

CARTOON-BASED EMOTION IN SIMULATIONS OF PRACTICE

Examining the potential of cartoon-based simulations for studying mathematics teachers' handling of student emotions: A replication study

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Abstract: *Technology-mediated simulations of teaching are used increasingly to represent practice in the context of professional development interventions and assessment. Some such simulations represent students as cartoon characters. An important question in this context is whether simplified cartoon representations of students can convey similar meanings as real facial expressions do. Here, we share results from an implementation and replication study designed to observe whether and how (1) cartoon-based representations of emotion using graphical facial expressions can be interpreted at similar levels of accuracy as photo representations of emotions using actors and (2) the inclusion of markers of student emotions in storyboard-based scenarios of secondary mathematics teaching affects teachers' appropriateness rating of the actions taken by a teacher represented in the storyboard. We show graphical representations of emotions can evoke particular intended emotions and that markers of student emotions in representations of practice could cue mathematics teachers into particular judgments of action.*

Keywords: Technology; Simulations; Instructional practices; Emotions; Facial expressions; Cartoons

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1: Introduction

The work of teaching requires emotional literacy—being able to read students' displays of emotion. Computer-based virtual environments, using avatars to represent students, have grown in popularity in teacher education for supporting teachers to learn instructional practice through simulated interactions with scenarios of instruction (e.g., Brown et al., 2021; Charalambous, 2019; Dieker et al., 2014; Friesen & Kuntze, 2021; Gibson, 2007; Herbst et al., 2011, 2020, 2022; Ma et al., 2016; Milewski et al., 2020; Sweeney et al., 2018) as well as for assessment of teachers. Avatar-based virtual environments have been shown to be effective in helping individuals gain increased understanding of social situations (e.g., Cheng & Ye, 2010; Lehtonen, Page, Miloseva, & Thorsteinsson, 2008; Tettegah, 2005). This suggests the potential for such environments to convey students' emotional information that teachers may use as in their decision making. This paper shares results from an internally-conducted close replication study that examines the potential of technology-mediated interactive simulations for conveying student's emotions using cartoon-based graphic resources to represent facial expressions.

Research has shown that emotional intelligence—the ability to perceive one's own emotional state—has evident value in professional circumstances (e.g., Jaeger, 2003; Lopes et al., 2006), including playing an important role in teacher's job satisfaction and organizational commitment (Naderi Anari, 2012). Beyond the studies on teacher's emotional intelligence, there is reason to believe that the broader construct of emotional competence—the ability to recognize and understand the emotions of others—may be highly related to improved outcomes for student learning (Aldrup et al., 2020; Jennings & Greenburg, 2009). As such, emotional competence

CARTOON-BASED EMOTION IN SIMULATIONS OF PRACTICE

have been included in some of the recent models seeking to identify the professional competencies for mathematics teachers (e.g., the COATIV model, see Baumert & Kunter, 2013; Klusmann, 2013; Baier et al., 2019). The hypothesis that emotional competence is a crucial part of professional knowledge for mathematics teachers seems reasonable in light of recent findings that the relational aspects of teaching are as important for student outcomes as the cognitive aspects (Battey & Neal, 2018). Knowing how teachers' emotional competence shapes their work is particularly important given that they often have to know what students are feeling without being able to directly probe them to report their feelings—e.g., attending to and interpreting students' emotions through reading their facial expressions when in the midst of teaching. Such competencies may play a key role in retaining a diverse population of teachers (Demetriou et al., 2009). Learning to effectively read facial expressions, however, is non-trivial and particularly challenging during instructional transactions where there exists a power differential between the individuals, as is the case with teachers and students (Galinsky et al., 2003). For some time now, educational researchers have suggested that more work is needed in the field to gauge and support teachers in gaining such competencies (Hargreaves, 1998; Ciarrochi & Mayer, 2007).

This paper contributes to the growing body of literature about the role of emotions, in particular teachers' emotional competence, in teaching mathematics (e.g., Baier et al., 2019; Bieg et al., 2017; Gómez-Chacón, 2017; Lewis, 2013; Martínez-Sierra & García González, 2014; Schelhorn et al., 2023). We have been designing scenario-based assessments to understand teachers' reasoning about mathematics instruction. We have been wondering whether and how emotions displayed in cartoon representations of students in classroom scenarios of practice play a role in the ways that teachers interpret scenarios of teaching. Thus far, we have been cautious about using facial expressions in our own scenario-based instruments for a few reasons. The

CARTOON-BASED EMOTION IN SIMULATIONS OF PRACTICE

literature on judgment suggests that the presence of facial expressions can and does sway individuals' decisions (e.g., Salekin, Ogloff, McFarland, & Rogers, 1995; MacLin, Downs, MacLin, & Caspers, 2009). However, such facial expressions can have spurious effects on individuals' judgments if interpreted in different ways by different individuals. Some of the classic examples of such effects include judicial cases in which a jury assigns harsher judgments to individuals with stoic dispositions, perhaps incorrectly interpreting the individual as lacking remorse (Bandes & Blumenthal, 2012; Maclin et al., 2009; Salerno & Bottoms, 2009). In one such study (Maclin et al., 2009), researchers noted effect sizes as high as 0.621 when reporting differences in participants' ratings of a defendants' truthfulness based on their exposure to a photograph depicting a remorseful facial expression compared with one depicting a neutral facial expression. We wondered how students' facial expressions might affect ways that teachers rate the appropriateness of instructional actions.

We designed two related studies to observe whether and how teachers respond to student facial expressions in teaching scenarios. In the first study, we piloted the cartoon-based representations of facial expressions with the goal to compare participants' performance in recognizing facial expressions in our cartoon-based representations and in a photo-based instrument (i.e., Keltner et al., 2019—informed by the FACs system; Ekman & Friesen, 1978). We wanted to know whether or not the facial expressions we had developed would cohere with effective representations of emotion using human faces. Further, we wanted to know whether the addition of facial expressions to cartoon representations of students might bias the interpretation of scenario-based items for individuals more capable of reading facial expressions (in both human faces and cartoon representations). In the second study, we (1) sought to replicate our findings from the first study and (2) explore whether the presence of facial expressions on

CARTOON-BASED EMOTION IN SIMULATIONS OF PRACTICE

representations of students in the scenarios affected teachers' judgments on otherwise equal decisions made by a represented teacher. To this end, we randomly assigned participants to observe a teaching scenario that either included or did not include facial expressions in students.

2: Theoretical Framework

Digital simulations of teaching (e.g., Chazan & Herbst, 2012; Herbst et al., 2022) use a variety of semiotic resources to represent the individuals and settings of practice, including icons, indices, and symbols (i.e., language; Peirce, 1935/1958). Herbst and colleagues (in press) note how those tokens permit the creation of multimodal texts (e.g., storyboards, animations) that can be analyzed using theoretical frameworks adapted from the social semiotic analysis of language. In particular, Herbst and colleagues (2011) have contended that the utilization of two-dimensional, nondescript icons to depict the actions of teachers and students in graphic representations of teaching practice can serve as a valuable tool for visualizing nonverbal aspects of teaching practice. In that work, authors argued that comic-based representations can convey episodes of instruction as effectively as, for example, textual accounts of practice, but do so in a way that offers additional affordances (e.g. more control over timescale, ability to have particular elements present in a case without having to explicitly draw attention to them by naming them). In other work (Chazan & Herbst, 2012; Herbst et al., 2017), we have described how *lean*, *nondescript* graphic elements allow the designer to easily represent practice as emergent in mathematics classroom interactions and enable viewers to project into those characters their own settings and students—in contrast with avatars whose graphical features are used to mark high individuality.

CARTOON-BASED EMOTION IN SIMULATIONS OF PRACTICE

Following this line of inquiry, this paper explores whether emotions can be encoded using a similarly lean semiotic system when representing professional scenarios of teaching. One crucial foundation for that work is research from Ekman and colleagues who developed the facial action coding system (FACS) (Ekman & Friesen, 1978)—an analytic scheme for precisely describing various configurations of human faces as functions of muscle movements. The FACS emerges from Basic Emotion Theory that defines emotions as “a ‘grammar of social living’ that situate the self within a social and moral order” (Keltner et al., 2019) and provide a structure that enables and informs human interactions. A central component of *Basic Emotion Theory* is the study of emotion expression, particularly non-verbal aspects of emotional expression—to which the FACS has played a crucial role. The FACS has made possible the cataloging of human facial expressions for reliably representing human emotion interpretable by humans across cultural boundaries (Ekman & Friesen, 1986). Researchers have investigated the connection between facial expressions and emotions, arguing that facial expressions are realizations of emotional states (Friesen & Ekman, 1983) that transcend cultural boundaries (Ekman & Friesen, 1986). The facial expression-emotion connection suggests that the ability to interpret facial expressions could provide the interpreter with insight into how people are feeling. The reliable interpretation of emotions based on facial expression representations suggests that the ability to interpret facial expressions is an important aspect of emotional intelligence (Keltner et al., 2019). The FACS has also been used to inform the development of animated and cartoon facial expressions (McCloud, 2006; Thórisson, 1996; Spindler & Fadrus, 2009; Stamenković et al., 2018). Furthermore, schematic expressions of emotion that uses rudimentary elements of the FACS system (e.g., diagonal lines rather than downturned eyebrows) have been demonstrated effective for evoking emotional responses (Aronoff et al., 1988; Palermo et al., 2006; Yamada, 1993).

CARTOON-BASED EMOTION IN SIMULATIONS OF PRACTICE

While the FACS (with its focus on describing the ways that humans express emotions through non-verbal cues) has been a useful tool for informing the development of cartoon facial expressions, the underlying theoretical assumptions of Ekman and colleagues (e.g., 1992a, 1992b, 1997, 2011) do not align well with our own perspectives about emotion. Specifically, without denying the possibility that some (basic) emotions may result from purely biological processes (e.g., emotions such as fear or anger that emerge from fight or flight responses), we are inclined by some of the more recent arguments (see Scarantino, 2012) which argue for the need to reframe (at least some) emotional responses as not simply biologically driven, but influenced “dynamically with perceptual and cognitive processes” (Izard, 2009, p. 9).

For our own purposes, we are more interested in understanding how teachers notice (Sherin, 2014) and make use of students’ emotions in their instructional decisions. For this reason, we are less inclined to get embroiled in the ongoing debates regarding “*How emotions are made*” (Barrett, 2017). Rather, we are interested in how emotions are attended to and interpreted by teachers in the context of instruction. This topic is a subset of the larger body of growing literature related to teachers’ professional noticing (Sherin, 2014). In the field of education, the process of noticing is also not without its theoretical debates (see Rotem & Ayalon, 2022; Sherin & Star, 2011, Scheiner, 2016, 2021). Historically, some have treated noticing as a purely perceptual phenomena (Star & Strickland, 2008), while others have emphasized it as a cognitive phenomena, including processes such as interpreting (e.g., van Es & Sherin, 2002) and deciding (e.g., Jacobs et al., 2010; van Es and Sherin 2008; Schack et al., 2013). More recently there have been critiques of the noticing literature as undertheorized (Rotem & Ayalon, 2022; Scheiner, 2016, 2021). In a pair of recent commentaries, Scheiner criticizes the literature on noticing for defining the phenomena in too narrow a set of terms (attending, interpreting, and deciding) that

CARTOON-BASED EMOTION IN SIMULATIONS OF PRACTICE

have been borrowed exclusively from cognitive psychology and represent the phenomena naively by “position[ing] the teacher as separated or separable from the observing environment” (Scheiner, 2021, p. 92).

In our own line of work to understand mathematics teaching, we draw on the theory of *practical rationality* (see Herbst & Chazan, 2012)—which seeks to account for teachers’ decision making in terms wider than purely cognitive frames (i.e., such as knowledge, beliefs, dispositions). Specifically, the theory of practical rationality seeks to account for the ways that situations and social resources play a role in shaping teachers’ decision making. By situations, we refer to the set of recurring scenarios that make up the work of teaching (e.g., the giving and collecting of homework, the teaching of proof in geometry, wrapping up a lesson). In our view, these situations are shaped by the sets of norms that help guide the actions of both teachers and students—giving them cues about what each agent is expected to do. Further, as teachers are socialized into the profession, they become increasingly familiar with the set of professional obligations (Herbst & Chazan, 2012, 2016) to which they are held publicly accountable for, including their obligation to the individual students, the discipline of mathematics, the interpersonal dynamics of classroom life, and the institution that makes room for the work of teaching. Together the norms and obligations provide teachers with a stable set of resources that they can draw on to help guide their actions within a given situation of instruction. These ideas are not unlike the concepts of *professional vision* (Goodwin, 1994) on which much of the work of professional noticing has been built. Professional vision was defined by Goodwin as the “socially organized ways of seeing and understanding events that are answerable to the distinctive interests of a particular social group” (ibid, p. 606). Yet, at least in the view of some scholars of which we count ourselves, the literature on professional noticing has not taken

CARTOON-BASED EMOTION IN SIMULATIONS OF PRACTICE

enough account of the situated and socially constituted aspects of teachers' noticing (see Scheiner, 2021).

Given these views, we are partial to understanding the teacher as not simply a cognitive being, but one who acts within instructional situations (for which there are norms to contend with) as one responsible for fulfilling a professional role (for which there are professional obligations); and these situations and the professional role necessarily constrain the ways that teachers perceive, appraise, and ultimately decide how to handle the stimuli that emerge within those situations. This way of framing the teacher aligns quite nicely with the *Cognitive Appraisal Theories of Emotion* (e.g., Arnold, 1980; Ortony et al., 1988; Roseman, 1984). The general idea of cognitive appraisal theories is that emotions emerge from an individuals' appraisal of external stimuli stemming from situations (Arnold, 1980). That is, the type of emotions that emerge for an individual participating in any given situation depend on the way an individual notices, attends to, and decides about how to appraise a given stimuli within a situation (Ortony et al. 1988); and what a teacher takes note of in a given situation of instruction draws crucially from their professional identity and role as a teacher (Francis et al., 2017; Jackson & Shirakawa, 2007).

For example, when observing a situation in which a student in a classroom is at the front board uncertain of how to answer a question asked by the teacher, the emotions of the student that is at the front of the classroom will depend on what they attend to and how they appraise that which they attend to. According to the cognitive appraisal theory of emotion, one can perceive of the student as electing to appraise one of three aspects of the situation, the: (1) consequences of the event, (2) actions of one of the agents in the situation, or (3) aspects of one of the objects within the situation. Depending on which aspect of the situation (consequence, actions, or

CARTOON-BASED EMOTION IN SIMULATIONS OF PRACTICE

objects) the student focuses on and the way that the student appraises those aspects, different emotions are more or less likely to emerge (see Figure 1).

Figure 1. *Various emotional reactions that (1) come into play for a student at the board who doesn't know the answer to a question asked by the teacher and (2) depends on what and how the student attends to various aspects in that situation*

Attends to	Valence	Sample appraisal of the student at the board	Resulting Emotion
consequences (for a student) of being at the board and not having an answer for a teacher's question (consequences of the event)	positive	"Perhaps the teacher will give me extra credit for coming to the board."	hope
	negative	"Perhaps the teacher (or my classmates) will think poorly of me for not knowing the answer to this question."	fear
the mathematics entailed in being at the board and not having an answer for a teacher's question (particular aspects of objects in the scenario)	positive	"I love mathematics." "I like a good challenge."	liking
	negative	"I hate mathematics." "I don't like this problem/unit."	disliking
the actions of one self being at the board and not able to answer a teacher's question (the actions of one of the agents in the situation from the vantage point of being that agent)	positive	"I'm the only one with enough courage to volunteer to be up at the board."	pride
	negative	"I am really stupid for not knowing the answer to this question." "I didn't study hard enough."	shame
the actions of another individual (not oneself, perhaps the teacher) in the situation	positive	"The teacher is really good at asking good questions."	admiration
	negative	"The teacher is not teaching us." "This teacher is really mean and unfair."	reproach

CARTOON-BASED EMOTION IN SIMULATIONS OF PRACTICE

(the actions of one of the agents in the situation from the vantage point of not being that agent)			
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In this way, cognitive appraisal theories of emotion provide a logical structure for predicting which emotions will be thought of as more or less likely within a given situation. This theory can help account for the adaptation of our scenario-based items, as will be described in more detail in the methods section.

While emotional intelligence has evident value in professional circumstances (Jaeger, 2003), developing the competence to effectively read the facial expressions of people is non-trivial. A central challenge for developing the capacity for facial expression literacy is the difficulty most humans—with the exception of skilled actors—have to “consciously reproduce [facial expressions] with style and grace in art” (Feng & O’Halloran, 2012, p. 2070;). That is, training professionals to develop facial expression literacy would require a resource that could reliably signal particular facial expressions. Our work takes up this challenge by investigating the reliability of a graphical language for communicating facial expressions. In line with the approach described by McCloud (2006, p. 83), our team developed a set of graphical representations that use a reduced version of the facial action coding system to signal facial expressions in nondescript cartoon characters. The purpose of realizing the expressions in a graphic language was to be able to implement them in a process of engineering representations of situations that tap into teachers’ emotional literacy in the context of scenario-based judgment items. In line with the cognitive appraisal theories of emotions, we narrowed the set of options that could be understood as realistic for a student in a classroom standing at the board to

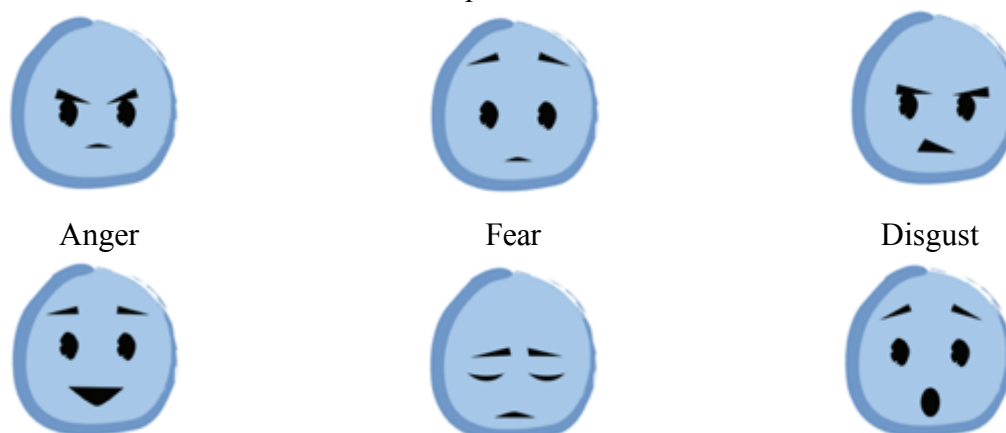
CARTOON-BASED EMOTION IN SIMULATIONS OF PRACTICE

experience. We also selected emotional expressions for use in the context of scenarios of judgment in order to gauge whether and how teachers attend to the actions of the teachers differently when a student's emotion is represented in this way.

3: The Present Studies

In this paper, we describe two interconnected studies in which we probed the potential role of cartoon-based facial expressions (see Figure 2) in shaping participants' interpretations and responses to professional scenarios of teaching. In Study 1, we compare participants' interpretations of cartoon-based, lean renderings of facial expressions (see Figure 2) to the interpretations of facial expressions represented by human actors in static photos (drawn from 20 emotional expressions representing 19 distinct emotions include in Keltner & Cordano, 2016) in order to demonstrate that participants are, in fact, able to interpret the cartoon-based representations of emotion with similar levels of accuracy to that of photos.

Figure 2. Six of the 16 representations of emotions using the ThExpians B character set to create facial expressions. © 2023 The Regents of the University of Michigan¹, used with permission



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CARTOON-BASED EMOTION IN SIMULATIONS OF PRACTICE

Happiness

Sadness

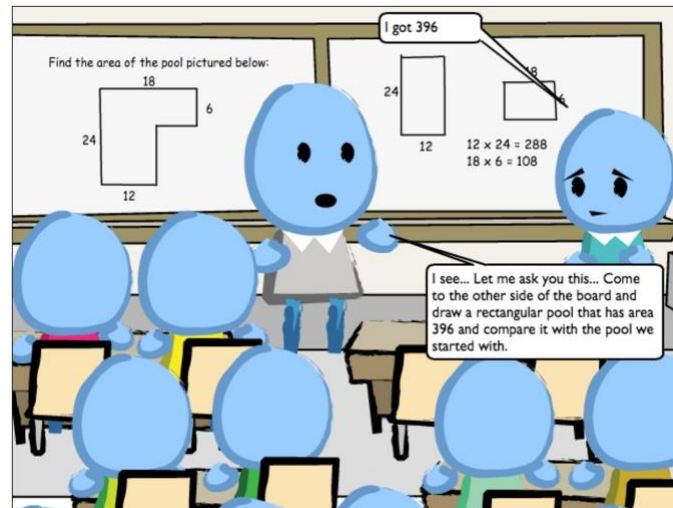
Surprise

In Study 1, we asked the following research question: *Can a customizable graphical language realize facial expressions on nondescript cartoon characters to a comparable level of reliability as photo representations of human faces?* To answer this question, a comparison study was designed in an attempt to gauge the efficacy of 16 facial expressions that were developed to realize emotions that are commonly expressed by students in classrooms (i.e, fear, happiness_v1, happiness_v2, anger, embarrassment, pride, surprise, contempt, disgust, pain, compassion, amusement, interest, sadness, shame, politeness) This list of emotions match all of the the emotions that were represented in the previously developed Keltner & Cordano (2016) instrument save three (i.e, love, flirtatiousness, and sexual desire) which were removed due to their lack of fit (consistent with cognitive appraisal theories of emotion) for the context of a teacher reading the emotion of a student in a classroom situation where the facial expressions would eventually be deployed (see study 2).

In Study 2, we replicate and extend our findings from Study 1 by asking how the addition of such expressions into scenarios of teaching make a difference for participants' judgment of the instructional actions taken within such scenarios (see Figure 3).

Figure 3. *Item from the PROSE instrument modified to include a facial expression for the student at the board*

CARTOON-BASED EMOTION IN SIMULATIONS OF PRACTICE



We leverage the FACS to modify the default expressions of a set of cartoon characters to include lean semiotic markers of emotions in professional scenarios of teaching. Consistent with cognitive appraisal theories of emotions, we made decisions about which emotions might be reasonable to represent in given circumstances. In Study 2, we asked the following research question: *To what extent and how do the icons of emotions on student characters in a cartoon-based representation of practice change the way that practicing teachers judge the appropriateness of instructional actions of teacher characters?*

4: Study 1

4.1: Methods

4.1.1: Outcome and Instrument

The goal of Study 1 was to assess the efficacy of a nondescript graphical language for realizing facial expressions. To that end, we designed a two-part instrument (see Figure 4). The first part of the instrument presented 20 forced-choice assessment items that asked participants to

CARTOON-BASED EMOTION IN SIMULATIONS OF PRACTICE

identify the emotion of a human face shown in a photo (EQ).² We used this first group of photo-based items to gauge participants' proficiency for reading emotions on human faces. The second part of the instrument showed participants 16 forced-choice assessment items using graphic representation containing nondescript cartoon graphics (NDC) to represent a subset of the photo-based items (see Figure 2 for example facial expressions).

Figure 4. *Components of Study 1 instrument.*

Study	Part 1 of the Instrument	Part 2 of the Instrument
1	20 forced-choice assessment items Photo-Based Items of Facial Expressions on Actors (EQ)	16 forced-choice assessment items Cartoon-Based Items of Facial Expressions on Characters (NDC)

Each item in this second group showed a nondescript cartoon image of a student in the context of a classroom (standing at the board) realizing one of the facial expressions represented in the first part of the study (see Figure 5 for example item).

Figure 5. *Sample item from facial expression instrument.*



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² In this part of our instrument, we used a pre-existing instrument (Keltner et al., 2019) that shows participants photographs of actors trained to display emoted facial expressions according to the the FACs system (Ekman & Friesen, 1978) and asks participants to identify the corresponding emotion.

CARTOON-BASED EMOTION IN SIMULATIONS OF PRACTICE

We produced only a subset of the original 20 photo-based items because some of the items in the original set were repeated with slight variations in the actor's portrayal (i.e., embarrassment, pain) or were outside the bounds of issues we are presently invested in representing within the professional setting of a classroom (i.e., love, flirtatiousness, sexual desire).

We aimed to make the cartoon-based items as similar as possible to the photo-based items to ensure the ability to compare participant responses to each item set. We used the affordances of a storyboarding software (Herbst & Chieu, 2011) to translate the facial expressions from the photos to the nondescript cartoon faces. For example, since the facial expression for happiness was displayed with a smile and raised eyebrows, we reproduced the smile and raised eyebrows in the cartoon face by changing the shape and location of the cartoon character's mouth and adding eyebrows (see Figure 6).

Figure 6. *A representation of happiness using the ThExpians B character set and following the FACs system to realize that expression using small changes to the mouth and eyebrows*



Happiness

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4.1.2: Participants

Fifteen secondary mathematics teachers sampled from within a 60-mile radius of Midwestern University³ completed the instrument described above. Items were scored by coding “1” if the target emotion was selected and “0” if any of the distracter choices (the other options as provided

³Midwestern University is a Pseudonym for a University located in the Midwest of the U.S.

CARTOON-BASED EMOTION IN SIMULATIONS OF PRACTICE

in the original instrument designed by Keltner & Cordano, 2016) were selected. Composite scores were defined for each participant as the unweighted average of the scores on the items in each set: the set of photos of humans (EQ) and the set containing nondescript cartoon graphics (NDC). The instrument was delivered using an online platform to ensure the presentation and instructions for the task were administered in a consistent way to all participants. The study design and recruitment procedure was reviewed and approved as exempt by the University of Michigan's Institutional Review Board. Participants received a small monetary incentive for participation in this study. These scores are reported in Table 1 below. The means of participants' scores were analyzed using Pearson's product-moment correlation and paired samples t-tests, as described below.

4.1.3: Analysis

After calculating each participant's score on the EQ and NDC item sets, we used Pearson's product-moment correlation to assess the level of association between these two scores. We report results of paired-samples t-tests to determine whether there are significant differences in participants' EQ and NDC recognition scores.

4.2: Results

Participant scores on the EQ and NDC item sets are reported in Table 1.

Table 1. Descriptive statistics for participants' scores on EQ and NDC items.

Item-Type	<i>n</i>	Mean	Standard deviation
EQ	15	0.70	0.126
NDC	15	0.67	0.104

CARTOON-BASED EMOTION IN SIMULATIONS OF PRACTICE

A Pearson's product-moment correlation was computed to assess the relationship between participants' EQ and NDC scores. We found a positive and moderate correlation between participants' emotion recognition scores ($r = 0.511$, $n=15$, 2-tailed $p=0.051$). A paired-samples t-test was conducted to compare participants' EQ and NDC scores. We find that we cannot reject the null hypothesis that there is no difference in participants' EQ and NDC scores ($t(14)=1.484$, $p=0.160$). This non-significant result provides initial, suggestive evidence that the graphic language realization of facial expressions can convey a similar emotional meaning as the human set of facial expressions. Even though these results provide initial evidence that the graphics facial expressions were successfully identified at a comparable rate to images of actual human faces, the small sample size limits the power⁴ of these findings. For this reason, we conducted an internally-conducted close replication (Melhuish & Thanheiser, 2018) as a first step towards substantiating and extending these results in Study 2.

4.3: Discussion

Study 1 suggests these facial expressions perform as well as photographs of emotions. This highlights the affordances of the semiotic system (composed of eyebrows, eyes, and mouths) in enabling the reading of facial expressions while dramatically reducing the number of tokens used for such denotation. This can help in designing new instruments that represent facial expressions in the context of professional scenarios with the goal of either (1) understanding more about how

⁴ We conducted two power analyses for the main statistics reported in Study 1 and Study 2. We fixed the alpha level at 0.05, beta at 0.80, and each study's set up in these calculations. We let the sample size vary which led us to estimate the minimum detectable effect for each paper. For study 1, we found that our sample size of 15 corresponds to a minimum detectable correlation of 0.669, while our observed correlation is 0.511. Our power calculations suggest that Study 2 could be adequately sized for our observed difference in means between the treatment and control groups. Our calculations suggest that the minimum detectable difference is 0.315, while we observed a difference of 0.356.

CARTOON-BASED EMOTION IN SIMULATIONS OF PRACTICE

teachers reason about emotions, or (2) supporting teacher professional development focused on the role of emotions in teaching.

5: Study 2

5.1: Methods

5.1.1: Outcome and Instruments

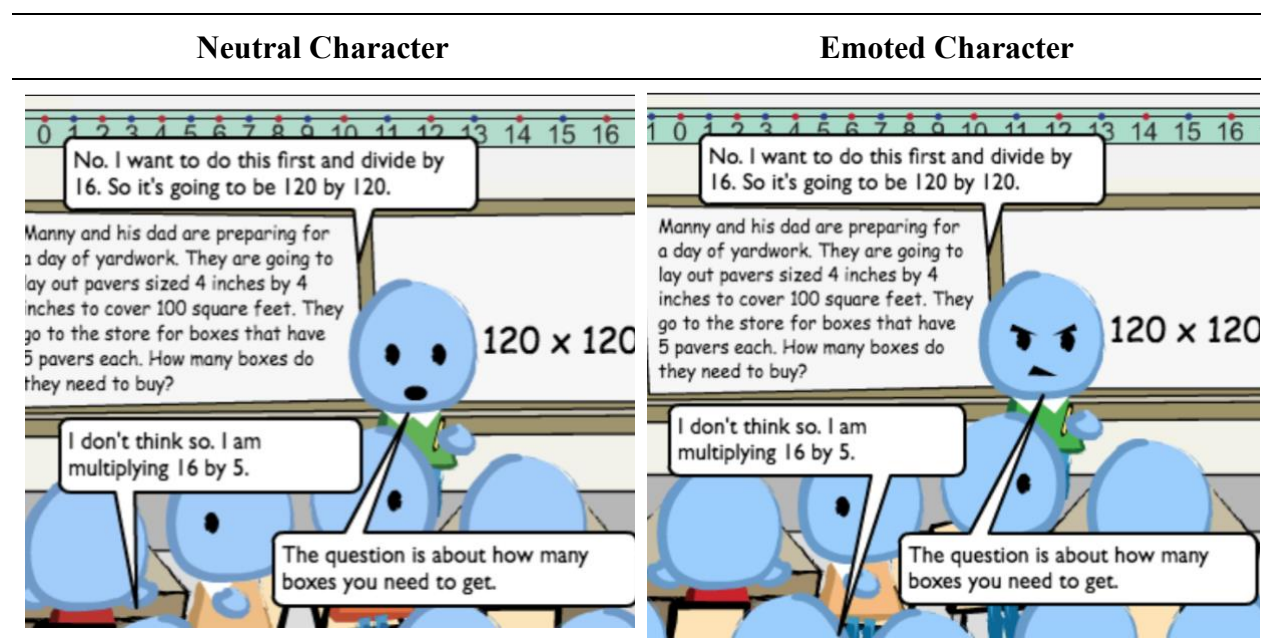
The main outcome for Study 2 is teachers' reactions to scenarios of instruction. To this end, we adapted scenarios of instruction contained in the PROSE instrument (Herbst & Ko, 2018) by either adding or removing facial expressions in order to create two instruments: Emoted PROSE instrument and Neutral PROSE instrument. Figure 7 shows an item from the Neutral PROSE instrument side-by-side with the corresponding item from the Emoted PROSE instrument in which we used the NCD facial expression semiotic system to represent student emotions. In both panels of Figure 7, a student at the board disagrees with a peer who has critiqued the solution they just shared. In the left panel, the student's eyes and mouth express a neutral state. In the right panel, we added to the eyes triangular-shaped eyebrows that slope inward and changed the shape of the mouth from round to triangular to represent the emotional state of anger. These changes are meant to explicitly communicate a possible emotional response that could only be implicitly construed in the left panel.

The main outcome of interest of the original, unadapted PROSE instrument is teachers' recognition of professional obligations as a source of justification of instructional actions. In that instrument, teachers are asked to assess the extent to which a teacher's instructional action was justified on the grounds of professional obligations (see Herbst & Chazan, 2012). In the

CARTOON-BASED EMOTION IN SIMULATIONS OF PRACTICE

adaptation of this instrument to our study, we selected nine item⁵ from the overall battery of twenty-four PROSE items for two possible reasons.

Figure 7. *Neutral and Emoted NDC Characters in PROSE Items*



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First, following Milewski and colleagues (2021), we located items for which a sizable number of prior participants had indicated that their rating of the item depended on some assumptions they needed to make about the scenarios—we have called these *high construal items*. We scanned teachers' responses to high construal items to locate items for which participants professed needing more information about the emotions of the students—we call these *high emotional construal items*. For example, in prior uses of this instrument a fair number of participants had indicated that their rating depended on whether or not a student in the scenario was upset or had justified their rating of the item based on the fact that the represented

CARTOON-BASED EMOTION IN SIMULATIONS OF PRACTICE

student was upset (even though the expression on the student's face was neutral in the original PROSE item). That said, not all responses contained references to emotion and presumably some participants did not construe emotion into the item and thus we hypothesized the inclusion of emotional cues into the item might alter the way that participants responded to the item. We located seven *high emotional construal items* for inclusion in the study (see items a1012, a3022, a3032, a3102, a3112, a3152, a3162 from Figure 8).

Second, some of the items in the original PROSE instrument had included some facial expressions which participants could have interpreted as signals student emotions. Because the facial expression was present in the original item, we presume that some of the participants may have used that information when rating the items and therefore we hypothesized that the removal of the facial expression might alter the way that participants responded to the item. We call these items *PROSE emotion present items* and for the purposes of this study selected two such items (see item a3012 from Figure 8; we originally also included an additional item a3132 in the experiment, but it was removed from analyses because we discovered a typo in the question prompt—leaving us with eight items included for analysis).

For all eight of these items, either the original data or design of the PROSE item led us to believe that emotional literacy might have been part of the way that participants were reasoning about their judgments. Our main outcome of interest with these adapted items from the PROSE instrument was to understand more about how the inclusion of facial expressions as markers of emotion was affecting the ways in which participants' rated the items. Figure 8 reports a brief synopsis of each item included in the analysis.

Figure 8. *Description of eight PROSE items used in final analysis*

CARTOON-BASED EMOTION IN SIMULATIONS OF PRACTICE

Item	Description
a1012**	A/n (embarrassed) student shares a solution to a problem on the board. The teacher asks others to build on that solution strategy.
a3012*	A student is sharing her/his solution on the board. Another student in the classroom suggests another solution strategy and the student at the board responds (with anger). The teacher compliments the students handling the disagreement.
a3022**	The teacher is asking questions to the class. One student answers all the questions, while other (frustrated) students look on. The teacher calls on students by pulling names from a cup.
a3032**	A (confused) student privately asks the teacher a question. The teacher asks the student to ask the question out loud to the class.
a3102**	A student tells the teacher that she/he is done with her work. The teacher asks her/him to help other students instead of working on the homework and she/he (begrudgingly) complies.
a3112**	A teacher ignores volunteering students to cold-call a (confused) student to publicly share a definition of a term.
a3152**	A student is solving a problem on the board. The teacher asks her/him to start over because other (frustrated) students cannot read the writing.
a3162**	Teacher offers magnets to (excited) students. When many students volunteer, the teacher decides to raffle the magnets.
*	PROSE emotion present items
**	High emotional construal items

Participants also completed the exact same emotion recognition questionnaire that we used in Study 1 featuring facial expressions from both photos of actors (EQ; Keltner et al., 2019) and our own facial expression semiotic system (NDC). These two instruments (see Figure 9) allowed us to measure the extent to which our participants were able to recognize emotions in both photographs and cartoons. We use these data as a robustness check of our results.

Figure 9. *Components of Study 2 Emoted and Neutral Instruments.*

Study	Part 1 of the	Part 2 of the	Part 3 of the
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CARTOON-BASED EMOTION IN SIMULATIONS OF PRACTICE

	Instrument	Instrument	Instrument
2: Emoted Condition	9 Likert-Scale <i>Emoted Items</i> Adapted from the PROSE Items	20 forced-choice assessment items Photo-Based Items of Facial Expressions on Actors (EQ)	16 forced-choice assessment items Cartoon-Based Items of Facial Expressions on Characters (NDC)
2: Neutral Condition	9 Likert-Scale <i>Neutral Items</i> Adapted from the PROSE Items	20 forced-choice assessment items Photo-Based Items of Facial Expressions on Actors (EQ)	16 forced-choice assessment items Cartoon-Based Items of Facial Expressions on Characters (NDC)

5.1.2: Participants

In this study, we use a randomized control trial design to assess the extent to which representations of emotions impact teacher interpretations of scenarios of teaching. We recruited 66 participants from the respondent pool for the validation study of the PROSE instrument (Herbst & Ko, 2018). As with Study 1, the instrument was delivered using an online platform to ensure the presentation and instructions for the task were administered in a consistent way to all participants. Similarly, the study design and recruitment procedure was reviewed and classified as exempt from continuous review by the University of Michigan's Institutional Review Board. Participants received a small monetary incentive for participation in this study. Two of the 66 participants were disqualified for the study because they indicated they were not presently serving as a teacher (i.e., Please tell us whether you are now, or ever have been, a teacher: Yes, I am presently a teacher; I am not a teacher now, but have been one in the past; No, I have never been a teacher.)

We randomly assigned qualified participants to either the emoted or neutral experimental conditions. For the emoted condition, we edited the original seven *high emotional construal*

CARTOON-BASED EMOTION IN SIMULATIONS OF PRACTICE

PROSE items to include relevant facial expressions and added those to the two *PROSE emotion present items*, for a total of nine emotion-present items (as shown on the right pane of Figure 7). For the neutral condition, we removed all existing facial expressions from the original *PROSE emotion present items* and added those to the original seven *high emotional construal PROSE items*—for a total of nine neutral items that represented all characters in the scenario using the neutral eye and mouth shapes (as shown on the left pane of Figure 7). Intuitively, comparing the responses to the emoted and neutral scenarios allows us to assess the extent to which the explicit representation of facial expressions in scenarios of teaching has an impact on teachers' interpretation of instructional actions.

5.1.3: Analysis

Our data is nested both within respondent and item because we asked the same participants to answer multiple items. As we are interested in the effect of facial expressions on the overall evaluation of the instructional action, we use a multilevel linear model to account for the nesting of responses within participants and items. In detail, we use a mixed effects model (Raudenbush & Bryk, 2002) with crossed participant and item random effects. We fit the equation

$$Y_{pi} = \beta_0 + \beta_1 \cdot Emoted_{pi} + u_p + u_i + e_{pi}$$

where u_p is the participant-level random effect that accounts for participant-level differences in the assessment of the instructional action that are unrelated to our experimental condition and u_i is the item-level random effect accounts for item-specific differences in the assessment of the instructional action that are due to contextual factors embedded in the specific *PROSE* instrument. The coefficient of interest is β_1 . This coefficient estimates the causal effect of including facial expressions (i.e., the difference between seeing an emoted item versus a neutral item) on participant assessment of the instructional action represented in the *PROSE* items.

CARTOON-BASED EMOTION IN SIMULATIONS OF PRACTICE

5.2: Results

Replication of Study 1. We are not able to completely replicate the results of Study 1. For the replication of the first result, we again used a Pearson's product-moment correlation to assess the relationship between participants' EQ and NDC scores. As in Study 1, we found a significant positive correlation between participants' emotional recognition scores ($r=0.306$, $n=64$, $p=0.014$). For the replication of the second result, we again used a paired-samples t-test to compare participants' EQ and NDC scores. This time, however, we found that we could reject the null hypothesis that there is no difference in participants' EQ ($M=0.693$, $SD=0.13$) and NDC ($M=0.594$, $SD=0.13$) scores ($t(126)=4.278$, $p=0.000$).

While the scores still correlate, we now observe a significant difference in the recognition scores between photos and cartoons, with the photos being significantly easier for participants to read. That said, we wondered whether or not the specificity with which one is expected to identify emotions on the instrument (e.g., shame vs. embarrassment or anger vs. disgust) might not be important in terms of the ways they affect a participants' reaction to a scenario of teaching. That is, we suspected that whether the participant reads a cartoon expression meant to signal anger as disgust may not make a substantial difference in terms of their rating of the situations. Furthermore, given the underlying assumptions of the *Cognitive Appraisal Theory of Emotion*, it is reasonable to presume that the additional information that a participant gets when seeing the facial expression embedded in a scenario of teaching may enable those less efficient at reading the cartoon-based facial expressions of emotion with the information necessary to properly identify the targeted emotion (see Ortony et al. 1988). A possible way to indirectly assess the extent to which the differences between emotion recognition in photos and cartoons affects teachers' reactions to scenarios of teaching is to check whether their scores on these two

CARTOON-BASED EMOTION IN SIMULATIONS OF PRACTICE

different instruments changes their reaction to them. We test this in the set of results described below

Effect of Emotions on the Assessment of Instructional Actions. Table 2 reports the estimates of the effect of facial expressions on teachers' assessment of instructional actions. Column 1 reports the results of the unconstrained mixed effects model, column 2 reports the effect on the raw assessment score (1-6 Likert scale), column 3 reports the same effect in standard deviation units. Columns 4 and 5 report the results of robustness checks testing whether our main results are sensitive to participants' recognition of emotions in photographs or cartoons.

We find that the inclusion of facial expressions in scenarios of teaching has an impact on teachers' assessment of instructional actions of, on average and in absolute value, 0.356 points on a 1-6 Likert scale or 0.280 standard deviation units. This result appears to be robust against participants' ability to correctly identify the signaled emotion in photographs or cartoons. That is, the magnitude of the effect does not change after controlling for participants' emotion recognition in photographs and cartoon images. This allows us to conclude that participants' change in their assessment of the instructional actions in emoted items is due to the emotions that are represented in the characters' facial expressions. If this was not the case, we would observe a change in the estimated effect once controlling for participants' emotion recognition⁶.

Table 2. Average Effect of Facial Expressions on the Assessment of Instructional Actions

(1)	(2)	(3)	(4)	(5)
Unconditional	Pooled	STD	STD +	STD +

⁶ We explored the robustness of our experimental results to outliers using both density plots for the standardized score distribution by treatment condition and estimating the treatment effects on six different quantile (i.e., at the 10th, 20th, 40th, 60th, 80th, and 90th percentile) regressions of the standardized score distribution. These explorations give us evidence that our treatment estimate that we report in our manuscript is robust to the distribution of scores and consistent across different points of the score distribution.

CARTOON-BASED EMOTION IN SIMULATIONS OF PRACTICE

		Cartoon Rec (NDC)		Photo Rec (EQ)
Emoted		0.356** (0.111)	0.260** (0.081)	0.262** (0.082)
Constant	1.798*** (0.239)	1.583*** (0.247)	0.000* (0.063)	0.022 (0.185)
Var(Resp)	0.014	0.000	0.000	0.000
Var(Item)	0.430	0.430	0.000	0.000
Var(Residual)	1.633	1.617	0.844	0.841
Observations	544	544	544	544

Note. The unconditional model reports the results of a cross-effect mixed model that controls for respondent- and item-level variance components. Pooled results report the difference between treatment and control groups on raw item scores. Standardized results use the control group mean and standard deviation to center the raw scores. Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

5.3: Discussion

Study 2 findings suggest that: (1) the inclusion of facial expressions (in the case of the emoted condition) for representing emotions can impact the overall participant agreement with instructional actions (when compared with the neutral condition) and (2) the direction of that effect is not uniform—that is, the presence of facial expression can accentuate the appraisals, making the negative ratings more negative and the positive ratings more positive. The first finding has important implications for the use of cartoon-based scenarios of teaching in teacher professional development. This could help in describing the variation in instructional actions due to response to emotions. More work will need to be done to understand the implications of the second result. In our future work, we plan to explore how the addition of emotions makes a difference for participants' overall rating of an item. We also plan to explore the role of the scenario in providing participants with information that may help those less efficient at reading the cartoon expressions to make sense of facial expressions in terms of targeted emotions.

CARTOON-BASED EMOTION IN SIMULATIONS OF PRACTICE

6: General Discussion & Conclusion

Study 1 used a small sample ($n=15$) to examine the promise of nondescript cartoon graphics for signaling emotions in the representations of professional scenarios. Study 2 sought to both replicate and extend the results of Study 1 with a larger sample of participants ($n=69$). Regarding the replication of the results from Study 1, we were only able to replicate the result showing a positive correlation between participants' EQ and NDC scores. Before proceeding, we pause to acknowledge that the claim that one has replicated and extended a previous study has been a bit controversial in mathematics education (see Aguilar, 2020; Schoenfeld, 2018; Star, 2018). Yet, the need for more replication studies in mathematics education is gaining recognition (Aguilar, 2020) and at present replication studies in the field of education are quite scarce (with Makel & Plucker, 2014 estimating that less than 0.25% of education articles are replication studies). That said, in light of these controversies it is important to be clear what we mean when we say we have conducted a replication study. Using typologies of replication outlined by Aguilar (2020), this replication can be considered an internally-conducted close replication—a close replication because study 2 is a direct repetition of the experimental procedures carried out in study 1; an internal replication because both studies were carried out by a single research group. The fact that this replication is internal could be seen by some as threatening the validity of the study, because the researchers have intimate (tacit) knowledge of the initial study design that could serve as a bias and challenge the generalizability of the results (see Jacobson & Simpson, 2019; Schoenfeld, 2018). On the other hand, the internal nature of the replication can be seen as an important advantage in that the original researchers are able “to faithfully replicate the original study by accounting for unintentional variation that might be introduced by a researcher in an external replication” (Melhuish & Thanheiser, 2018, p. 105). Our own perspective is that internal

CARTOON-BASED EMOTION IN SIMULATIONS OF PRACTICE

replication studies can provide the field with an important first step toward exploring and disseminating about a research question.

Independent of the type of replication, and its related controversies, it is also important to note there is an emerging sense that criteria is needed to help the field determine “when and why to publish a replication study” (Aguilar, 2020, p. S44). While the establishment of such criteria is not without its share of debates (see Melhuish & Thanheiser, 2018), there does seem to be agreement for the need for replication studies to come under the same scrutiny as other kinds of empirical research studies—that such studies should be expected to make the case that the work offers something new and important for the field to learn through the dissemination of the study.

Thus we close this paper with an argument about the significance of this set of studies for the field. To begin, we assert that the successful replication of the Study 1 finding is important in that it demonstrates that this graphical language can work as comparable symbols to actual human faces and has significance for any profession where transacting interpersonal meanings is a critical part of competent practice, including the profession of mathematics teaching. Study 2 also sought to understand more about how the inclusion of facial expressions in scenario-based items for signaling emotions can impact participants’ judgment of instructional actions. This result is particularly important for professions where service is transacted in such a way that the professional is expected to control the dominant verbal modes of communication (e.g., teaching, medicine, law) and the client is normatively relegated to subdominant (e.g., non-verbal) modes of communication. In these types of professions, clients communicate more through facial expressions than they do with words, heightening the importance of preparing professionals to read and react to emotions competently.

CARTOON-BASED EMOTION IN SIMULATIONS OF PRACTICE

The efficacy of nondescript cartoon graphics for signaling emotions and the impact of their inclusion in scenarios of judgment provides evidence for the capacity of storyboards to act as viable representations of professional scenarios. This has financial implications, as the production of storyboards provides an attractive alternative to the production of videos (where privacy or cost can prove to be substantial roadblocks). It also has important methodological implications, as the graphically realized signals of emotion have some important advantages over representing scenarios through narrative cases alone (e.g., Aldrup et al., 2020)—which rely on participants' ability to identify students' emotions by reading between the lines of a given scenario. Finally, these findings also have pedagogical implications. While video representations of practice allow for novices to consume professional scenarios (e.g., viewing, reacting, and discussing), it does not provide the sort of language that would allow novices to compose scenarios. We would argue that similar to other types of skills, professional skills require that learners be engaged in both sorts of activities: consuming and composing (consider for example the sorts of critical connections between reading and writing). The act of composing a professional scenario requires an individual to anticipate several aspects of the scenario, such as clients' emotions; and for this reason we argue that the act of composing scenarios can add to the training of professionals (see Brown et al., 2021; Herbst et al., 2014; Milewski et al., 2018; 2020).

In our case, the use of this graphics language to show facial expressions common to classroom systems of communication is key to the representations of professional practice. Establishing the viability of such graphics to convey a standard set of emotions from the literature allows us to explore the use of such graphics to convey other states typical in classrooms, such as cognitive affective states. Others have extended the use of the Facial Action

CARTOON-BASED EMOTION IN SIMULATIONS OF PRACTICE

Coding System (Ekman and Friesen, 1978) to establish a reliable pairing between facial action codes and cognitive states such as of boredom, confusion, engagement, concentration, and frustration (Baker et al., 2010; D'Mello et al., 2009).

With the increase in interest in student non-cognitive outcomes (Battey & Neal, 2018), it has become more important to understand the role of emotions in teacher decision-making. In this paper, we explored how the reading of emotions plays a role in teacher decision-making. We found that facial expressions communicate emotions in scenarios of teaching and that teachers are responsive to these emotions when reacting to a scenario of teaching. While the effect size of the inclusion of emotions in PROSE items is small to moderate (a quarter of a standard deviation), this effect is non-negligible. A lack of attention to emotions by the designer of classroom scenarios, either construed or represented, could bias participants' assessment of instructional actions in ways that are difficult to predict a priori because facial expressions can both increase and decrease the direction of these assessments. In closing, we argue for two considerations for the broader field of education research that uses simulations of classroom practice. First, we suggest that digital simulations may have some important affordances over other kinds of live simulations in that they do not depend on actors (e.g., Schelhorn et al., 2023) to reliably represent facial expressions in a way that they are translated into meaningful signs of emotion for students. Second, we argue for the importance of giving explicit attention to the representations of emotion in the design of digital simulations for practice in order to ensure that participants have opportunities to practice reasoning about emotions as they learn to engage in the work of teaching.

CARTOON-BASED EMOTION IN SIMULATIONS OF PRACTICE

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