Momentary Student Engagement as a Dynamic Developmental System

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Abstract

In this theoretical statement we answer the call for increased scientific precision in research on student engagement, by providing a conceptualization of student engagement as a dynamic developmental system occurring across momentary time in classrooms. Momentary student engagement can be summarized as the situated, embodied, affective-motivational experience of integrated mental-physical activity in a task. In the statement we describe how momentary student engagement comprises parts (emotion, motivation, mental action, and physical action), structure (coactions between parts) and process (how parts and the whole develop through a sequence of engagement triggers and non-linear action). We discuss how researchers can conceptualize and study momentary student engagement at the microlevel grain sizes of agent (individual student), task (individual academic tasks) and time (momentary), providing a contrast to research on other forms of engagement occurring at higher level grain sizes (e.g., engagement with schooling as a macrolevel process). We overview methods of studying momentary student engagement complexity, emergence and dynamics, and end the statement by discussing how researchers can use the momentary student engagement perspective to enhance student engagement interventions.

Keywords

Student engagement, classroom engagement, momentary engagement, motivation, mental action, dynamic systems

Momentary Student Engagement as a Dynamic Developmental System

The concept of engagement is a popular lens for researchers seeking to understand how and why people focus, invest, act, interact, and learn in diverse educational activities and settings across time. Indeed, engagement has been called the “holy grail of learning” (Sinatra, Heddy & Lombardi, 2015, p.1), because it is a core mechanism of knowledge building in and out of educational contexts (Howard-Jones, Ioannou, Bailey, Prior, Hui Yau & Jay, 2018). Despite its importance for students and society, a consensual science of engagement has been slow to form, with engagement described as “one of the most widely misused and over-generalized constructs found in the educational, learning, instructional, and psychological sciences” (Azevedo, 2015, p. 84). In this paper, we answer the call for building integrative models of engagement (Azevedo, 2015; Sinatra et al., 2015) and argue for adopting a dynamic systems perspective (DSP) (e.g., Hilpert & Marchand, 2018) as a paradigm to conceptualize student engagement as a process that develops on a moment by moment basis in classroom settings.

Current Challenges in Defining Student Engagement

In the current literature, researchers conceptualize student engagement as a multidimensional construct (Christenson, Reschly & Wylie, 2012). Common dimensions of student engagement include emotional engagement (feelings about school, learning, and/or a task), behavioral engagement (observable participation in activities), cognitive engagement (mental effort and strategies employed while learning), social engagement (cooperation with others; Wang, & Hofkens, 2019) and agentic engagement (the student’s active contribution to shaping the academic activity; Reeve & Tseng, 2011). Although other dimensions are also researched (e.g., engagement as energy, dedication and absorption; Salmela-Aro & Upadyaya, 2012), in the past two decades the dominant perspective has emphasized multiple dimensions of behavior, cognition, and emotion (Fredricks, Blumenfeld & Paris, 2004). This multidimensional perspective has advanced our understanding of the complex nature of engagement, but it is hampered by several conceptual challenges (Azevedo, 2015). To ground our conceptualization of momentary student engagement as a developmental system, we begin this theoretical statement by detailing four key challenges in current research: the conceptual boundaries of engagement, the conceptual grain-size of engagement, the conceptual boundaries of engagement's dimensions, and the dynamic interplay among the constituents of engagement.

The conceptual boundaries of engagement. One definitional challenge is the lack of consensus over the psychological and social phenomena that should be considered part of student engagement (Eccles, 2016). For example, there is some disagreement regarding whether social support in classrooms is part of engagement or not. A widely used instrument for measuring student psychological and cognitive engagement (the Student Engagement Instrument [SEI]; Appleton, Christenson, Kim, & Reschly, 2006) includes social support by others within the engagement scales (e.g., "my teachers are there for me when I need them"). More recently, Wang and Hofkens (2019) have put forward the notion of social engagement, meaning a student's engagement in social processes at school. However, when students are engaging in schoolwork in classrooms, the supportive qualities of teacher-student and student-student relationships act to promote or inhibit engagement. Therefore, relationships are external to the student engagement system, rather than being within it (Skinner, 2016). A more useful way of researching relationships and engagement is by studying their external dynamics with each other, as we discuss later.

The conceptual grain-size of engagement. Skinner and Pitzer (2012) pointed out that students' engagement is nested sequentially in academic tasks, classrooms, schools, and larger societal institutions. Following from this, Sinatra et al. (2015) have noted the need to identify the different grain-size, or unit-of-analysis, that engagement is studied at, defining grain size as "the level at which engagement is conceptualized, observed, and measured" (p. 2). In this paper, we argue that the grain size of engagement can refer to at least three dimensions: time, task, and agent. In the time dimension, microlevel time-scale engagement refers to momentary involvement in a task of reasonably short duration such as five minutes or an hour, and macrolevel time-scale engagement refers to involvement that is more prolonged such as going to school across several years. Researchers working at the micro-level of time have used experience sampling to take snapshots of engagement at random timed intervals (e.g. Scheider et al., 2016), and think aloud methodology to investigate how engagement unfolds along consecutive, fine-grained units of time i.e., an academic task (e.g., Kaplan, Lichtinger, & Margulis, 2011). In comparison, those working at the macro-level of time have asked students to report on their engagement over aggregated time i.e., a school year (e.g., Archambault & Dupéré, 2017).

In the task unit-of-analysis, smaller scale may refer to engagement in a very specific task, such as calculating a sum, whereas larger scale would refer to engagement on more complex tasks that are sustained across longer time periods, such as attending math class, doing schoolwork, or even 'going to school' across childhood and adolescence. Although there is some overlap between the time and the task unit-of-analysis, the two dimensions are distinct. Confusion in engagement research arises from asking students to report on their engagement in larger tasks (e.g. schoolwork in general), but capturing this memory during a single moment in time (e.g., how do you feel about schoolwork 'right now'), confusing the micro-level time and macro-level task grain sizes. Furthermore, it has been argued that people's retroactive reporting, which is based on memories and post-hoc evaluations of experiences, constitute *outcomes* of that activity, rather than reflecting the experience of engagement at the time (Fogel, 2011).

In the agent unit-of-analysis, engagement can be conceptualized at the level of the individual or of a collective: from dyads, to teams, to larger groups, up to whole schools (Sinatra et al., 2015). Thus, it seems possible also that engagement would manifest differently when conceptualized and assessed at different agent grain sizes, for example aggregating the average engagement of students in a classroom, studying the collaborative engagement of two students working together on a chemistry task, or doing a case study of a student engaged in answering a comprehension question. Theories of engagement need to contend with the diversity of engagement phenomena across time, task, and agent units-of-analysis, and the nested nature of these different grain sizes within these units-of-analysis (Skinner, 2016; Skinner & Pitzer, 2012).

The conceptual boundaries of the dimensions of engagement. Another conceptual challenge in the engagement literature has arisen from labelling the dimensions within engagement (e.g., cognitive, behavioral, emotional) as ‘sub-types’ of engagement in themselves. For example, the term ‘emotional engagement’ suggests that there is a ‘type’ of engagement with solely emotional content. Using the terms emotional, behavioral, and cognitive engagement, implies that these components have a sort of independence from each other and can be studied as different forms of engagement (Shernoff et al., 2017), rather than being interdependent parts of a holistic engagement phenomenon. This misspecification has arisen in part from the use of these terms to classify different types of studies in Fredericks et al.’s (2004) groundbreaking review of the research on student engagement. There, the authors identified that different studies of student engagement typically researched either cognitive, emotional or behavioral aspects. However, the review was never meant to set out a general theory of engagement. The rapid uptake of these categories as a framework or ‘model’ has bypassed the need for progressing general theories of how engagement operates.

A further problem arising from the use of the terms ‘emotional engagement’, etc., is that researchers try to operationalize them using indicators which often overlap between dimensions, across studies. This makes it impossible to rigorously synthesize the findings of quantitative engagement research, for example in a meta-analysis. For example, are effortful concentration and persistence in classwork part of behavioral engagement, or part of cognitive engagement, or perhaps part of both (Sinatra et al., 2015)? And what is the role of motivation in engagement? While some argue that motivation is not part of school engagement (Lawson & Lawson, 2013), others consider it to permeate all the engagement dimensions (Sinatra et al., 2015). Consequently, there has been persistent confusion regarding the role of motivational constructs such as self-efficacy, classwork effort, and educational goals in the engagement construct (Symonds & Hargreaves, 2016). As Azevedo (2015) notes, scholars should seek to study engagement as a whole, rather than study its parts in isolation.

The dynamic interplay of engagement’s constituents. A final issue of conceptual ambiguity concerns the internal dynamics, or interplay, of the phenomena making up engagement (Wang & Degol, 2014). Some researchers conceptualize engagement as the integration of its constituting dimensions. For example, flow theory (Csikszentmihalyi, 2008) predicts that people will become engaged to the point of absorption when they experience a harmonious match between challenge and skills during the activity (Schneider et al., 2016; Shernoff, Ruzek, Sannella, Schorr, Sanchez-Wall, & Bressler, 2017). Such balanced integration between challenge and skill leads to simultaneous concentration, interest, and enjoyment (Shernoff et al., 2017). In comparison, other scholars treat engagement’s dimensions as distinct and causally influencing each other, modelled for example through cross-lagged regression (Li & Lerner, 2013). Again, a more integrated conceptualization of engagement as a process is needed, to help steer researchers towards testing models of the engagement system in action.

Summary of conceptual challenges. In agreement with previous critiques of the engagement literature (Azevedo, 2015; Sinatra et al., 2015; Shernoff et al., 2017; Skinner, 2016), we identify that conceptualizations of engagement must contend with the current ambiguity of its boundaries, grain-size, dimensions, and dynamic interplay of its constituents. This is a major scholarly challenge that requires, first and foremost, a conceptual paradigm that will be able to coherently capture the integration of context and action, macro and micro grain sizes of agent, task and time, and the dynamic interplay of engagement constituents that are conceptually distinct, yet have blurry boundaries as they overlap within the overarching phenomenon of engagement. One such paradigm that has been applied successfully to similar conceptual challenges in other domains of inquiry is the dynamic systems perspective (DSP) (e.g. Hilpert & Marchand, 2018; Koopmans & Stamovlasis, 2016). The DSP has gained momentum in developmental psychology (e.g., Kaplan & Garner, 2017; Lerner & Schmid Callina, 2014; Nogueiras, Kunnen & Iborra, 2017; Overton, 2015; van Geert, 2011) and educational psychology (e.g., Barger & Linnenbrink-Garcia, 2017; Hilpert & Marchand, 2018; Kaplan & Garner, 2017; Nogueiras, Kunnen & Iborra, 2017), providing a comprehensive ontology that can guide theory-building, research, and interventions. The following section overviews some core tenets of DSP which we build on in our conceptualization of momentary student engagement.

The Dynamic Systems Perspective

The use of a DSP in social sciences has intensified over the past 50 years (Lewis, 2011). In consideration of space, we do not attempt to cover its multiple traditions here. Instead, we give a brief overview of the persistent, core tenets of DSP. For more information about the DSP applied in educational contexts, interested readers might consult Koopmans and Stamovlasis (2016). Below, we work a description of the DSP out of Pepper's (1942) root metaphors of mechanism, organicism, and contextualism, based on the work of developmental psychologists who applied these metaphors to the issue of human development during the 1970s and 1980s (cf. Reese & Overton, 1970; Hayes, Hayes & Reese, 1988; Lerner 1986).

Mechanistic Root Metaphor

In the *mechanistic root metaphor*, living organisms are viewed as machines that can be understood through examining their different levels of functioning (e.g., psychological, biological, molecular), each of which can be dissected into parts (e.g., molecules, cells, organs, synapses) (Lerner, 1986). Each level is understood to constitute the sum of the parts in the level just below, allowing for continuity between levels. Parts act as levers that exert measurable and proportional influence on other parts to evoke those parts' activity (Hayes et al. 1988). The mechanistic view is therefore reductionist, quantitative, and assumes predictable and linear input-output relations between parts within the system (Lerner, 1986). If applying this perspective to momentary student engagement, we would conceive the parts as always impacting each other in predictable "mechanical" ways; for example, curiosity always affecting motivation to act. However, this mechanistic view contrasts with the lived experience of momentary student engagement, which as we shall explain later is a non-linear, unpredictable phenomenon that cannot be reduced to a simple input-output and internally causative structure.

Organicism Root Metaphor

Pepper's *organicism root metaphor* can be used to conceptualize psychological phenomena as organic, biological processes. In this view, parts integrate to form 'ideal' final structures, just as a plant grows into a tree with roots, stem, branches, and leaves (Pepper, 1942). The integration of parts across development occurs as an autonomous and self-contained process that is determined by an organism's biological pre-programming. Organicism focuses on explaining the inner dynamics of growth, whilst deprioritizing time and context (Pepper, 1942). Using this metaphor, momentary student engagement would be conceptualized as an autonomous and pre-programmed process leading to a typical outcome, such as the concurrence of motivation and emotion creating a specific type of activity participation. Although engagement does develop across time, the significant role of agency in engagement (e.g., Reeve & Tseng, 2011) means that developmental determinism does not accurately define momentary engagement.

Contextualism Root Metaphor

The *contextualism root metaphor* is the notion that (psychological) phenomena are in themselves historic events, acts, or episodes, that make up the lifespan. Rather than viewing past events as bygone, in contextualism they are viewed as being the fabric of the phenomenon, such as when past events like running a race or creating a poem are integrated within a present life experience (Pepper, 1942). Each event is "intrinsically complex and… composed of interconnected activities with continuously changing patterns" (Pepper, 1942, p. 233). In contrast to organicism, in contextualism, time and context are key in understanding how phenomena manifest. This metaphor is a better fit for understanding momentary student engagement as a situated experience that unfolds across time.

Synthesis of Metaphors

The DSP has emerged as a synthesis of these worldviews, particularly those of organicism and contextualism. The mechanistic premise that a whole is equivalent to the sum of its parts is rejected in favor of viewing the whole as a qualitatively unique phenomenon that is emerging out of the coaction of its parts, each of which is its own emergent phenomenon (Lerner, 1986). In the next few sections, we draw out core principles underpinning this synthesis of metaphors that form the building blocks for our dynamic systems perspective on momentary student engagement. These are the principles of holism, self-organization, emergence, contextualism, and non-linearity.

Holism and Coaction

The DSP approach is guided by the epistemological principle of holism. In holism, phenomena are perceived as systems that are made up of parts and are inseparable from the context in which they are embedded (Overton, 2015). The parts within a dynamic system are each a dynamic system of their own. Accordingly, a dynamic system is a hierarchy of multiple nested dynamic systems and at the same time is an individual, holistic entity.

The parts within dynamic systems are interdependent, and rather than operating as connecting cogs with each moving another in turn, they have mutually influencing "recursive interactions" across time which are referred to as coactions (Lewis, 2011, p. 4) The changes in one part, therefore, affects a change in all others parts, resulting in parts changing dynamically together. We use the term coaction rather than interaction, because coaction signals that the parts in a dynamic system are never fully segregated therefore must always act together. In comparison, the term interaction implies that parts are separate and have external relations with each other (e.g., mechanical) (Overton, 2015).

Holism reflects, therefore, a transactional, systemic process that transcends the sum of the system's parts (Lerner, 1986; Reese & Overton, 1970; Overton, 2015). For example, at the grain-size of collective engagement in schoolwork, a group of students collaborating on a science experiment constitutes a holistic dynamic system. The group is made of the students and their emerging coactions, which are continuously influenced by the context and task. A change in one student's actions, or in the emotional connection between two students, would reverberate across the group and influence the other students' coactions and the resultant collective engagement.

Self-Organization, Attractors, and Dynamic Stability

Elements of a dynamic system can be people – such as music students playing together, or adolescents forming and sustaining a friendship group in school – who constitute interacting agents who influence and are influenced by each other to give rise to group behavior. The elements can also be parts within a person – for example, emotions, perceptions, goals, tendencies – that, similarly, integrate dynamically to give rise to the person's experience and actions (Kaplan & Garner, 2017). The emergence of such phenomena occurs through organismic (unconscious) processes that involve positive and negative feedback loops that inform and constrain the coaction of the elements - whether people or personal characteristics. The organismic processes that are the foundation of dynamic systems strive toward order in a process called self-organization. But, in human systems, these processes can also include agency and intentional self-regulation (Gestsdottir & Lerner, 2008) that can aim to guide self-organization towards "adaptive ends" (Overton, 2015, p. 47) such as maintaining concentration on schoolwork, or asking questions to aid with learning (Reeve & Tseng, 2011). Self-organization of a dynamic system can lead to relatively stable patterns called attractors (Fogel, 2011). A student's habitual tendency to be engaged or disengaged in mathematics is an example of an attractor state, created by the student's holistic engagement system self-organizing in context. While attractors manifest stability - e.g., the student may seem to be consistent in her or his attitude and behavior - the system is still dynamic, with the elements continuing to influence each other in ways that maintain the system's state.

Emergence and Circular Causality

As general feature of a dynamic system, the coactions among the system's parts ensure that all parts change their properties in response to a change in one or more parts (van Geert, 2011). For example, in collective engagement in schoolwork, a behavior of one student in the group would influence the behavior of the other students. In momentary (individual) student engagement, a change in cognition would reciprocally influence a change in emotion and behavior and vice versa. In comparison, in mechanistic systems, causality flows in a single direction, and some elements may be unaffected by change in other elements. In dynamic systems, the continuous "becoming" of the phenomenon - the system's behavior - which is not fully causally determined by any single element or factor within or outside of the system, is called "emergence." Such emergence can manifest in new states and behaviors, and even in the formation of new parts and systems that may be qualitatively different from the lower level parts that have coacted to create them (Lerner, 1986; Lewis, 2011). For example, the interaction among students in a collaborative group can give rise to the emergence of smaller cooperative sub-groups. Similarly, within an individual student, the coaction of cognition, motivation, emotion, and behavior during an academic task may give rise to a new perceived interest in an aspect of the task, or a new mode of participation in the task. This process of bottom-up causal emergence is complemented by top-down causal emergence, where the qualitatively new phenomena that emerge during the task, affect the dynamic system. This process is described as circular causality, where there is a simultaneous link between parts-to-whole and whole-to-parts relations (Witherington, 2011).

Context, Time, and Development

School students' personal and interpersonal dynamics emerge within the cultural, organizational, social, and physical characteristics of the classrooms in which they are embedded, given that they are "actively engaged with the world of sociocultural and physical objects" (Overton, 2015, p. 50). However, rather than the context predictably impacting the student's dynamic system of engagement (such as teacher's praise always having a motivational impact on a student's engagement), dynamic systems reflect the continual mutual transfiguration of both the environment and the self. The student and the context combine into a higher-level unit – another dynamic system - that changes over time (Overton, 2015). The temporal emergence of a student's momentary engagement, for example, studying for an English examination, is a part nested within a broader dynamic system comprising the student, the study material and contextual characteristics and events that continue to unfold dynamically and chronologically. Changes in person, time, and context necessarily reverberate throughout the system, therefore any comprehensive understanding of the student's experience of studying would be incomplete without attending to all of these units of analysis and their relations. We use this example to make the point that engagement at any level is a dynamic system, although we focus in this article on engagement at the micro-level grain sizes of task, agent and time.

Non-Linearity

Given that the parts within dynamic systems coact in response to continually changing environments, the functioning of the system is never fully predictable. Rather, the coaction of parts can result in the emergence of qualitatively new phenomena that can trigger sudden changes and irregularities in the dynamic system (Nogueiras et al., 2017). For example, a student's momentary engagement in a task is marked by non-linear re-actions and pro-actions to internal (e.g., rising and falling fatigue, interest, hunger) and external (e.g., peer comments, teacher instructions) events. Planned and organized interventions as well as randomly occurring changes in the system can have unpredictable consequences; for example, a minor change in one part (e.g., a teacher's minor comment) has a disproportional impact across the system (e.g., a major shift in the student's sense of self-worth) that is only evident after time has elapsed (van Geert, 2011). In this manner, dynamic systems cannot be studied simply as "input-output" mechanisms with assumed predictable, linear relations between their parts, and resultant linear manifestation of behavior (Overton, 2015, p. 22).

In summary, a dynamic system represents a holistic, non-linear phenomenon that is irreducible to its parts, and is interdependent with the context within which it is embedded, and the time along which it continuously emerges. Parts (which are themselves nested dynamic systems) coact to give rise to qualitatively new phenomena, which, in turn, affect the coactions among parts. Although its behavior manifests in nonlinear patterns that can involve sudden changes, the system generally strives to retain its integrity through self-organization towards attractor states, which manifest as dynamic stability. This definition provides a platform for conceptualizing student engagement as a momentary dynamic system.

Application of the DSP to Momentary Student Engagement

Applying the Dynamic System Perspective (DSP) assumptions to momentary student engagement may help to address several of the conceptual challenges in the literature. Specifically, it integrates a variety of engagement dimensions into a holistic, dynamic, contextualized, non-linear, momentary phenomenon that corresponds to students' lived experiences of engagement in academic tasks. The current literature provides an excellent basis for this conceptualization. For example, Skinner (2016) defines engagement as based in student action by harnessing the broad categories of emotion, cognition, behavior, and agency from the multidimensional construct perspective (Fredricks et al., 2004; Reeve & Tseng, 2011). In Skinner's (2016) framework, engagement is comprised of the emotions a student experiences during an activity (e.g., enthusiasm, enjoyment, fun, interest, and zest), the cognitive processes that are activated during the activity (e.g., self-regulation, determination and commitment, learning strategies, and mastery), the behaviors performed in the activity (e.g., concentration, compliance, persistence and exertion), and agency as key to coordinating and enacting these processes during involvement in an activity. In what follows, we build on Skinner's (2016) classroom engagement framework by going one step further to conceptualize this momentary process as a dynamic system that operates at the micro-level grain size (Sinatra et al., 2015) of individual students, individual academic tasks and short periods of momentary time.

Moving Towards a Dynamic Systems Perspective on Momentary Student Engagement

Our conception of momentary student engagement as a dynamic system draws on a metaphor generated at the 1995 meeting of the MacArthur Foundation Research Network on Successful Pathways through Middle Childhood. There, researchers described student engagement as what happens "when the rubber meets the road" (Eccles, 2016, p. 71). In this metaphor, "the car's wheels represent the psychological parts of engagement and the road represents the activity or setting in which the individual is engaged. In a sense, the wheels were enacting the motivation of the individual within the context of the road" (Eccles, 2016, p. 71). Here, engagement is described as "a momentary, emergent property derived from all of the ways in which a person could engage in the moment in an activity or a contextual setting" (Eccles, 2016, p. 71).

For example, imagine an adolescent sitting in a school classroom on a cold day. The student is asked to solve a mathematics problem using a textbook, a sheet of paper, and a calculator. The classroom is illuminated by four slit windows atop a high concrete wall. The heater is lukewarm. The teacher is cheerful, promising that the student will feel good about themselves after solving the problem. The student begins the task but is soon distracted by another student who throws paper at their desk. Remembering the need to keep a good relationship with the teacher, the student ignores the event and returns to the task. However, they soon experience boredom. In order to maintain concentration, they generate the image of feeling greater self-worth after completing the task and keep this salient within their mind to provide themselves with a motive to persist.

How might we study the student's engagement using approaches typically used in the field? We could ask the student to use rating scales to self-report on their emotions (of boredom and accomplishment), cognition (self-control and problem solving), behavior (paying attention to the math problem) and agency (deliberately ignoring the distraction). These reports could be gathered during or after the math task. However, self-report snapshots seem insufficient to capture and explain how this momentary engagement took place. Rather, we would need to study momentary engagement in a manner that would capture the dynamic flow of an integrated system of shifting cognition, emotion, motivation, and behavior in a moment-to-moment sequence, with engagement emerging irreducibly from the coactions of these parts. In the following section, we make an initial attempt at mapping what these parts are, and how they might coact, although we do so with the caveat that more theory building and empirical research is needed after this point to take the initial concept forwards.

Foundational Assumptions about Momentary Student Engagement as a Dynamic System

Following the core tenets of DSP outlined earlier, we envision momentary engagement as a person's self-directed involvement in an activity: a dynamically unfolding phenomenon that integrates coacting parts into an irreducible whole. Momentary engagement can be described in terms of content (of the parts or elements within engagement), structure (the nature and magnitude of coactions among those parts) and process (the way the content and coaction unfold across time) (Kaplan & Garner, 2017). More specifically:

1. We conceive of momentary student engagement as the situated, embodied, affective-motivational experience of integrated mental-physical activity in a task. Figure 1 depicts this process as comprising four parts of emotion, motivation, physical and mental activity, that coact within and manifest in momentary engagement.
2. The structure of momentary engagement involves parts-to-parts, parts-to-whole, and whole-to-parts dynamics (Overton, 2015), and in this has circular causality (Witherington, 2011). These dynamics are also depicted in Figure 1. Returning to the student in the vignette, they are bored, but motivated to learn. As they experience boredom (a change in emotion), they alter their motivational strategy to affect a change in their concentration (a change in mental action). These coactions dynamically influence a change in engagement as a holistic phenomenon.
3. Momentary engagement necessarily occurs within discrete time periods during which the task is carried out, such as ten minutes of involvement in a mathematics task. As such, momentary engagement is a ‘rapid’ dynamic system, comprising the momentary coaction of emotion, motivation, mental and physical action.
4. The process of momentary engagement occurs as an action sequence that begins with a ‘trigger’ for engagement, follows with engagement action, and ends with disengagement. Figure 2 presents a schematic of this process with the possibility of irregularities occurring along the way. Our student began the math task upon

instruction from their teacher (trigger), carried out the math task through dynamically changing momentary actions, then disengaged when the math task was complete.

5. Momentary engagement may be interrupted and set on a different course by unanticipated psychological (i.e., internal to the person) or environmental irregularities (Nogueiras et al., 2017), such as our student being interrupted by the classmate throwing paper.
6. The extent to which engagement is agentic depends on the circumstances, with some tasks and contexts requiring more agency to sustain engagement than others. In the vignette, the student had to apply agency in order to harness their mental resources and sustain their engagement in the face of a distractor and boredom.
7. Momentary engagement can aggregate across larger grain sizes of time (e.g., a week, a year) to manifest in habitual engagement in larger grain sizes of task (e.g., math) and context (e.g., a particular school). This longer-term process is linked to the development of dispositions to engage, manifest for example as attitudes towards school, which in turn can frame momentary engagement in future tasks.
8. The most appropriate data collection methods to capture momentary engagement should target real-time action, and ideally involve longitudinal and frequent data, to account for the unanticipated irregularities and changes that occur across moments (Hilpert & Marchand, 2018; Nogueiras et al., 2017). These data can be collected at different temporal metrics (Lerner, Schwartz & Phelps, 2009), creating the potential for analyzing momentary engagement at increasingly smaller grain sizes.

The Content of Momentary Student Engagement

Defining the content of student engagement is no easy task, if viewing engagement as "all of students' perceptions, emotions, and cognitions in the course of interacting with instruction" (Shernoff et al., 2017, p. 4). However, psychological phenomena are complex, and our theories should reflect this complexity. Classification frameworks are useful for enabling windows into complex phenomena even if they do not capture them completely. Accordingly, we discuss the content of momentary engagement as made up of parts that include physical action (including motor skills and organismic processes like breathing), mental action (including concentration, cognition, and meta-cognition), motivation (initiation and momentum) and emotion (affect, mood and emotional responses) (Figure 1). This classification builds on the notion that momentary engagement has emotional, cognitive and behavioral components (Skinner & Pitzer, 2012; Shernoff et al., 2017) that are often enacted with agency as we discuss later. Here, action is distinguished as a specific type of mental process or behavior that is oriented towards satisfaction of a goal state (Metzinger, 2017).

Physical action. Rather than use the term 'behavioral engagement,' which suggests that engagement has a discrete behavioral form separate from cognition and emotion, we conceptualize momentary engagement as being comprised in part by physical action, such as talking to the teacher, or performing the necessary movements to participate in a sports lesson. A key attribute of physical action in our conceptualization of engagement is that it is momentary and goal directed (Metzinger, 2017), and can incorporate vigorous movement (such as performing the long jump in physical education) as well as more discrete actions including body position, postures, gestures, and hand, head and gaze movements that direct attention to and away from stimuli and affect alertness, concentration, and mood (Sohlberg & Mateer, 2001). This smaller grain size of momentary physical action complements the larger grain size of longitudinal participation in activities, truancy, and time spent on homework that has been used to operationalize behavioral engagement (Li & Lerner, 2011).

Actions involving any components of the body serve an important function in momentary engagement. For example, when engaged in solving the math problem in class, the student was using their hands and fingers to write, eyes to see, torso to stay upright, and so on. In a pure DSP, all physical actions would be considered as part of the dynamic system of engagement, each a complex system of its own (for example typing) even if these actions are sedentary. Likewise, the physical part of engagement may be vital to consider when studying students' engagement in vocational and vigorous activities, for example involvement in physical education or drama.

Mental action. Another part of momentary engagement is mental action. This has been defined as a wide set of goal oriented mental processes, including motor imagery and planning (Mendelsohn, Piner & Schiller, 2014), focusing attention on an object or goal, retrieving images from episodic memory, categorizing or constructing part-whole relationships, mental reasoning (Metzinger, 2017), maintaining focus on the background context or task, shifting attention and controlling the content of the mind (Upton & Brent, 2019). In the school engagement framework, Fredricks and colleagues described cognitive engagement as "being thoughtful, using deep learning strategies, and… comprehending complex ideas" (Wang et al., 2017, p.2), which resonates well with our concept of mental action. Like physical action, the defining factor of mental action is that it is goal directed, moving the person closer towards obtaining emotional or cognitive satisfaction (Metzinger, 2017) through their engagement in the task. Using the term mental action explicitly identifies that cognitive activity required to engage with a task is goal directed. It also side-steps the potential empirical confusion caused by labelling cognitive activity as ‘cognitive engagement,’ which indicates that it is a sub-type of engagement that is somehow disconnected from other ‘sub-types’ including behavior and emotion.

Using the example of the student solving the math problem, we can imagine how mental action facilitates knowledge building and consolidation (Howard-Jones et al., 2018), for example through activating perception, selection, encoding, working memory, long-term memory, and retrieval, which are all key mechanisms of learning (Schunk, 2015). However, mental action is distinct from the broader notion of all cognitive processes by being goal-directed, whether this is conscious or not (Metzinger, 2017). Therefore, not all cognitive processes qualify as part of engagement, for example daydreaming or mind wandering, unless they are a deliberate part of engaging in the task.

Motivation. Motivation concerns the “processes that underlie the energy (vigor, intensity, arousal), purpose (initiation, direction, channeling, choice), and durability (persistence, maintenance, endurance, sustenance) of human activity” (Skinner, Kindermann, Connel & Wellborn, 2009, p. 225). In the 2012 Handbook of Research on Student Engagement (Christenson et al., 2012), and in a review of school engagement conceptualizations (Lawson & Lawson, 2013), scholars have debated whether motivation is a part of engagement. Conceptualizing engagement as a dynamic system helps to resolve this issue, because all psychological and physiological functions that create engagement, including motivation, constitute engagement as a dynamic system. In our vignette, the student’s experience was of engagement as an embodied, affective-motivational phenomenon. This is in line with descriptions of engagement as the outward manifestation of motivation (Eccles & Wang, 2012; Skinner, 2016).

Emotion. Emotions, mood, and affect are central to momentary engagement. As with motivation, there is debate as to whether emotions experienced during educational tasks, including enjoyment, interest, anger, frustration and boredom, are antecedents and outcomes of engagement or are part of engagement (Pekrun & Linnenbrink-Garcia, 2012). In our momentary student engagement perspective, emotions are part of engagement when they are experienced as part of a person's active involvement in a task. We explore the way that emotions coact with the other parts of engagement (motivation, mental and physical action) next.

The Structure of Momentary Student Engagement

The notion of structure concerns how the parts of momentary student engagement coact to manifest as a holistic phenomenon. An important notion is of an attractor state (described earlier) that encourages the system to converge into a specific form, through ongoing mutual affirming coactions (Fogel, 2011). Once the system is in an attractor state, mutually affirming coactions continue, and even though the system continues to emerge it manifests as relatively stable. This stability lasts until an event modifies the parts' relations away from affirming, at which time the system appears as unstable. In our vignette, structure can be observed in the way the student's motivation, emotion and mental action coacted with each other and with the upper-level phenomenon of engagement. Below, we detail how engagement can emerge as an attractor state through the coaction of its constituent parts (parts-to-parts coactions) (Overton, 2015), the influence of parts on engagement (parts-to-whole coactions), and the impact of engagement as a holistic phenomenon on its parts (whole-to-parts coactions). Another way to conceptualize these structural aspects of engagement are as horizontal, upward and downward causation, with the two latter structures enabling circular causality to occur (Witherington, 2011).

Parts-to-parts coactions. Associations between the parts within momentary engagement (emotion, motivation, mental action and physical action) have been suggested by studies using the experience sampling method (ESM) to collect data on indicators of engagement within educational tasks (Ketonen et al., 2019; Patall et al. 2017; Rimm-Kaufman, Baroody, Larsen, Curby & Abry, 2015; Shernoff, Kelly, Tonks, Anderson, Cavanagh, Sinha & Abdi, 2016). These studies have revealed positive associations between parts oriented towards (not away from) action (e.g., the will to exert effort; cognitive learning strategies; and positive, activating emotions); however, it is difficult to distinguish specific patterns, partly due to the variety of measurements, methods, and national contexts involved. What these studies clearly demonstrate is that during a single task, or across numerous tasks, the types of parts that we presume are involved in momentary engagement are associated with each other during momentary time, supporting our assumption that engagement parts coact. More research is needed to ascertain how specific parts coact and emerge through non-linear dynamics. It is our hope that future research can take this position paper as a starting point, to refine and extend the perspective on momentary student engagement through empirical work.

To go deeper into possible parts-to-parts relations that this future research might uncover, we turn to motivational theories that for many years have predicted how parts of engagement will relate to each other within a broader system. Regarding how motivation can impel cognitive and physical action, in expectancy-value theory individuals are predicted to engage more within a task if they feel more competent at the task, have positive expectations for success and perceive net positive value for engaging in the task (Eccles, Fredricks, & Baay, 2015; Wigfield, Eccles, Fredricks, Simpkins, Roeser, & Schiefele, 2015). Support for this at the microlevel of momentary processes has been generated by a recent study of situational motivation, where

Dietrich, Viljaranta, Moeller, and Kracke, (2017) found that situational reports of task value and expectancy towards a college lecture topic positively associated with students' cognitive effort in the task, across situations and people.

It is further assumed in the Eccles et al. version of expectancy value theory (e.g. Eccles et al., 2015) that these beliefs and perceptions are grounded in identities, prior experiences and developmental trajectories, goals, and anticipated or concurrently experienced emotions. Accordingly, we would expect mental and physical action to be promoted when people hold a positive frame of reference for action in the task, and when they feel that the task is a good fit with their personal goals and values. However, these phenomena would have to occur in the moment of the task to be part of momentary engagement (e.g. the student imagining obtaining a greater feeling of self-worth after the math task, while doing the task).

A further coaction between parts is documented in neuroscience of emotion. For example, in a recent study, participants faced with a deliberately boring task were less able to activate the areas of their brain responsible for mental action (the 'central executive network'), than when given a task designed to stimulate interest and enjoyment (Danckert & Merrifield, 2018), demonstrating how emotions impact mental action.

Parts-to-whole coactions. Engagement structure also entails the impact of parts to the whole, meaning that emotion, motivation, and mental and physical action result in the emergence of the engagement state (upward causation). The process by which this occurs is dependent on the context of the task. For example, people can be engaged in watching a movie without any effortful thought or physical action as their attention is activated by feelings of interest, surprise, excitement etc., or by becoming cognitively absorbed in the narrative (Bezdek & Gerrig, 2017). These are examples of where agency does not feature greatly in engagement. Alternatively, engagement in some academic tasks requires considerable mental action, for example needing to concentrate on producing a piece of complex work. Concentration is described as focusing one's thinking on a task while avoiding distractors (Moran & Toner, 2018), which in our vignette involved the student in the math lesson generating and harnessing positive thoughts in order to maintain their mental action. Future research will need to examine part-to-whole processes for engagement in different types of tasks in order to study both the impact of different tasks on the part-to-whole process (e.g., math lesson versus movie) and people's conscious management of this process (e.g., consciously controlling motivation and mental action to achieve engagement in monotonous tasks), and to identify the different configurations of relations among parts that give rise to attractor states through the bottom-up emergent process.

Whole-to-parts coactions. Engagement is an ideal example of a dynamic system that also has a downward impact on its parts, given that it is lived in the moment. Engagement requires the person to interact with the task, and this interaction creates continually changing conditions that frame the emergent meaning of engagement. For example, the person's involvement with the task can alter if they encounter a frustrating challenge or see evidence that they have done part of it incorrectly. In turn, this can influence the salience and relations of parts. This was illustrated in our vignette as the student deliberately motivating themselves to overcome a feeling of boredom when they felt their engagement was declining, indicating how a change in the overarching state can have a downward impact on the parts within.

Circular causation. In the above sections, we indicated how upward and downward causation occurs within momentary engagement. One remarkable example of circular causation in engagement is when people enter a state of flow, which is deep absorption in a task (Csikszentmihalyi, 2008). As described earlier, flow emerges when there is an individual optimal configuration of challenge and skill (Shernoff et al., 2017). In turn, the hypnotic qualities of absorption can lead to a loss of time perception and altered sense of self, both of which reduce people's attention to distractors (Csikszentmihalyi, 2008). Flow, in this sense, can be conceptualized as one possible attractor state within the engagement conceptual space. It epitomizes automatic (rather than intentional) circular causation that leads to the emergence of mutually affirming relations among the component. Such an emergent configuration is qualitatively different from other possible engagement phenomena; for example, when the student deliberately invoked a feeling of self-worth to combat boredom in the math lesson vignette.

The Process of Momentary Student Engagement

In this section we focus on the overarching sequence of engagement as it plays out within a single episode of engaging in a task, involving triggers of engagement, action and disengagement (Figure 2). Each piece of this conceptualization is explained in detail below.

Triggers of engagement. Engaging in a task necessarily needs a trigger. In their seminal work on attention, agency and consciousness, Norman and Shallice (1986) described how attention can trigger action, in a manner that is consciously controlled or automatic. For example, you might notice the messy pile of papers on your desk and then deliberately move to tidy them, or you might unconsciously prevent yourself from falling off a cliff by adjusting your footing. In these examples, aspects of the environment have triggered engagement, just as a teacher might give students instructions to complete a new task. Perceptions of future states also commonly act as triggers; for example, setting a task-oriented goal (I want to solve this math problem) that energizes motivation to act. Similarly, Renninger and Bachrach (2015) have identified triggers for interest that spark more persistent engagement in tasks. Even if people transition into engagement automatically, there is a trigger, such as a change in context or activity that might not be salient to the person.

Action: emergence, irregularity and attractor states. Once momentary engagement in a task is in motion, it is in a constant state of emergence. For example, motivation and mental action at the start of a task can change qualitatively and quantitatively within a single engagement episode such as a lesson, with the desire to please the teacher being replaced by a more specified goal of solving a math problem when that stimulus becomes available. This presents a dynamic system of motives that ebb and flow in their salience through engagement across time (Kaplan, 2016; Kaplan et al., 2011). Too, multiple emotions and affective states can emerge, disappear, and resurface over short time periods.

Unanticipated irregularities that impact the parts of engagement, such as being distracted by another student throwing paper, or feeling suddenly hungry which leads to a loss of concentration, are also prone to occur given that momentary engagement proceeds across a fine-grained time scale (Nogueiras et al., 2017).

So how does momentary engagement keep together as a whole? Returning to the notion of the attractor state, we envision engagement as akin to a piece of music played by multiple children in an elementary school classroom who sensitively respond to each other across time, to create a form of dynamic stability by producing harmony. As the overarching sound changes, so too must the children adjust to the new quality of the sound, demonstrating the concept of circular causation (Witherington, 2011). In our vignette, once the student became aware of their boredom, they generated energy for their mental action by imagining themselves feeling good as a result of finishing the task. We illustrate this with the analogy of an equalizer (Figure 3), imagining each of engagement's parts (emotion, motivation, mental and physical action) as one of its settings (e.g., bass, treble, reverb, sustain). There, all the parts respond to each other and to the type of engagement that is produced, in a process of continual adjustment. This adjustment is necessary to create an optimal form of engagement through time and changes in context, and to keep people engaged in the face of barriers to engagement such as demotivating irregularities.

Disengaging. In the Motivational Theory of Life-Span Development, Heckhausen, Wrosch and Schulz (2010) explained that disengaging from a goal (or an activity) can be adaptive and can signal a readiness to move onto a phase of development that is more productive, given that the individual has maximized chances within the existing phase and that these actions may now be less effective if maintained. Similarly, in momentary engagement, disengagement can be productive, moving the person to a different activity that needs to be attended to; for example, a student who finished solving one problem moves to attend to the next. Disengagement, i.e., the act of stopping engagement in a task, is different from disaffection, which reflects a broader notion involving lack or loss of motivation, passivity, or disruption that is accompanied by negative emotions (such as boredom, frustration, resentment, or anxiety) (Skinner, 2016). In the momentary engagement process, disengagement can signal a natural ending to action, or be an intermittent state within a longer engagement process that occurs as people consciously or unconsciously withdraw their attention from the task at hand.

Agency

Agency has been conceptualized as a multi-faceted construct incorporating elements of goal orientation, self-efficacy, volition, and planning that occurs as a relational, situated process that develops across a person's life-course (Authors XXXX, Schoon & Lyons Amos, 2017). Agency differs from autonomy which refers to the ability to act, and from independence which means acting alone. The use of agency in research on student engagement is recent and refers to the agentic things a student does to shape their engagement experiences (Reeve & Tseng, 2011).

Whether or not engagement is agentic depends on the circumstance. A student can be automatically pulled towards an inherently engaging task, such as a video clip that promotes attention and interest through novelty and narrative intrigue. The student might not even notice they are engaged as they become absorbed in watching the video. In comparison, tasks that are less intrinsically engaging such as answering reading comprehension questions may require greater agentic direction of action for the student to engage.

When engagement is agentic, students are involved in shaping their experience of the task, either acting independently, or as co-agents (Salmela-Aro, 2009) with their peers and other people involved in the learning process. For individual students, agency can influence the internal dynamics of engagement; for example, self-regulating the coactions between emotion, motivation and mental and physical action (e.g., Schunk & Zimmerman, 2012). It can also involve shaping the flow of classroom instruction; for example, by asking questions, communicating needs, preferences and interests, and making suggestions (Reeve & Tseng, 2011). Agency is therefore a critical target for investigation into engagement in different tasks and contexts, among different students, and across the life-course.

Developmental Dynamics of Momentary Student Engagement

In our DSP, we expect that momentary experiences of motivation, emotion and mental and physical action might build up into pervasive habits, competencies and dispositions, such as the ability to pay attention even when schoolwork is demotivating. This presents an interesting longer-term developmental dynamic that has yet to be explored in depth in student engagement research. Below we discuss this phenomenon in relation to emotion and motivation.

Hidi and Renninger (2006) describe a state-to-trait process of interest development in which triggered situational interest in a topic during an activity develops into maintained situational interest during that lesson, which can then facilitate the development of emerging individual interest in the topic beyond the lesson, that can become a well-developed individual interest across time. Similarly, in qualitative research on student engagement, children have been found to mainly attribute their tendency to think positively about school as an entity (e.g., I like school) to experiencing repeated positive emotions in class as they interacted with lesson materials, peers and teachers (Symonds & Hargreaves, 2016). Here we can see how momentary emotional responses impact the development of more stable dispositions for engaging.

Within the Eccles et al. version of expectancy value theory (Eccles, 2009; Fredricks, et al. 2002), momentary experiences of success, challenge, flow and other sources of achievement-related pleasures and feelings of competence should accumulate into both more stable affective memories and dispositions, that in turn impact how people engage in the moment. In a longitudinal qualitative study, Fredricks and her colleagues identified a cyclical process through which highly engaged students became identified with being an athlete, musician, or academic over time by repeated experiences of competence, positive affect and encouragement from others in skills-based performance activities (Fredricks et al., 2002). This emerging identity formation gives a detailed example of what Eccles and her colleagues label attainment value (Eccles et al., 2015). They argued that attainment value is a particularly powerful source of motivation for repeated engagement in specific activities.

External dynamics between momentary engagement episodes and psychological schema were also described by Skinner and colleagues (e.g., Skinner & Pitzer, 2012) as a spiral of (dis)affection that can intensify longitudinally over a person's educational career. Symonds, Schoon and Salmela-Aro (2016) observed similar spirals occurring as different trajectories of interest in schoolwork across secondary schooling predicted mental health and educational participation at the school-to-work transition, demonstrating how engagement is part of a broader dynamic system of human development.

In the reverse direction, a student's dispositions formed over longer time periods have positive associations with momentary student engagement. In a sample of US college students, prospective course specific self-efficacy positively associated with later cognitive engagement in the task, collected using ESM (Xie, Heddy & Vongkulluskn, 2019). Similarly, in a sample of German college students, course specific task values reported at the start of a semester, positively associated with momentary task values collected during the semester using ESM (Dietrich, Moeller, Guo, Viljaranta & Kracke, 2019). These recent studies point the way forward to new avenues of research on the interactions of engagement across grain sizes. Our proposed DSP of momentary student engagement provides an innovative way to coherently conceptualize and investigate these processes across varying grain sizes of student, task and time.

Implications for Assessment and Research

Below we discuss methods and research designs suited to studying engagement at the microlevel grain size, and potential research topics arising from our ontological assumptions about momentary engagement as a dynamic system.

Researching Momentary Engagement at the Microlevel Grain Size

In a review of methods for studying engagement in science education, Azevedo (2015) overviews techniques and tools suitable for capturing data on engagement in academic tasks. We have summarized Azevedo's list of methods (2015, p. 91), focusing on those suitable for capturing data on the process and products of momentary motivation, emotion, and mental action

(Table 1). We have added the category of physical action to this list, and have extended the use of discourse analysis to studying process across dimensions: for example when the student's discussion (a physical action) with the teacher conveys emotion, motivation and cognitive strategies for learning. We have also included rapid repeated measures questionnaires for studying the process of engagement.

The overview of methods presented here and in Azevedo (2015) signals interesting opportunities for triangulation of data to ask key questions about momentary engagement as a process. For example, researchers could examine how emotion might help energize, disrupt or stabilize on-task behavior during learning by comparing physiological sensor data with systematic observation data. They might question how motivation and emotion intersect during learning by comparing concurrent think alouds on motivation with facial expression of emotions captured during the task. Descriptive data collected on the process can also be compared to product data (e.g., quiz results, pre-post-tests, task attainment) to investigate how different experiences of a process result in different products.

Time, Timing and Grain Size

Each method described in Table 1 can be used at slightly different temporal metrics (Lerner et al., 2009) to assess momentary student engagement. Trace methods that capture behavior as it occurs second by second use a faster temporal metric than systematic observation which might occur every half minute, or rapid self-report where students might respond every five minutes to a repeated measures questionnaire. Pre- and post-tests assessments might capture repeated measures data across intervals of five, ten, 20 or 120 minutes, for example, depending on the length of the task. After the unit of analysis is firmly focused on momentary processes, more rapid intervals allow researchers to describe engagement at a finer grain sizes of time (e.g., Azevedo, 2015). The timing of data collection is also an issue (Lerner et al., 2009), for example, what are the implications of studying momentary student engagement at different times of the day, school term or year?

Researching Momentary Engagement as a Developmental Process

The data collection methods described above can be usefully applied within microgenetic research designs for researching momentary engagement as a developmental process. In microgenetic designs (e.g. Lavelli, Pantoja, Hsu, Messinger & Fogel, 2005), the focus is on developmental change of an individual across a specific time period (such as an academic task, lesson or school term). Data are collected before and after the time period, and intensively throughout; and are analyzed intensively in relation to each other to identify how change occurred. A simple example is to study momentary engagement while a student is doing a 10-minute literacy task, by collecting a pre- and post-test of their literacy competence, systematic observation of their on-task behavior, and physiological sensor data to measure their emotional state. These data could be analyzed together to discover how engagement proceeded, and how this impacted post-test results.

Researching Momentary Engagement as a Dynamic System

The DSP brings a set of ontological assumptions to the process of momentary student engagement. We have explored many of these in this article, including causality (parts-to-parts, parts-to-whole, and whole-to-parts relations), irregularity, emergence and attractor states. Below we briefly discuss research topics stemming from these assumptions, that might be suitable to studying engagement at the microlevel grain size using microgenetic designs.

In their detailed review of researching dynamic systems in educational psychology, Hilpert and Marchand (2018) point researchers towards studying a dynamic system's *complexity* (the need to capture the system's parts and their relations); *dynamism* (explored by studying the parts and the whole longitudinally); and *emergence* (capturing the emergence of the system as a holistic contextualized phenomenon). We use this framework to guide our discussion on potential research topics for momentary engagement as a dynamic system.

Researching momentary engagement complexity.

We have proposed that momentary engagement is comprised of emotion, motivation, mental action and physical action, but more work is needed to examine which parts are salient at any one moment, and across momentary time, to understand the complexity of momentary engagement. The salience of each part within the system is likely to differ depending on the task, for example engagement in watching an instructional video might not require highly controlled motivational processes, whereas motivation might be consciously manifest and regulated when studying for an examination in class. Recent research points to multiple and divergent patterns of engagement parts, for example students have reported simultaneously high levels of emotional exhaustion, and energy, dedication and absorption, in studying (Salmela-Aro & Read, 2017). Given that the field of research on momentary engagement as a dynamic system is in its infancy, researchers may want to use inductive methods to establish which parts are present and their typical forms, during specific tasks such as solving a math problem, before attempting to measure the parts.

Researching momentary engagement dynamics. Dynamics regard how the parts and the engagement system as a whole change along time in non-linear ways. A distinction can be drawn between the internal dynamics of engagement (how the parts within engagement coact across time) and engagement's external dynamics (for example when engagement shapes learning or learning sparks engagement). Researchers may wish to investigate relations between parts, for example, by prompting for reflection on part interaction in concurrent think alouds (e.g., *what am I feeling and how is it influencing my attention?*), or by collecting time-series data on multiple parts and analyzing these data using bivariate multilevel autoregressive models (Schuurman, Ferrer, de Boer-Sonnenschein, & Hamaker, 2016). This latter technique models the lagged associations between multiple variables, with coefficients standardized within persons, to identify which variables are more central in the process across time (Schuurman et al., 2016).

Questions about irregularities and attractor states can also be explored using time-series data within microgenetic designs, for example researchers might query between-student differences in regaining motivation, concentration and positive affect after interruption, and examine the latent profiles of students who tend to have stable, consolidated forms of engagement versus those whose engagement (represented by its parts) fluctuates more rapidly. A further topic of interest is how these individual differences in engagement dynamics might impact learning, fitting with a growing research and policy focus on personalized learning processes (e.g., Tomasik, Berger & Moser, 2018).

Researching momentary engagement emergence. Earlier we suggested that flow (Csikszentmihalyi, 2008) is a form of engagement in which people are deeply absorbed in the task and lose sense of space and time. But which other forms of engagement might exist, and how might these link to individual differences and context? For example, researchers could use psychological network analysis (e.g., Bruun, Lindahl & Linder, 2018) or dynamic structural equation modelling (Asparouhov, Hamaker & Muthén, 2018) to identify how engagement parts cluster together to create specific forms of engagement, within timepoints and individuals, and across individuals and time. A recent study of momentary engagement revealed that during a single academic task, subgroups of students were simultaneously distracted but motivated, and attentive but disaffected (Authors XXXX). Further quantitative work is needed to examine how these types of motivational profiles co-exist with mental and physical action states, to reveal forms of momentary engagement as a holistic phenomenon.

A suitable qualitative methodology for studying engagement emergence is interpretive phenomenological analysis (IPA) (e.g., Smith, Larkin & Flowers, 2009). There, individual cases are analyzed in depth to uncover recurrent themes, which are then compared across cases and grouped into superordinate themes that are taken together to represent the phenomenon. Here, the set of superordinate themes is qualitatively different to the themes generated within individual cases. In this manner, IPA uses a combination of ideographic and nomothetic approaches to uncover the form of a phenomenon, for example engagement in a task. Researchers might use IPA to query how students describe the emergence of their momentary task engagement, to inductively identify within and across cases the types of emergent phenomenon that comprise engagement as a dynamic system.

Researching Momentary Engagement Across Different Grain Sizes of Agent, Task and Time

As discussed in the introduction, momentary engagement is positioned in this paper at the microlevel grain size of an individual student's involvement in a specific academic task, whereas engagement can also be conceptualized at larger grain sizes of agent (e.g. group), task (e.g., subjects or schooling) and time (e.g., longitudinal). Research examining connections between grain sizes could help elucidate the structure and process of macrolevel engagement. For example, to what extent does momentary physical action in an academic task relate to truancy, school attendance and completion? Do momentary task values in specific subjects (Dietrich et al., 2017) relate to students' valuing of schooling as a main activity (Symonds, Schoon, Eccles &

Salmela-Aro, 2019)? And what are the developmental dynamics between these grain sizes? Future research may need to combine microgenetic, multilevel and longitudinal methods to investigate these connections.

Implications for Intervention

Conceptualizing momentary engagement as a dynamic developmental system has important implications for interventions aimed at helping students engage in school, classrooms, schoolwork and learning. First, it is critical to clarify the grain size of engagement that interventions are targeting (e.g. students' general attitudes towards education, versus the sequential coaction of motivation, emotion and mental and physical action in a task). Interventions focusing solely on classroom and school engagement may help students build their capacity for motivation; however, they might fall short of helping students engage momentarily in academic tasks, where self-directed action and the ability to ignore distractors is often key. Here, the DSP on engagement highlights the importance of targeting applied metacognition, i.e., students' ability to think reflectively about what they are doing in class, and control of action, as these occur *in the moment*, meaning that interventions should help students practice staying engaged during real world classroom settings.

Another contribution of the DSP is the emphasis on the complexity of the engagement system, made up of multiple types of motivation, emotion and mental and physical action. The DSP could help teachers understand engagement as a complex, malleable phenomenon that might not always be visible in its entirety. Accordingly, interventions focusing solely on building self-regulatory and attentional skills might inadvertently deprioritize important drivers for volition, positioning engagement as pushed onwards by top-down cognitive strategies alone. This calls for attention to the full suite of parts including students' values and beliefs, their capacity to anticipate and regulate emotion, and their use of mental and physical action, all of which have been shown to be open to enhancement through intervention (e.g., Linnenbrink-Garcia, Patall & Pekrun, 2016). However, it is yet to be established whether interventions will be more successful if they target a broader range of parts, viewing engagement as a phenomenological whole (Authors XXXX), or focus on a small number of highly potent parts of engagement (to be established by future research on complexity and dynamics) that can best leverage change in the system.

The DSP has also confirmed that the qualities of the task and the learning environment are supremely important for helping students generate and sustain engagement, as identified in prior research on environmental complexity and challenge (Shernoff et al., 2016). Because engagement is momentary, it is intimately connected with the task and context. The extent to which tasks are designed to stimulate motivation, positive emotion and allow for effortful control over mental and physical action may determine a large part of how well students are able to engage in them. In this manner, interventions need also target pedagogy and curriculum if we are to scientifically improve student engagement in schools. Of interest will be how wise interventions (those that are light touch, short and easily delivered by teachers or researchers) can help students and teachers enhance the conditions for momentary engagement in classrooms (Walton & Wilson, 2018).

Conclusions

Our conceptualization of student momentary engagement as a dynamic developmental system aims to add clarity and specificity to the field of student engagement research called for in previous reviews (Azevedo, 2015). As other dynamic systems researchers have voiced, the necessary complexity of any dynamic system may deter some researchers from investigating it in detail, because they prefer to limit their activity to tried and tested methods that are readily welcomed by journal editors and reviewers (van Geert, 2011; Lewis, 2011). However, the research topics posed above indicate how a DSP on momentary engagement can advance our understanding of how students engage in academic tasks, which in turn will help us progress knowledge on how students engage in classrooms and schools.

Understanding momentary student engagement as a dynamic system requires a paradigm shift, a meaningful reconceptualization of existing data in our field, and a continued push for new methods for the collection and analysis of data. It will require time and the support of journal editors and reviewers who look open-mindedly on research that takes the risk of collecting and analyzing these data, but we believe that this is necessary for challenging the status quo in engagement theory and research. As stated by Lewis (2011, p. 4), “Dynamic thinkers should be the first to recognize that complex systems – including the conceptual habits of a scientific subdiscipline – resist change until they can no longer absorb perturbations.” We hope that this paper might be a significant step in this direction.

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Tables

Table 1. *Momentary engagement data collection methods based on Azevedo (2015)*

	Motivation	Emotion	Mental action	Physical action
Process	Think alouds (concurrent and retrospective) Physiological sensors Discourse analysis RRMQ	Think alouds (concurrent and retrospective) Physiological sensors Facial expressions of emotions Discourse analysis RRMQ	Think alouds (concurrent and retrospective) Physiological sensors Screen recordings Eye tracking Log files Discourse analysis RRMQ	Physiological sensors Systematic observation Video and audio recordings Eye tracking Discourse analysis RRMQ
Product	-	-	Pretest-posttest Quizzes Summaries Task attainment	Classroom maps

Notes: RRMQ = rapid repeated measures questionnaires

Figures

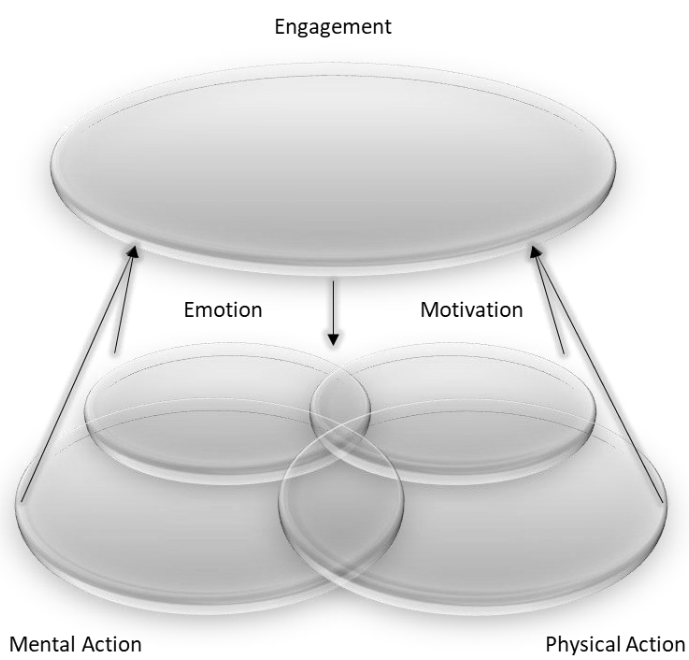

Figure 1. Momentary engagement as a dynamic developmental system

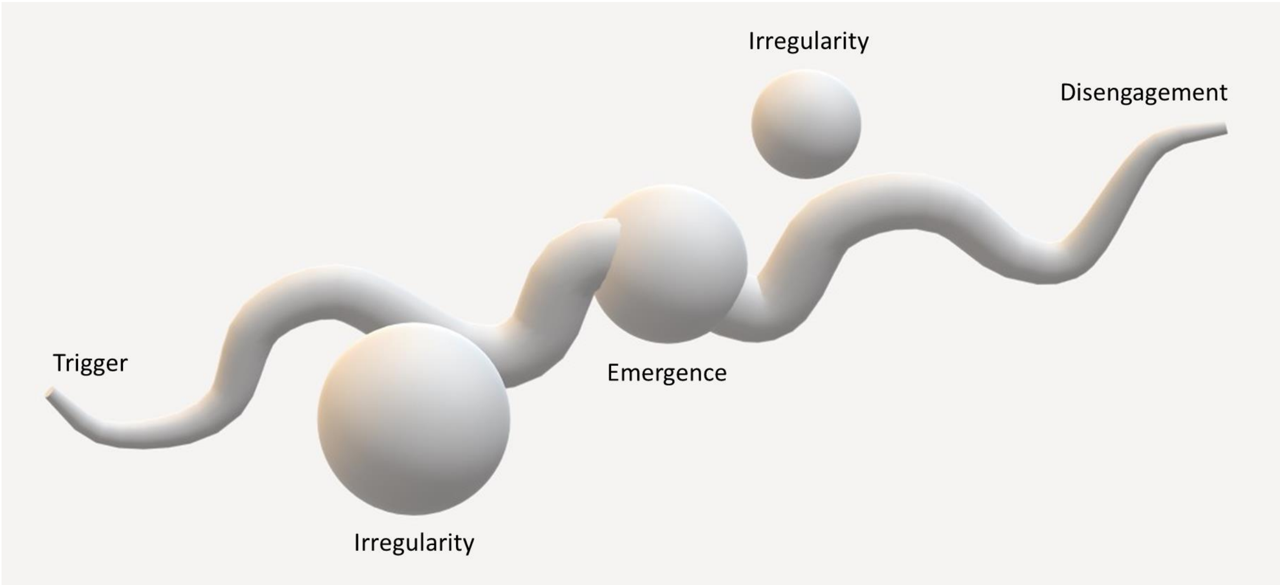

Figure 2. The process of momentary engagement

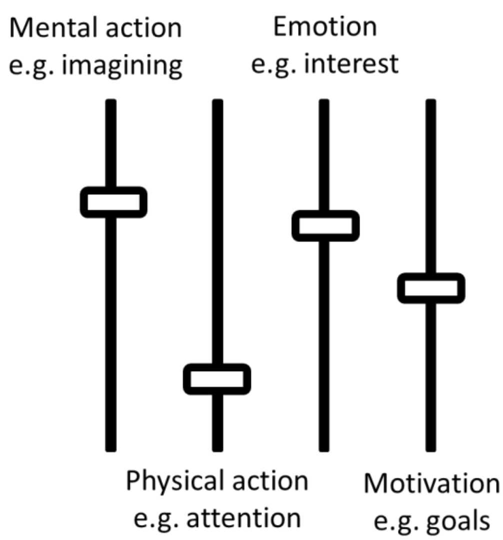

Figure 3. The equalizer metaphor of the coaction of parts