Chapter 2
Unfreezing Creativity: A Dynamic Micro-longitudinal Approach

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Abstract Creativity researchers have conceptualized and studied creativity in a variety of ways. One common approach is to treat creative thought and action as if they are static phenomena that can be assessed using fixed measures. In this chapter, we argue for a more dynamic, micro-longitudinal approach to studying creativity in classrooms. We open with a brief discussion of our operating assumptions about creative thought and action, which serve as the basis for our argument. We then discuss examples of how researchers might move from a more static to more dynamic approach. More specifically, we discuss how researchers can study creative phenomena (such as creative confidence beliefs) using more dynamic, micro-longitudinal designs. We also discuss various promising options for analyzing data collected from such designs, including latent growth curve modeling, network-based analysis, and qualitative interpretations of visual displays. We close with a brief discussion of implications for future research and practice.

2.1 Introduction

Scholars have long been interested in nurturing creative thought and action in the context of schools and classrooms. Indeed, some of the earliest conceptions of creativity have their origins in the works of educational philosophers, such as the German philosopher Friedrich Froebel[1] (1887/1906) who asserted, "The young,

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[1] Froebel's ideas about creativity had an anxious (Pieter Fannes, personal communication) and religious tinge to them, cloaked in the worry that unless young people worked on creative and productive endeavors, they would quickly devolve into destructive impulses (see translators note on p. 31 of Frobel's The Education of Man).

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growing human being should…be trained early…for creative and productive activity" (p. 34). John Dewey (2007/1999), the American pragmatist, also recognized the importance of nurturing the creative imagination of students,

> We hear much nowadays about the cultivation of the child's 'imagination.' Then we undo much of our own talk and work by a belief that the imagination is some special part of the child that finds its satisfaction in some one particular direction – generally speaking, that of the unreal and make-believe, of the myth and the made-up story (p. 72)

It should therefore come as no surprise that understanding creativity in the context of the classroom has served as an important line of research in the field of creativity studies (Guilford 1950, 1967; Torrance 1966). Indeed, some of the earliest research on creativity occurred in schools and classrooms. Much of this early work focused on developing and using "creativity tests[2]" to measure aspects of children's creative and imaginative thought (e.g., *Torrance Tests of Creative Thinking*, TTCT, Torrance 1966).

In the years that followed, research on creativity in schools and classrooms continued to serve as a robust and burgeoning line of research in the field of creativity studies. In addition to the TTCT (Torrance 1966), creativity researchers have developed and used a wide array of methods and measures (Reiter-Palmon et al. 2014), including checklists of creative behavior (*Inventory of Creative Activities and Achievements*, Jauk et al. 2014); self-belief measures (e.g., *Short Scale of Creative Self*, Karwowski et al. 2013); teacher perceptions of creativity (e.g., Aljughaiman and Mowrer-Reynolds 2005); observational check-lists of creative teaching (e.g., Schacter et al. 2006); teacher ratings of students (e.g., *Scales for Rating the Behavioral Characteristics of Superior Students*, Renzulli et al. 1976); product rating scales (e.g., *Creative Product Semantic Scale*, O'Quin and Besemer 1989); and expert ratings of creative products (e.g., *Consensual Assessment Technique*, Amabile 1996).

Although there are variations in how researchers have conceptualized and studied creativity, a common approach is to treat creative thought and action as if they are static phenomena, which can be assessed with fixed measures (Beghetto, in press). This is not to say that such work lacks value, but we maintain that it can only provide limited insights into the dynamic and multifaceted nature of creative phenomena (Gajda et al. 2017).

In what follows, we argue for a more dynamic, micro-longitudinal approach to studying creativity in classrooms. We open with a brief discussion of our operating assumptions about creative thought and action. We then focus on examples of how researchers might move from a static to more dynamic approach to studying creative phenomena. More specifically, we discuss how researchers can study creative self-beliefs using more dynamic, micro-longitudinal designs. We also discuss various

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[2] Torrance's Test of Creative Thinking (TTCT) is actually a measure of divergent thinking, which is viewed as an essential, but not sufficient component of creative thinking or outcomes. In fact, creativity scholars tend to view divergent thinking as an indicator of creative potential (rather than a measure of creativity itself – see Karwowski and Beghetto 2018 for a discussion). The TTCT remains as one of the most popular measure used in the field of creativity studies in general and in schools and classrooms in particular (Plucker and Makel 2010; Reiter-Palmon et al. 2014)

promising options for analyzing data collected from such designs, including latent growth curve modeling and network-based analysis. We close with a brief discussion of implications for future research and practice.

2.2 Basic Assumptions

Prior to describing examples of a more dynamic approach to studying creativity, it is first important to clarify a few basic assumptions about the nature of creativity in classrooms. These assumptions (which have been discussed elsewhere, e.g., Beghetto, in press) include:

- *Uncertainty serves as a creative catalyst;*
- *Creative thought and action results from a dynamic and emergent processes;*
- *Determinations about creativity are based on generally agreed upon criteria; and*
- *Judgements about creativity are dynamic and subject to change across time and contexts.*

In the sections that follow, we briefly discuss each of these assumptions.

2.2.1 Uncertainty as a Catalyst

Although there are many reasons why a person may choose to engage in creative thought and action, creative endeavors always involve some level of uncertainty. Indeed, if you know the outcome of an action in advance, then the result can hardly be called creative.

Consider the musical arts. A musician who is writing a composition starts at the point of uncertainty. The musician does not know exactly how the composition will take shape until it is finished. Once the composition is finished opportunities for creative expression are limited, but not entirely eliminated (see also Corazza 2016). Although it is true that little uncertainty remains in how to perform the composed piece, people can still have new and different "creative experiences" when hearing it performed. Moreover, performers of the composition can introduce additional uncertainty by experimenting with unique interpretations and novel flourishes when playing the piece.

In this way, uncertainty serves as a catalyst for creativity. In the context of the classroom, uncertainty can be encountered or induced (Beghetto in press). In the case of encountering uncertainty, a student may share an unexpected perspective or idea during an otherwise routine class discussion. Such ruptures in otherwise planned lessons, can serve as potentially creative openings (Beghetto 2016a). The potential of such openings can only be realized by engaging with (rather than dismissing) the uncertainty encountered in that surprising moment. Indeed,

whenever some experience breaks upon our habit of expectation (Peirce 1958), it is a sign that new thought and action are required (Beghetto in press).

If, for instance, a student shares an unexpected idea, the student's teacher does not know in advance what the outcome will be if class time is used to explore that idea. It is possible that pursuing such an idea will cause confusion for other students and expend class time. It is also possible, however, that exploring the idea will result in a new and meaningful (i.e., creative) contribution to the discussion (see Gajda et al. 2017). The only way to know is to engage with the uncertainty of the rupture.

In addition to these unexpected encounters with uncertainty, teachers can also induce uncertainty. Induced uncertainty refers to teachers intentional and systematic efforts to present students with structured experiences with uncertainty in an otherwise supportive lesson. One way of doing so involves what has been called "lesson unplanning" (Beghetto 2018), which refers to blending *to-be-determined* openings with pre-determined features of learning activities, assignments and tasks. Students are then required to resolve the uncertainty of the to-be-determined aspect by responding in a new and meaningful (i.e., creative) way.

In sum, regardless of whether uncertainty is encountered or induced, it serves as a catalyst for creative thought and action because resolving uncertainty requires thinking and acting in new and meaningful ways. Although it is true that a student's new and meaningful insight might only be considered creative at the subjective level, it is also possible that working with those insights can result in creative contributions to others (Beghetto 2016b). In order for this to happen, educators need to provide opportunities for students (and themselves) to explore the creative potential that uncertainty offers. If the outcomes, procedure for arriving at those outcomes, and problems to be solved are all predetermined, then there is little room for creative expression in the classroom.

2.2.2   Emergent Processes and Products

Given that some level of uncertainty is involved in creative thought and action, it is difficult to predict what will emerge from students and teachers attempts to resolve uncertainty in the classroom. The creative resolution of uncertainty is therefore dynamic and emergent because both the process and the outcomes of creative thought and action change and take shape overtime (Corazza 2016; Beghetto 2016a).

With respect to the process, there are heuristics that people have used to creatively resolve uncertainty. Techniques that involve combining diverse stimuli in an effort to generate creative ideas, insights, and outcomes is a common example. Such heuristics have their basis in work that has explored the combinatorial aspects of the creative process (Finke et al. 1992; Rothenberg 2014). Indeed, creativity researchers have demonstrated that some of the most creative outcomes come from combining highly divergent and even opposing stimuli.

Although creativity researchers have been able to point to several examples of how combinatorial thinking results in creative outcomes, there is no guarantee that using such techniques will lead to creative results. Indeed, combinatorial thinking is a strategy, not an algorithm. Moreover, even in cases where techniques, such as conceptual combination, lead to creative outcomes those outcomes tend not to be known in advance.

One reason that there are no surefire techniques for generating creative thought and action is because creativity has an emergent quality to it. Emergent properties represent new features that are not known to be present in the initial stimuli (Sawyer 2012). It is for this reason that creativity researchers sometimes refer to the processes that lead to creative outcomes as being blind (Simonton 2017). Indeed, if we know the way to a solution in advance, then we don't need to think or act creatively. Rather, we could simply apply a pre-determined set of steps (Getzels 1964).

Consequently, creativity always involves some element of surprise (Simonton 2017). Creative outcomes start to take shape as we take action on them. The creative process "comes to a rest" once an idea or outcome has reasonably resolved the uncertainty being confronted (Peirce 1958). The process can be reanimated at later time points and by different participants (Beghetto 2016a; Corazza 2016; Gajda et al. 2017). A student's unique idea which has been discussed and accepted as relevant, can later be referred to by the teacher in a class discussion with a new group of students who then build on it and transform it into a different insight.

In this way, creative thought and action has a to-be-determined quality to it (Beghetto in press), which even when reasonably resolved, maintains a state of inconclusiveness (Corazza 2016). As students (or teachers) work through the uncertainty of a situation or task, they can resolve that uncertainty by producing new ideas, perspectives, or outcomes that reasonably meet the task constraints. The process is both dynamic and emergent.

If, for example, students are using conceptual combination as strategy to think differently about a problem, then they would not necessarily know in advance the specific combinatorial features that ultimately lead to creative resolution of a problem. Rather students need to develop and test out various alternatives until a reasonable solution takes shape. Students and teachers would also benefit from realizing that even "finished" work can be reanimated, remixed, and transformed into new works (Navas 2012).

2.2.3 Generally Agreed Upon Criteria

Although creativity has proven to be somewhat of an elusive concept in education (Plucker et al. 2004), creativity researchers generally agree (e.g., Kaufman 2016; Runco and Jaeger 2012; Stein 1953) that definitions of creativity tend to require two

criteria[3]: *originality* (i.e., newness, uniqueness, or novelty) and *usefulness* (i.e., meaningful, meeting task constraints, or effective). Moreover, these criteria are defined within a particular socio-cultural and historical context.

The criteria of this definition implies a somewhat static characteristic to it and thereby might be thought of as applying to creative achievement, rather than the more dynamic aspects of the creative process (Giovanni Emanuele Corazza personal communication, April 26th, 2018). As we will discuss, however, judgments of creativity (even those that rely on these criteria) maintain a dynamic characteristic to them given that they vary by context and can be revisited at a later time and by a new audience.

In this way, creativity in the classroom can be thought of as a dynamic combination of original expression and meeting task constraints. Along these lines, a student's new and personally meaningful insights when learning something new can be considered creative in the context of that student's subjective experience (Beghetto and Kaufman 2007). In order for others to recognize a student's idea as creative, the student would need to demonstrate not only the originality of the idea, but also demonstrate how it fits the particular or situational tasks constraints (Beghetto 2016b). In many cases, the social recognition of creative outcomes is of most importance to creativity researchers because it is this level of creative expression that moves beyond a person's subjective experience and makes a contribution to the learning and insights of others (i.e., peers and teachers) in the classroom context.

2.2.4   Dynamic Judgments of Creativity

Much like the dynamic process that results in creative outcomes, so too are judgments about creative expression in classrooms. Although it is possible for teachers and peers to immediately recognize a student's unique perspective as creative, on other occasions student's unexpected ideas or actions may need to be explored or revisited in order to recognize that connection (Beghetto 2016b).

In the context of a classroom discussion, for instance, a student's unexpected utterance may be initially dismissed and then, only after the student's teacher or peers revisit the idea do they recognize its creative relevance (Gajda et al. 2017). In some cases, this recognition may be delayed over much longer time spans or only by virtue of analysis by outside observers (e.g., researchers analyzing transcripts, video footage or other artifacts from a classroom activity). Indeed, teachers and students may be so focused on attaining expected outcomes and fearing going off-topic that they do not recognize or value potentially fruitful deviations (Gralewski and Karwowski 2013; Kennedy 2005). In yet other cases, what was initially viewed as a creative response, may after consideration be recognized as lacking originality

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[3] Several scholars have offered variations and elaborations on the two criteria definition of creativity (for recent examples see Corazza 2016; Simonton 2016; Smith and Smith 2017).

or failing to meet the task constraints in the context of the particular assignment or activity (Beghetto 2016a).

Taken together, these four assumptions highlight the dynamic nature of creative thought and action in classrooms. Specifically, uncertainty (which can be encountered or induced) serves as a catalyst for thinking and acting in creative ways. The process of creatively resolving uncertainty is dynamic and emergent, which means creative outcomes are difficult to predict at the outset and start to take shape overtime. This includes the opening of many new possibilities and trajectories along the way.

Given the dynamic nature of judgments about creativity, researchers and educators might benefit from moving away from terminology that implies a more final or fixed state (i.e., judgement, assessment) and toward more dynamic language. Following Corazza (2016), we would suggest that terms like "estimation" might be more appropriate and useful when describing creative phenomena. More dynamic labels highlight the indefinite features of creative judgements and signal the potential for differing perspectives and future possibilities.

In sum, resolving uncertainty when facing one situation can open multiple new areas of uncertainty. In other situations, the uncertainty faced by a student or teacher may not be resolved or only be temporarily resolved. The social judgments of whether a student or teacher resolves uncertainty in a creative way is based on the generally agreed upon criteria of blending originality and meeting task constraints as defined in a particular situation, activity, or task. Finally, estimations of what is or is not creative are also dynamic and can change over time and across contexts.

2.3 Implications for Research

Given these assumptions, how might researchers design studies that take into account the dynamic and emergent nature of creative expression in classrooms? In the sections that follow, we address this question by arguing for the use of a micro-longitudinal approach (Beghetto and Karwowski 2017; Karwowski and Beghetto 2018). More specifically, we briefly define what we mean by a micro-longitudinal approach and then discuss how such an approach can be used to study creative phenomena both at the individual and socio-interactional level.

2.3.1 A Micro-Longitudinal Approach to Studying Creativity in Classrooms

A micro-longitudinal approach is a dynamic approach. It requires taking multiple measurements of the phenomena of interest over a small period of time. Unlike typical longitudinal designs that involve making repeated measures at moderate to long

intervals, micro-longitudinal designs take measurements at more rapid intervals (e.g., milliseconds, seconds, minutes). In this way, more dynamic and otherwise ephemeral phenomena can be recorded, analyzed, and interpreted (Beghetto 2016a; Gajda et al. 2017; Karwowski Beghetto 2018). Such approaches can be used with qualitative and quantitative data.

Qualitative Interpretations of Dynamic Visual Displays In the context of the classroom, researchers using micro-longitudinal approaches can develop dynamic visual displays of interactions to represent and analyze different patterns of interactions amongst students and teachers (Tanggaard and Beghetto 2015). Doing so can help explain classroom level variations in creative expression. Figure 2.1 provides an example of a micro-longitudinal display of a segment of class discussion (reproduced with permission from Gajda et al. 2017).

Figure 2.1 is based on a segment of classroom talk which involved 23 utterances (or turns), one teacher and seven students. Although it is beyond the scope of this chapter to provide a full detailed discussion and analysis of this visual display (see Gajda et al. 2017 for details), we want to briefly highlight a few key points germane to our discussion.

Using visual displays like the one depicted in Fig. 2.1 can provide a way for researchers to illustrate and interpret the dynamic patterns of interaction that occur in classrooms, including how ideas sometimes are dismissed (D), suspended (S), accepted (A), and returned to at later points (- - -). Such displays highlight the dynamic trajectories and potential of ideas that otherwise might be missed when relying solely on transcripts. Visual displays can support various analytic and interpretive possibilities, including comparing patterns of interaction between different types of classrooms and subject areas (see Beghetto 2016a;
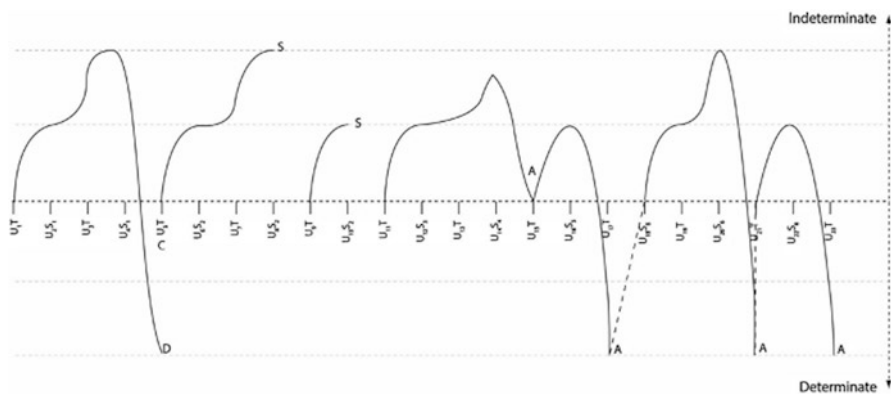

Fig. 2.1 Example of micro-longitudinal visual display. *Note*: U = each utterance. U# = temporal order of each utterance. T = teacher utterances. S = student utterances, S# = number of a particular student in order of the appearance. A = idea accepted or acknowledged by the teacher, D = dismissed by the teacher, S = idea not acknowledged, but suspended. Dotted lines (- - -) represent the teacher or students reanimating and building on a previous ideas

Gajda et al. 2017; Tanggaard and Beghetto 2015 for additional examples and more detailed discussion).

Dynamic Quantitative Approaches In addition to qualitative interpretations of classroom interactions, micro-longitudinal studies can complement and extend traditional approaches that rely on static snapshots to measure creative phenomena (e.g., single measure surveys, pre-post measures) and also compliment delayed interval approaches increasingly used by creativity researchers (e.g., experience sampling, diary-based methods; ecological momentary sampling).

Micro-longitudinal studies lend themselves to the kinds of analyses that allow researchers to examine the more nuanced and variable patterns of within and between subject variation in creative processes and outcomes of interest. Indeed, potentially important variations and patterns that are typically viewed as statistical noise or eliminated through statistical aggregate, can be analyzed and thereby offer new insights into the nature of creative phenomena.

One particularly promising application of such an approach is the examination of how different patterns of students' self-beliefs and emotions might explain differences in students' willingness to share creative ideas and make creative contributions in the classroom. Taking a micro-longitudinal approach to studying creative self-beliefs can help researchers to move from more traditional, static approaches and toward more sensitive and dynamic approaches.

In the sections that follow, we provide further discussion and examples of how micro-longitudinal approaches can be applied to estimating and analyzing creative-self beliefs. We close with a brief discussion of implications for future research and practice.

2.3.2   Creative Self–Beliefs: A Quick Overview

Creative self-beliefs refer to a "constellation of beliefs that shape one's creative self and play a unique role in helping to determine a person's engagement and performance on creative endeavors" (Karwowski and Beghetto 2018). The constellation of self-beliefs that make up one's creative identity can be organized into three broad categories: *Creative confidence* (i.e., beliefs in one' ability to think or act creatively), *creative self-awareness* (i.e., beliefs about the nature of one's creative abilities, including one's creative strengths and limitations), and *creative self-image* (i.e., beliefs about whether and how creative activities, aspirations, and abilities are part of one's sense of self) (Beghetto and Karwowski 2017; Karwowski and Beghetto 2018).

These beliefs vary across several dimensions (Beghetto and Karwowski 2017), including: temporal (i.e., past, present, and future orientation), stability (i.e., dynamic vs. static), and task (i.e., specific vs. general). For the purpose of this chapter we focus on creative confidence beliefs and discuss how taking a more dynamic, micro-longitudinal approach is necessary to measure and better understand the role these beliefs plays in creative behavior.

2.3.3 Measuring Creative Confidence: A Micro-Longitudinal Approach

One way to measure creative confidence beliefs more dynamically, is to incorporate them into a micro-longitudinal approach. As discussed, a micro-longitudinal approach involves taking multiple measures at brief intervals in an effort to more fully capture the variable nature of phenomena of interest. When it comes to creative confidence beliefs, researchers can apply this approach by first identifying a performance situation or task and then take measurements of creative confidence before, during, and after performing that task (Beghetto and Karwowski 2017; Karwowski et al. accepted).

Figure 2.2 illustrates a hypothetical example of how researchers can model components of a dynamic, micro-longitudinal assessment of creative confidence beliefs. The components are based on an activity that the first author (Beghetto) had initially designed for pedagogical purposes (i.e., help workshop participants become aware of the dynamic nature of their own creative confidence beliefs in conjunction with other factors, like emotions). Although the activity was designed for instructional purposes, researchers can easily adapt it for data collection and analysis.

As illustrated in Fig. 2.2, there are several components that can go into designing a micro-longitudinal study of creative confidence beliefs. These components can be organized across three measurement windows: Window 1 (i.e., prior to presenting the task to participants), Window 2 (i.e., immediately before and during task engagement), and Window 3 (i.e., following task completion).

Measurement Window 1 refers to the time period prior to introducing the specific performance task to participants. The goal of measurement Window 1 is to tap into the more general creative confidence beliefs (e.g., creative self-concept) related to the performance domain (e.g., problem solving) and any other variables of interest that might explain variations in confidence during task performance (e.g., background variables, emotional state, physiological arousal, situational variables) or be used as a point of comparison (e.g., general confidence completing tasks).

Depending on the goals of the study, general creative confidence can be estimated using a creative self-concept scale (Beghetto and Karwowski 2017) that taps into cognitive and affective perceptions of creative competence (e.g., I'm good at solving problems creatively; I enjoy coming up with creative solutions). Researchers can ask respondents to indicate their general confidence on a 100-point scale (*0 = not at all confident, 100 = extremely confident*). Importantly, general creative confidence is assessed *prior* to providing participants with a specific task.

Measurement Window 2 refers to the time period when participants are presented with a specific task (including instructions and criteria for success) and during actual task performance. During this time, researchers can assess the more dynamic nature of creative confidence for the specific task (e.g., confidence in producing a creative solution to this task, assessed on a 100-point scale) as well as any other variables of interest that might change across the duration of task engagement (e.g., emotional state, physiological arousal, confidence in completing the task).
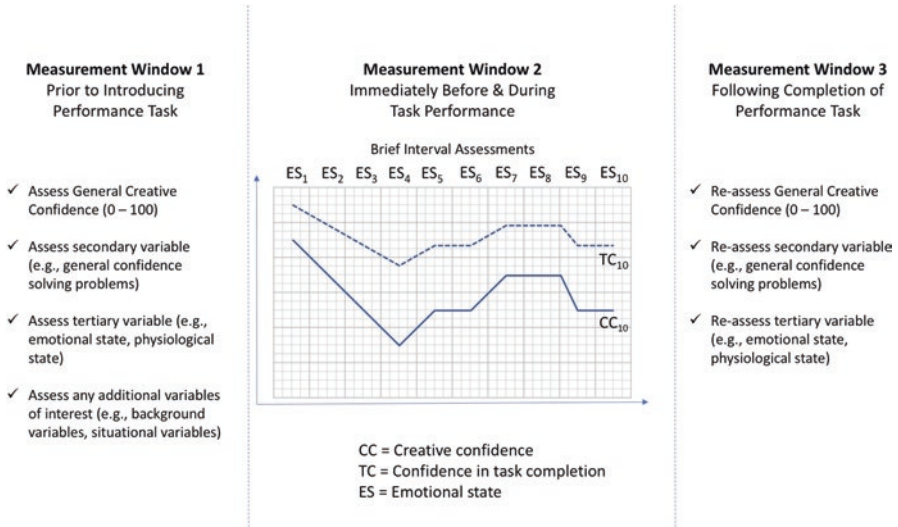
Measurement Window 1
Prior to Introducing
Performance Task

✓ Assess General Creative
Confidence (0 – 100)

✓ Assess secondary variable
(e.g., general confidence
solving problems)

✓ Assess tertiary variable (e.g.,
emotional state, physiological
state)

✓ Assess any additional variables
of interest (e.g., background
variables, situational variables)

Measurement Window 2
Immediately Before & During
Task Performance

Brief Interval Assessments

ES_1 ES_2 ES_3 ES_4 ES_5 ES_6 ES_7 ES_8 ES_9 ES_{10}

TC_{10}

CC_{10}

CC = Creative confidence
TC = Confidence in task completion
ES = Emotional state

Measurement Window 3
Following Completion of
Performance Task

✓ Re-assess General Creative
Confidence (0 – 100)

✓ Re-assess secondary variable
(e.g., general confidence
solving problems)

✓ Re-assess tertiary variable
(e.g., emotional state,
physiological state)

Fig. 2.2 Micro-longitudinal design of creative confidence beliefs

Measurement of variables should commence once participants have been pre-
sented with the task and have a clear understanding of what they are being asked to
do. Measurements will continue at regular and rapid intervals (e.g., every minute)
across the duration of the task. As illustrated in Fig. 2.1, within measurement
Window 2, researchers can assess both continuous (e.g., creative confidence mea-
sured on a 100-point scale), discrete variables (e.g., reported emotional state), or
some combination thereof (e.g., reported emotion and intensity of that emotion).

The task presented to participants should have a clear time limit (e.g., 10 min),
specific criteria for successful completion (e.g., "design a visual representation of
creative teaching using a total of six pattern blocks and write a 30-word description
of your design"), and provide an opportunity for participants to solve the task in
their own way and produce their own unique outcome. Put simply, the task should
provide enough structure so participants can draw on their efficacy beliefs to predict
and monitor their progress (Bandura 2012), but also have to-be-determined ele-
ments to afford opportunities for creative expression (Beghetto in press).

Finally, measurement Window 3 refers to measurements taken after the partici-
pants have completed the task or time has expired (whatever comes first).
Measurement Window 3 provides researchers with an opportunity to re-assess the
more general beliefs initially assessed during measurement window 1 and allow
researchers to test a variety of theoretical assertions (e.g., the role that specific ver-
sus general confidence beliefs have on creative task performance).

Ideally, measurement Window 3 would include measurements taken immedi-
ately after task performance *and* at some later delayed interval (e.g., days, weeks,
months later). In this way, micro-longitudinal work can complement more tradi-

tional longitudinal studies providing researchers with an opportunity to examine the stability of key variables and how performance on specific tasks might influence those variables.

2.3.4 Analyzing Micro-Longitudinal Creative Confidence Data

For decades, creativity researchers relied heavily on correlation-based or comparative (e.g., ANOVA-based) analytic methods to describe the relationships between creativity and its antecedents and consequences. Although these classic methods are still in use, a dynamic perspective requires more dynamic approaches to data analysis.

This dynamism is two-fold. First, it calls for interactive, intensive, longitudinal methods of data collection, as described above. Second, it requires fresh analytical techniques to properly model between and within-person variability in creative process, self-assessment or self-regulation. From a theoretical standpoint, the dynamic perspective is less focused on differences between people (i.e. the question of who feels more and who feels less confident) and more on intra-individual differences.

Consequently, the focus is on collecting and analyzing data that addresses questions of: When, where and under what circumstances the same people experience variations in their beliefs? Multilevel modelling and network modelling are two of the many possibilities to analyze such data.

Multilevel Models Multilevel models (or hierarchical linear models, see Snijders and Bosker 1999) extend typical analyses of regression by taking into account the nested structure of the data at hand. This "nesting" (a procedure that leads to biased statistical estimates) is often observed in research yet ignored. One obvious example of nesting are students clustered in classes or employees clustered in firms. Another type of clustering, more relevant for our discussion in this chapter, is nesting several responses or self-ratings within person.

When a participant provides several self-evaluations during a problem-solving session (see Fig. 2.1), researchers are not only interested in an average level of a person's creative confidence overall, but also in the variability of these intrapersonal changes. The level of within- and between occasion variability may be effectively quantified using the intraclass correlation coefficient (ICC, Bartko 1976). Conceptually, ICC denotes the percentage of the variance that lies between level-2 units – i.e. a person in our example. Consequently, 1-ICC denotes the percentages of variance that lie *within person* or *between occasions* for a specific person. Previous studies in creativity literature that utilized dynamic measurement (e.g. experience sampling method or diary studies (see Conner and Silvia 2015; da Costa et al. 2018; Karwowski et al. 2017) have demonstrated that the level of within person variability of creativity related emotions or beliefs tends to be large. This variability is in alignment with what our dynamic perspective assumes.

In other words, scholars using multi-level models have been able to describe how much people differ interpersonally (ICC) *and* how they differ from occasion to occasion (i.e., intrapersonally: 1-ICC). Importantly, the variance estimated at both levels can be effectively explained by subsequent multilevel models. Thus, researchers can use relatively stable characteristics of participants (i.e., their personality, previous creative achievements, or a creative self-concept) as between person predictors, but they can also include more dynamic, state-like variables collected during the process (e.g., creative confidence, affect or emotional arousal), as within person predictors.

A wide array of advanced, analytic and automated (AAA, see D'Mello et al. 2017) devices that allow for collecting data in real-time are available and may prove useful for creativity researchers. Examples include, measures of facial expression, attention shifts using eye-tracking methods, and emotional arousal based on galvanic skin response. With recent developments in technology, these kinds of data can be collected in a relatively non-intrusive way – without any effort from the participant, thus minimizing the risk of influencing and disturbing the processes the researcher is interested in.

It is important to note that the micro-longitudinal character of datasets makes it possible to explore important "chicken-and-egg" problems (i.e., the questions about possible cause-and-effect relationships and reciprocal links between psychological and social phenomena). Example questions include: Do positive emotions cause stronger creative self-beliefs during solving a problem or does growing creative confidence lead to emotional flourishing? Using micro-longitudinal datasets and applying multilevel models enables researchers to ask and address these more causal and dynamic questions (Conner et al. 2018).

Latent Growth Curve Modeling Latent growth curve modelling (LGC, see: Preacher 2008) is a special case of multilevel models that seems promising for dynamic creativity research. This method, originally developed for longitudinal studies within developmental psychology, bridges two analytical traditions: multilevel modelling and structural equation modelling (SEM). As we have discussed, multilevel modelling allows for a more appropriate estimation of parameters of interests by accounting for the nested structure of data and explaining within person variability.

Conceptually, LGC is based on multilevel modelling, but it also utilizes the SEM approach, whereby main variables of interest are modelled as latent variables. This allows for a proper control of measurement error and the model fit indices are available. In LGC models, two specific latent variables are modelled. The first is *intercept* – namely, the base level of creative confidence or any other variable of interest that is subject to change during the process. The second is *slope,* the average change between people (average slope) as well as the pattern of intra-individual changes (i.e., significance of the variance in slope).

Researchers using LGC can address questions such as: Does creative confidence increase or decrease while handling a creative task? Perhaps it follows a curvilinear trend from a relatively low level before the task, through high level during the task,

all the way to a significant decrease after the task (U-curved shape)? Alternatively, maybe a high level of creative confidence from pretest decreases during the task and then increases (reversed U pattern)? Thus, LGC allows the researchers to estimate the overall pattern (shape) and level (the percentage of variance) of intra-individual changes and including intrapersonal and interpersonal factors that might explain this variability.

Both intercept and slope can be regressed on potentially relevant psychological, social or demographic predictors. Moreover, parallel LGC models (Preacher 2008) can be used to explore the extent to which the level and pattern of intraindividual change (hence: the slope) of a single variable, such as creative confidence, is linked to the level and pattern of change of another variable (arousal, affect, effectiveness of problem solving, etc.).

Network-Based Analysis Network psychometrics represent another set of promising analytical techniques that tend to be underutilized by creativity researchers (Constantini et al. 2017; Epskamp et al. 2017). Researchers can use network techniques to examine complex relationships between creative processual variables. Originally, statistical techniques based on network analyses were developed to explore the relationships between individuals in groups (e.g., describing their popularity, strength of social ties, exclusion from the wider social groups; see Wasserman and Faust 1994 or to study within- and between-networks diffusion of different phenomena, like obesity (Christakis and Fowler 2007).

It is important to note, that it is only recently that researchers have used network analyses to examine creativity-relevant phenomena rather than its more traditional and limited uses (Moreno 1960). In the creativity literature, researchers have used network-based analyses to explain the social positions of students with higher or lower creative accomplishments (see McKay et al. 2017; Kéri 2011). Network-based models can be useful for modelling and illustrating the dynamics of various psychological phenomena –from psychopathology, to play, and creativity.

Although researchers have tended to use network models to examine cross-sectional data (e.g., Christensen et al. 2018), there are recent developments to apply network models to simultaneously model both between- and within-person networks (see Constantini et al. 2017). As Constantini and colleagues (in press) have demonstrated, it is possible to model the dynamics of the relationship between different characteristics both between-subject and within-subject. While between-subject networks illustrate the dynamics that involve more stable, trait-like characteristics (i.e., personality), within-subject networks illustrate links between momentary levels of individuals characteristics – for example their moment-to-moment or problem-to-problem creative confidence and affect.

In short, an estimated network of the relationships between different characteristics of variables, provides an overview of the structure of links and interactions between these characteristics. Creativity researchers can use this technique to examine complex and dynamic interaction among emotions, confidence and subsequent micro-actions. Consider the hypothetical example of two simulated networks presented in Fig. 2.3.
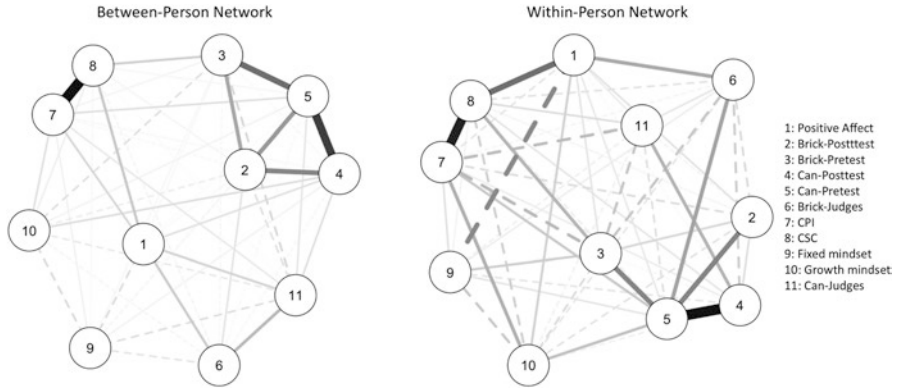
Fig. 2.3 Hypothetical example of between- and within-person network analysis. Simulated relationships between momentary creative self-efficacy while solving DT task and a number of related states. CPI = Creative personal identity. CSC = Creative self-concept

The left panel of this hypothetical example illustrates between-subject networks, while the right panel shows within-subject networks. Imagine that participants were asked to provide their creative confidence ratings in relation to two divergent thinking (DT) tasks – ability to come up with creative uses for a brick and a can. Imagine also that ratings were provided twice in relation to each DT problem – immediately after presentation of a problem (pre-test) and after solving it (post-test) – generated ideas were scored by external judges and a number of relevant characteristics of participants were also collected e.g., creative mindset (see Karwowski 2014), positive affect related to the task, creative self-concept (CSC), and creative personal identity (CPI).

These variables could then be analyzed using network-based analysis and potential similarities and differences of between-person and within-person networks could be identified. As illustrated in the hypothetical example presented in Fig. 2.3, one may conclude that at both between-person and within-person level, creative self-beliefs measures (creative self-concept, node 7 in the diagram) and creative personal identity, node 8 in the diagram) form a common cluster. In addition to helping identify similarities, these types of visual network can also highlight differences (e.g., general self-beliefs are relatively independent from the more dynamic, task related estimate of creative confidence, nodes 2–5). Moreover, the within-person panel of this hypothetical example demonstrates much denser relationships between these momentary assessments, growth mindset (node 10), and judges' ratings (nodes 6, 11). Thus, as this example illustrates, using network-based techniques may prove helpful in exploring whether and how changes occur in different types of beliefs and experiences while solving a problem (e.g., the intra-individual dynamics of creative confidence may be quite different from the aggregated, more stable between-person pattern of relationships).

At this point, we are not aware of any application of network models to study the dynamic of creative action, but as the above hypothetical example illustrates: The

potential for using this and other types of dynamic and visually based analytic technique seems very promising for such purposes. Indeed, network models can serve as a useful solution of analyzing and illustrating the within-student and between-student dynamics of self-beliefs-activity links, and help untangle teacher-student interactions in a dynamic way (by modelling those interactions from teacher and student perspectives).

2.4   Concluding Thoughts

Our central argument in this chapter is: Creative phenomena in classrooms, like other contexts, is dynamic and therefore needs to be treated as such by researchers. Although traditional, static approaches have provided some glimpses into creative expression, we now have the theoretical, methodological, and analytic basis for approaching creative expression more dynamically. As we have asserted, micro-longitudinal approaches offer a particularly promising way for researchers to conceptualize, design, and study key features of creative expression within, between, and amongst students and teachers.

Even though such approaches are promising, there are several issues that need to be explored, including how intense micro-longitudinal measurements influence the creative process itself. Indeed, researchers using such methods will benefit from exploring how different types of measures might impact the process and outcomes in expected and unexpected ways. This includes exploring what kinds of less intrusive measures might be better suited for studying the emergent process of creative expression.

On the flipside, real-time measures also have the potential to provide real-time feedback that may be of benefit to people engaged in creative tasks and endeavors (Giovanni Emanuele Corazza, personal communication; see also, Agnoli et al. 2018). In short, there is much exciting and untapped potential in using more dynamic, real-time and micro-longitudinal designs to understand creative phenomena in and outside of classroom settings.

We therefore invite researchers interested in taking a more dynamic approach to studying creative expression in classrooms to join us in developing, testing, and refining the ideas we presented herein. We also recommend that educators rethink their own conceptualizations about the nature of creativity. The assumptions we outlined at the outset of this chapter can serve as starting points for educators to consider how they think about, estimate, and develop opportunities for creative thought and action in their own classrooms. Here's a quick recap of our assertions

- *Uncertainty serves as a catalyst for creative thought and action;*
- *Creative thought and action results from a dynamic and emergent processes;*
- *Determinations about creativity are based on generally agreed upon criteria; and*
- *Judgements about creativity are dynamic and subject to change across time and contexts.*

Building from these assumptions, we have attempted to describe how educators and researchers might approach creativity differently in their work.

A dynamic perspective on creativity is promising, not because it reduces the complexity of how we think about, try to support, or study creative expression in classrooms. Rather, it is promising because it requires researchers and educators to come together in an effort to better understand how, when, and under what conditions creative thought and action manifests in classrooms.

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