraprofessional Elizabeth Meyers who prefers to remove students with special needs from the general education classroom. Across these three simulations, we see statistically significant declines in mean HR values when compared to the first and second simulations. We interpret this downward trend in stress response as a physiological measure of the 'settling in' that TCs have anecdotally reported for years. When Casey Butler threatens to fight another student, TCs' mean HR values are not as high as those with the benign Jennifer Burton in the first simulation, or the worried Donald Bolden in the second simulation. When Ashley Wilson reports a concerning physical assault (Simulation 4) and when Elizabeth Meyers indicates she wants to isolate students with disabilities (Simulation 5), we measured mean HR values that were statistically significantly lower than those of the first and second simulations.

This broader pattern of TCs' decreasing physiological responses points to increasing pedagogical confidence and instructional fluency over time. As noted in Table 1, the simulation topics vary, but the basic pedagogical processes – professional communication, documentation, situational planning – remain consistent throughout the semester-long learning experience. As the six-simulation sequence progresses and the challenges increase, the underlying action, decision-making, and verbalization demands remain steady. Across the third, fourth, and fifth simulations, TCs face intentionally increasing complexities, but have two prior experiences as the professional point-person from which to build. While TC's continually express questions about the individual pedagogical considerations in these mid-semester simulations, the largest unknowns of the semester are behind them. The repetition of the emerging professional role across the broader series of simulations allows TCs to grow in confidence and continue practicing expressing their own professional voice/identity, engaging in situational decision-making, and gaining fluency with data collection and reporting. Admittedly, their communications or responses to the simulated situations throughout the semester may or may not be aligned to "best practice", but their physiological responses in each simulation suggest their pedagogical confidence and situational fluency are increasing.

6. Implications

In their study of teacher "burnout" and its alignment to teacher career stages, Fives et al. (2007) discuss how physiological cues (e.g., nervousness, increased heart rate, etc.) represent data sources which novice teachers and researchers might consider monitoring for self-efficacy development. The link between mastery experiences and physiological cues is later explored by Clark et al. (2014), through their study of medical residents' stress level (as measured by heart rate) and performance in a medical simulation where the "non-technical" skills of situational awareness and professional communication were critical (Clark et al., 2014). Looking across the discussion of Fives et al. (2007) and the research of Clark et al. (2014), we see cross-profession parallel scrutiny of the connections between the realities of licensed practice, one's physiological responses within those rehearsed realities, and early investigations of novice professionals' physiological responses to approximations of practice. As we consider guiding novice teachers through mastery experiences – like simulations – to build skill, efficacy, and identity, we also consider their physiological responses within those mastery experiences. These conceptual considerations and the data from this study surface the following four implications for preparing teachers for the stresses of the profession.

Our first implication aligns with our first point of discussion, where we highlight specific situations and their demands for clear communication and situational fluency. As this study demonstrates that TCs were more stressed in some simulations than others, then it is logical to ask, *what were they stressed about*? Did a particular line of dialogue with the worried father, Donald Bolden, cause the heart rates of TCs to elevate? Similarly, when the standardized student, Casey Butler, indicated in simulation that she would "take care of" the students that were gossiping about her, did such a statement cause a stress response in TCs? In contrast, what physiological responses did TCs have when parents, colleagues, and students were presenting background context and sharing information? Were they less anxious during these moments of sharing, or were they particularly attuned to the importance of those moments? This current study holds strength in that it extends beyond past studies of teacher stress, where self-reported perceptions of stress reflected holistic, systemic stress within broad roles in schools and across extensive time frames. This study specifically examined TC stress through independent measures in distinct professional situations. Still, our data show us that we can fine-tune future research scrutiny even more, seeking to understand exactly what is being said, shared, or decided that is causing stress for TCs in particular simulated moments. Advancing our instrumentation and procedures will allow us to code in real-time the qualitative conversation occurring within the simulation, while simultaneously documenting the TC's physiological outputs during those very moments of conversation. We strive to design future studies such that real-time physiological outputs align exactly to real-time dialogue and potentially reveal further insights into the links between situational fluency, communication skills, and stress response.

A second implication of this study suggests closer investigations of the contexts of gender and power in the context of simulation physiology. Past anecdotes from TCs indicate some feel more or less "nervous" about interacting with a particular gender, or particular individuals (e.g., parent vs. student). In the context of this study, consider the three simulations that were teacher-initiated (Simulations 1, 3, & 5) in comparison to those that were parent-initiated (Simulations 2, 4, & 6). The teacher-initiated simulation with the highest stress value was the first simulation with the standardized mother, Jennifer Burton. TCs initiated other interactions with a standardized student (Simulation 3) and a standardized colleague (Simulation 5), reflecting progressively lower mean HR values. Of the three parent-initiated simulations, Simulations 2 & 6 were initiated by a standardized father, while Simulation 4 was initiated by a standardized mother. These data suggest a need to further examine if TCs consistently reflect higher or lower levels of stress as they engage with parents in comparison to their engagements with students and colleagues. Are interactions with students "less stressful" than those with parents? Do conversations with a concerned mother result in less anxiety than those with a concerned father, even if both parents are expressing the same concerns? These data reflect other lines of inquiry that need attention as well, exploring the relationship between gender and stress levels of TCs, and the potential impact of perceived authority and power in TCs' interactions with students, colleagues, and parents.

Our third implication builds from our second discussion point, where we see TCs' decreasing physiological responses across a semester of simulated practice. As the semester progresses, TCs gain more one-to-one experience in simulation, receive additional coaching from faculty and doctoral students in small- and whole-group debriefings, and construct written analyses of their practices, informed by recordings of their simulations. The debriefing and written analysis structures are design choices situated intentionally following each simulation. This instructional design supports each TC in the subsequent active analysis of pedagogical performance, or what is known as the important decomposition of practice (Grossman et al., 2009). As situational awareness increases across six distinctly different simulations, the post-simulation scaffolds of whole-group debriefings and data analyses allow individual TCs opportunities for meaning-making and evaluations of practice. We suggest findings from and design of this study positively informs and aligns directly with the broader designs of practice-based teacher education. Specifically, the contrast of increasing (simulated) challenges – balanced with predictable patterns of data analysis, peer debriefing, and guided reflection – offers a productive learning environment seeking to balance Shulman's (2005) call for "moderate anxiety (that) is adaptive". Shulman's suggestion is supported by a study showing that medical students who experienced moderate stress in a simulated setting performed better and retained more information than their peers who did not engage in that stressful situation (DeMaria et al., 2010). As a result, Clark et al. (2014) question how much stress is necessary to support learning and where lies the stress threshold. Shulman (2005) suggests "much of maturation involves transforming debilitating fear into tolerable anxiety…as students begin to know what's going to happen, get control, understand what they have to do in order to manage the anxiety, it becomes very adaptive and very educative" (np). Shulman's (2005) conceptual questions, and the scholarship of DeMaria et al. (2010) and Clark et al. (2014) reflects what we saw from the TCs who participated in this study. That is, we observe in simulations a significant instructional approach that captures TCs' attention, focuses their energies, and engages their intellectual and decision-making abilities in a manner not observed in other pedagogies.

As we consider scholarship that examines how much stress is educative, our final implication centers not just on stress, but on future investigations between *types of stress* and the pedagogical practices TCs are building or rehearsing. Specifically, as measured by variance in average heart rate, we want to know when – and in association with what instructional practices or competencies in simulation – might TCs experience 'fight or flight' sympathetic nervous system responses. Are there moments of didactic practice where TCs want to either escape the situation or times in which the situation causes them to more aggressively engage? Similarly, through future studies we seek to identify instructional moments in which TCs experience 'rest and digest' parasympathetic nervous system responses, where TCs readily listen, gather information, and patiently engage with the situation at hand. As we consider future questions at the intersection of educator preparation and human physiology, consider again the simulated contexts at the heart of this study. In this study, TCs responded with the lowest stress responses to the fifth simulation with Elizabeth Meyers, the standardized paraprofessional who indicated she wished to remove students with disabilities from the general education classroom. One might reasonably question if (and how) teacher educators expect TCs to respond to Meyer's plan for students with disabilities. Do we expect TCs to more aggressively resist this plan for excluding students, as reflected by activation of the sympathetic nervous system? Similarly, consider the concerns for his daughter that Donald Bolden shares with TCs in the second simulation. When Mr. Bolden worries aloud that his daughter is experiencing significant mental health challenges, and asks each TC for help, will future studies of HRV show TCs fleeing this challenging moment, or settling in to listen, carefully document, and engage the worried father deliberately?

7. Conclusion

We study the physiological responses of teacher candidates to advance understanding of – and practices toward – developing strong novice classroom teachers. Akin to how physiological response patterns are used to fine-tune athletic performance and monitor stress in military combat (e.g., Flanagan et al., 2012; Neil et al., 2012), we suggest an additional research lens on how we prepare novice teachers – through approximations of practice – and how close examinations of their physiological responses can be used to enhance their professional preparation. In response to the national challenge of novice teacher retention, and reflecting the calls of Shulman (2005), we suggest the value of studying teacher stress rests on how individuals engage, communicate, and take action within the challenges of K-12 schools, and what we can learn about the links between novice teachers' situational awareness, communication skills, and their physiological responses.

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