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Single-Case Design: A Promising Tool for Improvement Science

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ABSTRACT

This article provides an overview of single-case research design and how it can be used in concert with Improvement Science. Hypothetical examples of using single-case design to inform improvement efforts are provided, as is a discussion of connections between this methodology and Improvement Science. Resources for further study are also provided.

KEYWORDS

single-case research, change idea, school improvement, improvement science

Improvement Science provides a framework and practical tools to support educational leader efforts to improve the provision of opportunity. Through disciplined inquiry centering on a concerning variation of performance, practitioners of Improvement Science leverage local data, empirical evidence, student goals, and their professional judgment and values to (1) develop a nuanced understanding of a problem of school practice, (2) construct a theory of change that is likely to improve outcomes, and (3) evaluate the effectiveness of an intervention, or "change idea". Although practitioners can potentially utilize a variety of research methods in concert with Improvement Science, they are limited by the training in which they receive: Practitioner Scholars can only utilize the methods that have been taught and sufficiently practiced during the coursework that contributes to their Dissertation in Practice. The purpose of this paper is to provide an overview of a well-established research methodology that is particularly well suited for Improvement Science: single-case research design. Key features of this methodology are discussed, as are connections to core principals of Improvement Science. Examples of potential applications of single-case design and resources for further inquiry are provided.

SINGLE-CASE DESIGN

Single-case research is a set of adaptable methods that, when executed with a level of precision, permit applied researchers to make causal inferences between the implementation of a change idea and changes in an observable dependent variable (Maggin et al., 2021). By causal inference, I am referring to having a degree of confidence that observed changes in the dependent variable (ex: student outcomes) are due to the implementation of the change idea rather than other factors (Kratochwill et al., 2013). Single-case research differs from case studies by requiring evidence of an initial effect as well as evidence of effect replication at different points in time. Replication of an effect could occur with the same student, class, or school, depending on the type of single-case design that is used. Replication could also occur with a different student, class, or school. As part of this form of disciplined inquiry, implementation of the independent variable is carefully monitored, at least one dependent variable is repeatedly and consistently measured over time, and the accuracy of the data is established (e.g., data reliability). Thus, single-case design investigations require sustained engagement in the school environment with the intended implementers and beneficiaries of a change idea.

Regarding Improvement Science, single-case investigations can focus on a concerning variability of performance at the student, teacher, classroom, or school level. In fact, this methodology is commonly used to test the effects of interventions in a variety of fields including school psychology (Radley et al., 2020), special education (Common et al., 2017; Odom et al., 2005), and social work (Kazi & Wilson, 1996). Syntheses of single-case investigations are also commonly performed to identify empirically supported practices for school adoption (McKenna et al., 2017; Peltier et al., 2020). In its most basic application, single-case investigations are similar to the way academic or behavioral progress monitoring data are collected in response to intervention (RTI; Berkeley et al., 2020; Furey & Loftus-Rattan, 2022) and multitiered systems of supports (MTSS; National Center on Intensive Intervention, 2020). Thus, aspects of single-case research may be familiar to doctoral students who work in inclusive schools that utilize tiered systems of student support (see Berkeley et al.., 2020; McKenna et al., 2021).

HYPOTHETICAL EXAMPLE

Consider a district level team that is concerned with the performance of disruptive behavior at a high school, and the degree to which it interrupts teaching and learning. To address this important problem of school practice, the school team focuses their initial efforts on a small number of classrooms within the high school that are of particular concern. These classrooms are of particular concern

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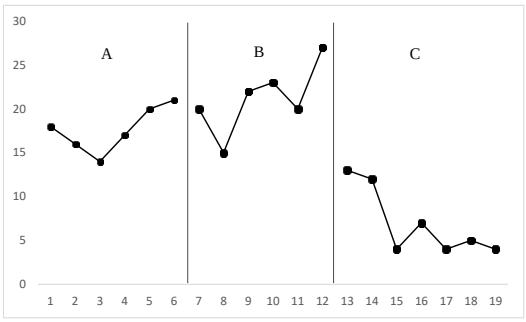
due to the frequency in which disruptive behavior is reported to occur and the frequency of student office referrals. One of these classes is a 9th grade Social Studies and Civics Education class that is co-taught by an experienced general education teacher, an experienced special education teacher, and a paraeducator who is assigned to provide one to one support to a student with a disability who is enrolled in the class. Overall, disruptive behavior is not a concern in the district, as evidenced by district level data including office referrals, disciplinary exclusions, academic performance data, and administrator observations. In this hypothetical scenario, student behavior in this high school represents a concerning variation in student performance within the district.

To address this problem of teaching practice, building level leadership and the classroom team consult with the school's Positive Behavior Intervention and Support (PBIS) Team. To better understand the nature of the problem, the PBIS Team informally interviews the classroom team to identify contextual factors that may be contributing to the performance of disruptive behavior and potential methods for remediation. The PBIS Team also requests that the classroom team collect data on the frequency in which disruptive behavior is performed so that these data can be used to obtain a better understanding of how frequently it is occurring. The PBIS Team also asks for these data so that it can be compared to data that are collected when the classroom team eventually tries a new method or strategy (e.g., a change idea). To facilitate data collection, the PBIS team discusses and models how to perform a frequency count of disruptive behavior while providing academic instruction during each class session. When performing a frequency count, each observed instance of disruptive behavior is noted with a tally mark on a data collection sheet, and the tally marks are counted at the end of class. Data from each class are then added to a line graph so that it can be later analyzed using visual analysis, as time series data that are visually displayed via a line graph is a defining characteristic of single-case research (Tarlow & Brossart, 2018). As part of this discussion, the team discusses examples and non-examples of disruptive behavior to operationally define this dependent variable so that data collection is more likely to be reliable (e.g., accurate, consistent, and representative of the true frequency in which disruptive behavior is performed during instruction).

The classroom team then collects data during the next few class sessions. Figure 1 is a line graph that visually displays the frequency in which disruptive behavior was observed, the dependent variable of interest in this hypothetical situation. Data on disruptive behavior are collected by the classroom team using frequency counts (e.g., a tallying system to count each instance of observed disruptive behavior) while the classroom team provides instruction.

In this initial data collection phase (e.g., "business as usual instruction" or BAU), referred to as phase "A", data on disruptive behavior are collected for six consecutive class sessions. Data collection documents the presence of the problem of practice, as evidenced by the frequency in which disruptive behavior is observed. This initial data collection phase also serves as a comparison condition, as data collected during this phase will be compared to data collected with the classroom team implementing a change idea. In this situation, we would expect a successful change idea to result in a decrease in disruptive behavior.

Figure 1. Visual Display of Class Data Collected Using an ABC Design: Instances of Disruptive Behavior



Note. This graph shows data from an ABC single-case research design. The graph is read from left to right, with numbers on the x axis noting class sessions over time, in this example daily. Each letter represents a different classroom condition. "A" is data collected during typical classroom conditions (e.g., "business as usual"). "B" is data collected while the classroom team used pre-correction. "C" is data that were collected after the classroom team received support in the form of modeling and coaching with performance feedback (e.g., pre-correction plus coaching). For all three phases, data collection methods remain constant so it is more likely that any changes in class performance can be attributed to changes in staff behavior (e.g., implementation of pre-correction with fidelity) rather than inconsistent data collection methods.

Upon the conclusion of phase "A" or "baseline" data collection, the classroom team and the school's PBIS Team meets to discuss the data, teacher observations and reflections, and potential reasons why disruptive behavior is occurring. This then leads to a discussion of potentially effective methods for decreasing the occurrence of disruptive behavior (e.g., development of a theory of change, centering on potential change ideas that are likely to be effective). During this discussion, practices with empirical evidence for reducing disruptive behavior are discussed. The classroom team decides to try a behavior management strategy called pre-correction. Pre-correction essentially involves correcting problem behaviors before they occur by reminding students of expectations and procedures associated with class routines before they are expected to comply or follow them. In essence, pre-correction is correcting errors before students make them (see Evanovich & Kern, 2018).

This hypothetical single-case investigation then moves to the next phase. The classroom team uses pre-correction while providing academic instruction and continues to collect data on disruptive behavior in the same way. Consistency in data collection methods is critical because changes in dependent variables need to be attributed to the change idea and not to potential changes or errors in data collection. In this hypothetical example, the classroom team continues to apply the same definition of disruptive behavior during each data collection session, to use frequency counts, and to collect data during observations of the same duration.

Data collected during implementation of pre-correction are visually displayed in phase "B". This phase is labeled with a different letter than the first data collection phase because the data were collected under a different classroom condition. In phase "A", data were collected under BAU conditions. In this next phase, data were collected while the classroom team used pre-correction. "B" is used

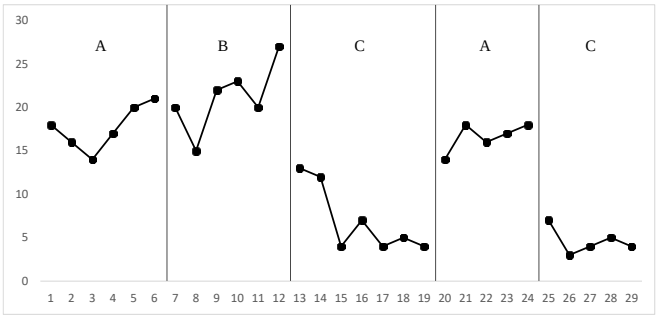
to label this phase because it is the second phase of this applied study and "B" denotes the use of pre-correction. Looking at Figure 1, we see that disruptive behavior did not improve. For example, the level in which disruptive behavior was observed did not decrease, and we do not see a decreasing trend over time. In fact, disruptive behavior appears to be increasing over time, from class session to class session. Thus, the classroom team concludes that the change idea, as implemented, was ineffective.

Not to be discouraged, the classroom team meets again with the PBIS Team to discuss the data and their perceptions of how pre-correction was utilized and student response. During the discussion, the classroom team has many questions about when and how to use pre-correction. The classroom team is also uncertain if they are using the strategy effectively and efficiently. Perhaps pre-correction could be effective if implementation is more consistent (e.g., utilized in most if not all instances in which it should) and of better quality (e.g., obtaining student attention before using pre-correction; improving the clarity of verbal pre-correction statements; checking for student understanding of pre-correction statements). They then agree for a member of the PBIS team to attend class sessions to model pre-correction while the classroom team provides instruction. A member of the PBIS team also observes and provides feedback on the classroom team's use of pre-correction. Support and feedback are provided to the classroom team during class instruction and scheduled debriefing sessions. This support is provided for one week, after which the classroom team utilizes pre-correction independently. Again, the team is careful to use the same data collection methods over time so that any changes in student performance are more likely to be attributed to the change idea rather than inconsistent or faulty data collection methods.

Data collected during this third study phase are labeled with the letter "C" in the line graph which denotes modeled pre-correction (see Figure 1). As you can see, modeled pre-correction appears to have had the desired effect of decreasing instances of disruptive behavior. However, the classroom team must be cautious when making the claim that disruptive behavior decreased due to the use of pre-correction, as an ABC single-case design does not permit causal inferences to be made from the implementation of a change idea and observed changes in dependent variables. This is because this design requires an additional A and C phase so that additional comparisons of student behavior in each condition can be made (e.g., additional opportunities to provide evidence of effect replication). To have an opportunity to make a causal inference between the use of pre-correction and improvement in student behavior, the classroom team would need to have an additional "A" phase (e.g., BAU) followed by an additional "C" phase (instruction with teacher implementation of pre-correction). However, an ABC design may be suitable for applied settings and may represent an improvement to typical school practice such as when data collection is unsystematic or absent (see Etscheidt, 2006; Vicente, 2021; Stecker et al., 2008).

Figure 2 shows data collected from this hypothetical study. Phase A documents the presence of an important variation in school performance, and phase B and C display data collected while the teaching team refines their implementation of the change idea (pre-correction). With the refined change idea in place in phase C and the documentation of student benefit (e.g., an effect), the teaching team stops using pre-correction (e.g., a withdrawal of the change idea). Collected data documents the return of disruptive behavior to baseline levels, providing evidence of pre-correction's effectiveness (e.g., disruptive behavior increased in the absence of the change idea, providing evidence of the change idea's effectiveness). During the last study phase, the classroom team uses modeled pre-correction and lower levels of disruptive behavior are observed, providing additional evidence of the effectiveness of pre-correction. In this comparison, disruptive behavior data are compared to disruptive behavior in the previous phase (absence of pre-correction). In sum, this hypothetical study design provides four opportunities to establish an intervention effect at four different points in time, which according to some professional guidelines for single-case research is sufficient to permit a causal inference.

Figure 2. Visual Display of Class Data Collected Using an ABCAC Design: Instances of Disruptive Behavior



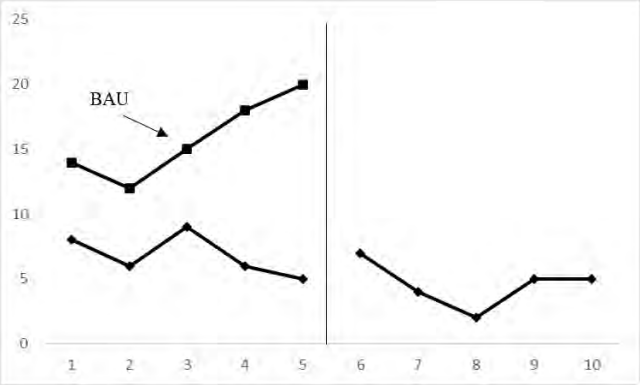
ADDITIONAL TYPES OF SINGLE-CASE DESIGNS

Another type of single-case design study is the alternating treatment design. In this type of study, practitioners alternate between two different conditions, such as typical school practice and a change idea. Practitioners might also alternate between two different change ideas to determine which is most effective and/or efficient. Regardless, the idea is to alternate between conditions until one is determined to be superior to the other, based on the visual analysis of time series data. Alternating treatment designs can also be performed in the absence of baseline data (e.g., data collected during BAU), thus permitting the school team to implement a change idea more quickly. This design may be particularly beneficial when there are ethical concerns with delaying intervention or time constraints associated with the Dissertation in Practice. Figure 3 is an example of data collected during an alternating treatment design. Using our previous example, the practitioner scholar implementing this dissertation study is alternating between BAU instruction and pre-correction, while systematically collecting data on disruptive behavior. In this hypothetical example, there are five opportunities to compare data collected during each of the two conditions:

1. session 1 for BAU is compared to session 1 for pre-correction
2. session 2 for BAU is compared to session 2 for pre-correction
3. session 3 for BAU is compared to session 3 for pre-correction
4. session 4 for BAU is compared to session 4 for pre-correction
5. session 5 for BAU is compared to session 5 for pre-correction.

When visually inspecting the data for each comparison, we see that pre-correction is more effective than BAU, as evidenced by lower levels of observed disruptive behavior. In this hypothetical example, data are collected during sessions 6 to 10 to provide additional evidence of pre-correction's effectiveness. Alternating between conditions is no longer necessary, as sufficient replications of an effect were obtained in comparisons 1 to 5.

Figure 3. Data From an Alternating Treatment Design

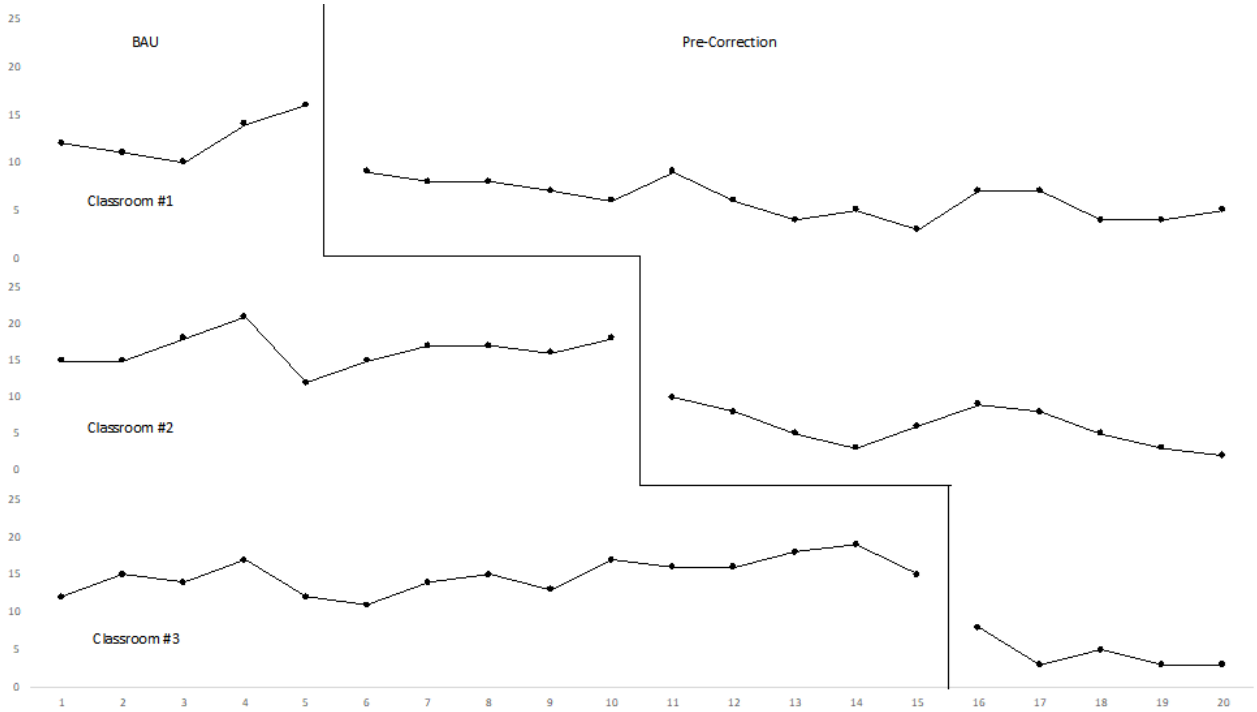


Practitioner Scholars can conduct larger single-case investigations by using multiple baseline designs. In this type, data are collected simultaneously over time for three or more participants, whether it be a student, pairs or small groups of students, a classroom, or school. Figure 4 shows how a multiple baseline design can be used to investigate the effectiveness of pre-correction with three classes. Data are collected over time each day for each class. Data are collected under BAU conditions, as well as when educators use pre-correction. For example, session 1 data for each class are collected on the same day. Session 2 data for each class are also collected on the same day. Data are collected in this manner consistently over time. However, educator use of pre-correction is staggered over time, with the independent variable introduced to each class at a different point in time. In this example, the Practitioner Scholar does not have the second classroom use pre-correction until an effect is established with the first class, in the absence of an effect in two classes in the BAU condition. This is a key element of multiple baseline designs: evidence of an intervention effect with the participant or participants that receive the change idea, and evidence of no effect for participants who do not receive the change idea. When implementing the change idea in the second classroom, the Practitioner Scholar is hoping to observe a decrease in disruptive behavior in this class, the absence of a decrease in disruptive behavior in the third class and continued lower levels of disruptive behavior in the first class. When sufficient data have been collected to establish an effect in the second classroom, pre-correction is utilized in the third classroom while pre-correction continues to be implemented in the first two classes. Evidence of an intervention effect is established when lower levels of disruptive behavior are observed in this class, while lower levels of disruptive behavior are maintained in the first and second class.

CONNECTIONS TO IMPROVEMENT SCIENCE

In the following section, connections between single-case research and Improvement Science are discussed. The following foundational principles are considered: (1) identify, describe, and address variability of performance, (2) making the work problem specific and user centered, (3) starting small but thinking big, (4) resisting the temptation of "solutionitis", (5) focus on process variables, (6) learning fast to implement well, and (7) using a community-based approach. Resources for further inquiry are also provided.

Figure 4. Visual Display of Class Data Collected Using a Multiple Baseline Across Classrooms Design: Instances of Disruptive Behavior



Identify, Describe, and Address Variability of Performance

Repeated measurement of a dependent variable over time contributes to the identification and description of concerning variabilities of performance. This proves particularly true when baseline data are collected systematically over time prior to the implementation of a change idea. Time series data collected during single-case investigations can also be supplemented with other data sources such as stakeholder interviews or focus groups. For example, qualitative inquiry could focus on the intended beneficiaries of the change idea and/or the implementers. Single-case research is also a type of intervention research, which is necessary to improve any concerning variability of performance. If carefully implemented, single-case research provides an opportunity to have a degree of confidence that observed improvements are due to the change idea. In consideration of the high stakes nature of improving the provision of opportunity, this degree of confidence is necessary to make informed decisions in school practice.

Making the Work Problem Specific and User-Centered

Improvement Science and single-case research focus on a specific problem of practice, and this serves as the foundation for disciplined inquiry. In the first example, the classroom team was concerned with the occurrence of disruptive behavior in the classroom and sought to identify a strategy that could improve student behavior. Single-case design investigations are also user-centered, in that they may focus on changing adult behavior (in this case, members of the classroom team) to change student behavior. The use of pre-correction, and the eventual provision of appropriate classroom team training and support, represent changes in adult behavior. In the first example, pre-correction was initially ineffective. Upon further discussion between the classroom and PBIS teams that was user centered, implementation challenges were identified and addressed.

Single-case research designs can also be used to investigate the effects of change ideas that are student or peer-centered, such as behavioral interventions that involve teaching replacement behaviors or peer tutoring to improve academic and/or behavioral performance (McKenna et al., 2016; Reid et al., 2004; Wang et al., 2021). Problems of practice addressed through single-case designs can also be viewed from the perspectives of students and their parents/guardians. For example, the following research questions may be pursued:

1. What are the potential implications for student learning if a problem of practice is not addressed?
2. What concerns may parents/guardians have in this situation?
3. What concerns may students have regarding the performance of disruptive behavior in their class?
4. What are the characteristics of change ideas that students and/or parent/guardians perceive as socially valid and significant?
5. What are the characteristics of change ideas that students and/or parent/guardians perceive as being culturally responsive?

These research questions can be answered through disciplined inquiry, such as reading relevant research, considering student data as a form of practice-based evidence, and holding student and/or parent/guardian focus groups to identify concerns and suggestions for school improvement. In this example, single-case research serves as a foundation for utilizing other data sources and methodologies to identify socially significant dependent and independent variables for investigation.

Starting Small but Thinking Big

Single-case research can be used to investigate the effectiveness of change ideas with a single student, teacher, classroom, or school. Investigations can be small and still provide a rigorous test of a change idea before committing resources to change at scale. This is particularly important for adapting change ideas to fit local contexts, which is a core principle of Improvement Science (Bryk et al., 2016). In addition, scholar practitioners can collect various forms of process data to confirm and refine their theory of change before transitioning to larger scale change efforts. Examples of process data that can be collected during a single-case investigation include, but are not limited to, stakeholder interviews, stakeholder focus groups, and fidelity of implementation data. Regarding fidelity data, these can be collected through an analysis of permanent products associated with the implementation of a change idea, observation of persons implementing the change idea using a checklist that includes the key features of the change idea that are likely to be observed when it is used, or self-evaluation of change idea implementation using a similar type of checklist (McKenna & Parenti, 2017). Each of these data sources have the potential to provide context to time series data and is consistent with Improvement Science's emphasis on considering process data in concert with outcome data. Thus, by performing small tests of change using single-case research, practitioner scholars can refine and more fully develop their theory of change before engaging in larger scale investigations.

Resisting the Temptation of "Solutionitis"

Similar to practitioners of Improvement Science, single-case researchers engage in evidence-based practice as a decision-making process. According to this principal, applied researchers use scholarly research, their personal values, professional judgement, and their goals for students to make an informed decision on how best to address a concerning variability in performance (see Cook et al., 2016 for a discussion of evidence-based practice as a decision-making process). Selecting a change idea to test is not a reactionary decision, such as when practitioners engage in "solutionitis" (Bryk et al., 2016). Single-case research emphasizes leveraging empirical evidence in concert with information on the local context, which is consistent with Improvement Science' emphasis on disciplined inquiry.

Learning Fast to Implement Well

Evaluating the effectiveness of a change idea in a short period of time is essential to Improvement Science (Bryk et al., 2016). Single-case research can be utilized to achieve this goal. As previously stated, single-case research can be used to design tests of change that permit causal inferences. This level of evaluation rigor is beneficial as it helps prevent the allocation of resources to change ideas that are unlikely to be effective. Rigorous evaluations can also be completed in a short period of time. For example, alternating

treatment designs can be used to quickly evaluate the relative benefits of two change ideas, or a change idea relative to BAU. Lessons learned from this investigation could then be used to inform a multiple baseline design study involving additional classrooms, students, and/or teachers. Practitioners of Improvement Science can also elect to conduct simultaneous replication studies, which are essentially two or more single-case investigations that utilize the same design and focus on the same problem of practice, change idea, and dependent variables. Thus, lessons learned from single-case evaluations can be obtained quickly, inform efforts to take improvement efforts to scale, and can be viewed with a degree of confidence.

COMMUNITY-BASED APPROACH

Similar to improvement science, single-case investigations are best utilized when a community-based approach is employed. As in the initial example, single-case investigations involve engagement with the consumers and intended beneficiaries of change ideas. This engagement involves discussions of the characteristics of the problem of practice, the selection of a change idea that is likely to be effective and feasible, discussion of issues related to implementation, and methods for refining change ideas to improve effectiveness and feasibility. In this example, a community-based approach is used to inform the selection of a change idea and its implementation, to monitor the response of the interventionists and the intended beneficiaries, and to make timely and effective adjustments to change ideas as necessary. As additional single-case investigations are planned and implemented, a greater number and perhaps wider range of stakeholders may become involved in the practice of Improvement Science.

CLOSING COMMENTS

The current social, political, and public health climate presents significant challenges to public institutions. Educational leaders must be prepared to leverage available resources to inform improvement efforts. In turn, improvement efforts should focus on inclusion rather than mere integration. By inclusion, I am referring to equality of opportunity and outcomes for student populations that have historically struggled and/or been marginalized in public education. Improvement Science provides a framework to identify and investigate concerning variations in school performance, many of which are likely to conflict with inclusion and an emphasis on equality of opportunity and outcomes. Single-case research provides a set of flexible methods that compliment Improvement Science by providing a means to conduct rigorous tests of change, identify contextual factors to consider in scale up efforts, and to refine theories of change in a timely manner.

The appendix provides resources for faculty and doctoral students with an interest in considering single-case research as an additional tool for doctoral study. Resources provide general information on single-case research and its implementation, examples of published studies, and resources for collecting academic and behavioral time series data. As with any research methodology, single-case requires careful study and practice. However, these resources provide a foundation for further disciplined inquiry in this area.

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APPENDIX

Resources for Practitioner Scholars

Single-case Research Design

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