Applying the Behavior Change Technique Taxonomy from Public Health Interventions to Educational Research

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ABSTRACT

Public health research has developed a deep understanding of ways to help people live healthier lives through scalable interventions that change their behaviors. This work offers valuable insights for supporting learners in educational contexts, especially for improving self-regulation and goal-directed behaviors like completing a course of study–a persistent issue in formal and information post-secondary education. We present the widely adopted Behavior Change Technique (BCT) taxonomy as a model for systematically cataloging interventions in education and as a resource for inspiring new interventions in education based on public health evidence. Approaching the issue of learner attrition from the BCT perspective, we show how recent educational interventions fit into the BCT taxonomy and how the taxonomy can be used to develop new evidence-based intervention approaches. Borrowing insights from decades of public health research can advance parallel efforts in education to help learners at scale to stay on track and reach their academic goals.

Author Keywords

Behavior science; Interventions; Engagement in online education; Translation research

CCS Concepts

•**Applied computing** → *E-learning; Distance learning;*

INTRODUCTION

Public health research can offer a wealth of empirical evidence on how to promote desirable behaviors for diverse populations. A wide range of interventions have been developed and tested to influence people's health behaviors, including improving diets, increasing physical activity, reducing the use of substances such as alcohol, tobacco, and drugs (e.g., [16, 9, 18]). These interventions have targeted diverse groups of people, from the general public to special groups, including people with obesity, diabetes, substance addictions, mental disorders, sedentary professions, underprivileged backgrounds, from young children to senior citizens. In recent years, a growing number of public health interventions have leveraged modern technology (e.g., machine learning techniques [48], mobile apps [56, 12]) to monitor health behaviors and deliver timely intervention at scale. These intervention studies have demonstrated scalable and effective ways to improve health behaviors (e.g., [52, 16, 9, 18]).

Interventions in education aim to support students' academic success using various approaches, ranging from *behavioral interventions* concerning students' problematic behaviors in classrooms or on campus (e.g., [33, 13]) to *instructional interventions* providing academic supports to at-risk students [32, 42]. One of the major impediments to academic success is student attrition, in both in-person and online education. According to a US national survey in 2018-19, approximately one-fifths of the students enrolled in a 4-year college and about two-fifth of the students enrolled in a 2-year college dropped out [19]—attrition rates tend to be even higher in online degree programs. In informal online learning, such as massive open online courses (MOOCs), high attrition rates have also been commonplace, even among committed learners [22, 26, 28]. A myriad of interventions in education have been conducted to tackle the problem of attrition (hereafter we will use 'education interventions' to refer to interventions that aim to improve attrition in education; to avoid confusion, we note that *educational interventions* typically refer to interventions that use educational activities in the public health literature). The education research community has been working on ways to improve academic outcomes with education interventions for a number of years [8, 55, 54].

From the behavioral science perspective, education interventions share similarities with public health interventions, and thus work on public health interventions can be a useful reference for improving education interventions that use a behavioral science approach. They both target goal-oriented behavior(s), which means interventions typically entail changing various behaviors to achieve goals. For example, weight loss interventions guide participants to conduct multiple health behaviors such as jogging, weight training and eating low-calorie food to lose weight. Similarly, dropout prevention programs in education, where the main goal is to increase school completion, advise students to engage in numerous learning activities, including attending class, doing the reading, and submitting assignments on time. Moreover, interventions in both education and public health require a long-term commitment. To achieve goals, participants and students need to conduct suggested behaviors (e.g., exercising) or required behaviors (e.g., attend-

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ing classes) regularly until the goal is achieved (e.g., weight loss and school graduation). In addition, self-regulation is the key to success in goal achievement for both, particularly because individualization is inevitable in both interventions. Although interventions provide guidelines, individuals have different goals and plans according to their own needs and circumstances, and in the end, they decide how to act based on the advice from the intervention program. For example, expected weight, workout plans, and types of exercise are different for each person, and people need to self-regulate to keep up with the plans. Similarly, in dropout prevention programs, participants may have different course schedules, graduation years, levels of academic support, and career goals. Thus, collective knowledge on effective techniques for behavior change in the public health literature might be useful to help students stick with desirable learning behaviors as well.

Techniques used in public health interventions for behavior change could have far-reaching impacts on students, especially those engaged in online learning environments. Education at present can reach a wide student population as educational technology has become essential not only in distance learning but also in in-person learning contexts. For example, web-based learning management systems like Canvas and Blackboard have become commonplace for in-person college classes to support various learning-related activities, such as sharing learning materials, keeping track of students' learning progress, submitting assignments, and asking and answering questions. Typically, these learning management systems are also accessible via smartphones, and students can receive real-time notifications. Students are connected with instructors, peers, and learning resources through ubiquitous channels. Digitally mediated learning environments thus provide ample opportunities to develop education interventions that closely assist students by assessing the state of their learning process and providing adequate techniques for behavior change.

Educators and education researchers can draw benefits from the Behavior Change Technique (BCT) taxonomy that public health researchers have developed. It provides a standard set of definitions for techniques to change behavior in an effort to build cumulative knowledge from the enormous number of empirical studies conducted in public health research. Health interventions are typically in the format of a program that people participate in, and these programs are often complex and contain multiple phases over a long period of time. For example, interventions that promote a healthy lifestyle usually operate over a month and include a variety of services such as planning, mentoring, self-monitoring tools, and educational sessions. The BCT taxonomy is used to identify techniques used in a health intervention and synthesize effective techniques from multiple empirical studies—they distill and isolate the active ingredients of interventions. Educators and education researchers can glean insights for developing education interventions from health intervention work that investigated effective BCTs in specific contexts for a population of interest (e.g., review papers of interventions to increase physical activities of sedentary workers). Moreover, they can use the BCT taxonomy to compile and synthesize findings of education interventions from the behavior change perspective. This synthesis paper demonstrates the potential of applying research from health interventions in the field of education. From the behavior change perspective, the goal of education interventions is to increase learning behaviors in ways that help students stay engaged throughout the course (e.g., attending lectures and doing the assigned reading). Health interventions share similar concerns about how to make their population of interest continue conducting desirable health behaviors, such as exercising, eating healthy food, and taking medication until they achieve health-related goals like weight loss. We present the BCT taxonomy that is widely used in the public health community as a basis for translating effective strategies from health interventions into education interventions. Moreover, the BCT taxonomy can serve as a fine-grained coding scheme to gather knowledge from education interventions to be used by education researchers for systematic reviews. In this synthesis paper, we describe the characteristics and benefits of the BCT taxonomy, present examples of BCT coding for the Look AHEAD study (one of the largest health interventions to date), demonstrate BCT coding of recent self-regulated learning interventions in online education, and share a BCT-inspired example intervention design to develop learning habits.

BEHAVIOR CHANGE TECHNIQUES TAXONOMY

Public health researchers have standardized the definitions of health intervention components to better understand what makes them effective and to facilitate communication among researchers and practitioners in the health community. Specifically, they developed the Behavior Change Technique (BCT) taxonomy [1, 38], which is a versatile, fine-grained coding scheme to synthesize data from multiple empirical studies to classify the intervention techniques used. It has become standard practice to use the BCT taxonomy in the health behavior change literature. Various review papers ranging from meta-analyses to scoping reviews have used the BCT taxonomy for different target health behaviors, including promoting physical activity [16, 3], healthy diets [9], smoking cessation [4], alcohol reduction [18], and medication adherence [40]. These review papers not only apply the BCT taxonomy to studies of the general public [39], but also specific groups of interest, including adolescents [17], people with diabetes [43], people with intellectual disabilities [53], and children from lower socioeconomic environments [2]. Moreover, public health researchers have used the BCT taxonomy to identify effective BCTs in various contexts, including Internet-based programs [35, 51] and mobile applications [12, 56, 59].

In the next section, we describe four characteristics of the BCT taxonomy and their benefits.

1. A BCT is The Smallest Unit of Analysis

A BCT is defined as "an observable, replicable and irreducible component of an intervention designed to alter or redirect causal processes that regulate behavior" (p.4) [38]. In practice, each of the BCTs is defined with a verb to describe an action or a series of actions taken by the self or the facilitator as part of the intervention. For example, *social comparison (6.2)* is defined as "draw[ing] attention to others' performance to allow comparison with the person's own performance." The BCT definitions require that intervention components are

classified in a fine-grained manner. For instance, social norms interventions [45, 44] are popular health interventions that take advantage of social comparison to increase or decrease a target behavior, typically either conveying a descriptive norm (e.g., "a majority of people eat vegetables everyday") or an injunctive norm (e.g., "a majority of people think that we ought to eat vegetables everyday"). If a descriptive norm is used, the intervention is coded as *social comparison (6.2)*, but if an injunctive norm used, a more relevant BCT to code is *information about others' approval (6.3)*, which is defined as "provid[ing] information about what other people think about the behavior. The information clarifies whether others will like, approve or disapprove of what the person is doing or will do." The distinction between the two norm messages in BCT coding allows researchers to probe how different norm messages may function differently through the behavior change lens.

As another example, the BCT taxonomy defines nine BCTs for goal setting and planning. It clearly distinguishes goal setting (*Goal setting (behavior) (1.1)* vs. *Goal setting (outcome) (1.3)*), planning activities (*Problem solving (1.2)* vs. *Action planning (1.4)*), reviewing goals (*Review behavior goal(s) (1.5)* vs. *Review outcome goal(s)* vs. *Discrepancy between current behavior and goal*), and certifying the goals or plans made (*Behavioral contract (1.8)* vs. *Commitment (1.9)*). For example, the BCT taxonomy distinguishes goal setting techniques based on whether a goal is set to a specific behavior (e.g., jogging) or an outcome (e.g., weight loss). The former is *Goal setting (behavior) (1.1)* and the latter is *Goal setting (outcome) (1.3)*. The definitions of the BCTs are listed in Table 1.

Table 1. BCTs in the goal setting and planning clusters. Additional information and examples can be found in the original paper [38].

No.	BCT label	Definition
1.1	Goal setting (behavior)	Set or agree on a goal defined in terms of the behavior to be achieved
1.2	Problem solving	Analyse or prompt the person to analyse, factors influencing the behavior and generate or select strategies that include overcoming barriers and/or increasing facilitators (includes 'Relapse Prevention' and 'Coping Planning')
1.3	Goal setting (outcome)	Set or agree on a goal defined in terms of a positive outcome of wanted behavior Note: only code guidelines if set as a goal in an intervention context
1.4	Action planning	Prompt detailed planning of performance of the behavior (must include at least one of context, frequency, duration and intensity). Context may be environmental (physical or social) or internal (physical, emotional or cognitive) (includes 'Implementation Intentions')
1.5	Review behavior goal(s)	Review behavior goal(s) jointly with the person and consider modifying goal(s) or behavior change strategy in light of achievement. This may lead to re-setting the same goal, a small change in that goal or setting a new goal instead of (or in addition to) the first, or no change
1.6	Discrepancy between current behavior and goal	Draw attention to discrepancies between a person's current behavior (in terms of the form, frequency, duration, or intensity of that behavior) and the person's previously set outcome goals, behavioral goals or action plans (goes beyond self- monitoring of behavior)
1.7	Review outcome goal(s)	Review outcome goal(s) jointly with the person and consider modifying goal(s) in light of achievement. This may lead to re- setting the same goal, a small change in that goal or setting a new goal instead of, or in addition to the first
1.8	Behavioral contract	Create a written specification of the behavior to be performed, agreed on by the person, and witnessed by another
1.9	Commitment	Ask the person to affirm or reaffirm statements indicating commitment to change the behavior

2. The BCT Taxonomy Provides Detailed Guidelines for Classification

A BCT definition uses well-established terminology for intervention techniques that are used in clinical studies and behavioral science research if they conceptually belong to the definition. For example, *demonstration of the behavior (6.1)* is defined as "provid[ing] an observable sample of the performance of the behavior, directly in person or indirectly (e.g., film pictures) for the person to aspire to or imitate" and a note attached says this BCT includes *modeling*, which is a technique in cognitive behavior therapy.

The BCT taxonomy also allows coding an intervention with more than one BCT. For the aforementioned BCT, the definition instructs to mark *behavioral practice and rehearsal (8.1)* if the demonstrated behavior is also guided to practice. It also instructs to code *instruction on how to perform the behavior (4.1)* if instructions are provided. These guidelines enable precise and reliable classification of techniques in interventions across researchers and review studies.

3. The BCT Clusters Enable Easy Coding and a Quick Overview of BCTs Used in Interventions

The BCT taxonomy defines 93 behavior change techniques grouped into 16 clusters by their mechanism of change. For example, *6. Comparison of behavior* consists of three BCTs: *demonstration of the behavior (6.1)*, *social comparison (6.2)*, and *information about others' approval (6.3)*. The clusters act as high-order labels for BCTs accompanying similar psychological processes. The hierarchy provides two benefits. First, researchers can easily look up BCTs corresponding to active components in interventions with the clusters. For example, if an intervention asks participants to plan for their goal, researchers can check BCTs listed in *1. Goals and planning* instead of checking all BCTs. Second, the high-order grouping provides intuition to grasp the predominant type of techniques used in an intervention. Health interventions typically combine multiple intervention components and operate on a complex psychological mechanism, and having the big picture of an intervention (i.e., the main ingredients of the intervention) is valuable especially to inform future intervention design. The higher-order labels (i.e., BCT clusters) can be used for this purpose. For example, if most of the BCTs identified and found effective in an intervention belong to the *1. Goals and planning* cluster, the intervention could change behavior mainly via goal setting and planning. All BCTs are organized according to the following 16 clusters in the taxonomy:

1. Goals and planning
2. Feedback and monitoring
3. Social support
4. Shaping knowledge
5. Natural consequences
6. Comparison of behavior
7. Associations
8. Repetition and substitution
9. Comparison of outcomes
10. Reward and threat
11. Regulation
12. Antecedents
13. Identity
14. Scheduled consequences
15. Self-belief
16. Covert learning

4. The BCT Taxonomy Is Evolving

Although the BCT taxonomy is widely adopted as the standard taxonomy, researchers have worked on ways to improve it. First, additional efforts have been made to contextualize the BCT taxonomy. For example, Michie and colleagues [37] developed the CALO-RE taxonomy based on the BCT taxonomy, specifically for enhancing physical activity and healthy eating. Moreover, there are active discussions about expanding the BCT taxonomy, reflecting the growing role of technology in public health interventions. Recently, Dugas and colleagues [11] proposed to add two more clusters to capture the techniques utilizing up-to-date technology, including real-time sensing and machine learning in mobile health interventions. The new *17. personalization* cluster consists of BCTs, such as *adjusting intervention content to performance* which refers to "adjust[ing] messaging/intervention content based on current performance." The new *18. Gamification* cluster considers digital culture, especially the prevailing gaming culture in Gen Z. This cluster includes BCTs like *earning badges/levels* which is defined as "reach[ing] specific goals earns participants a badge or 'level' up" and *Competitions* which is "participants compete against one another to perform the most healthy behavior/earn the most points. Competitions are different from informal social comparison opportunities, and include a defined period for competition, defined competitors, and defined behaviors or outcomes assessed for the competition. Note: Should also code 6.2, social comparison."

UNDERSTANDING ATTRITION FROM THE BEHAVIOR CHANGE PERSPECTIVE

For education interventions that promote goal-directed behavior, every learning activity that is required to complete the course, such as watching lectures and writing discussion posts, is a target of the intervention. Some interventions that aim to improve the effectiveness of online learning may already have adopted strategies similar to BCTs in health interventions. Consider, for instance, interventions promoting self-regulated learning. According to Zimmerman's model [60], self-regulated learning is a cyclic process of three phases directed by a learner: forethought phase (set learning goals and make plans), performance phase (engage in learning and self-monitor), and reflection phase (evaluate learning outcomes). Planning in the forethought phase is an essential step in the self-regulated learning process, but it is also one of the most effective BCTs in health interventions. For instance, asking course participants to plan how they will take the course would enhance self-regulated learning and promote engagement in learning activities (i.e., learning behavior). Providing self-monitoring tools is also a well-known approach to promote both self-regulated learning and desirable behaviors in health interventions. Thus, despite their different aims, there are a number of commonalities between self-regulated learning strategies and BCTs in health interventions.

Despite these commonalities, there is substantial room for translating insights from health interventions into education to advance outcomes in self-directed learning environments. A good number of BCTs used in health interventions are distinct from the BCTs that are presently used in self-regulated learning interventions. We will focus on what new insights BCTs in health interventions can offer relative to what we know from current education interventions by presenting BCTs that are not frequently used in learning-focused interventions but can be useful to improve attrition in online courses. To this end, we highlight some of the BCTs used in the Look AHEAD study [15, 50, 20] that can be applied to promote engaging in learning behavior.

The Look AHEAD study is one of the largest and longest lifestyle health interventions with randomized controlled trials on overweight and obese type 2 diabetes patients with more than 5,000 participants over a decade (2001-2012). The goal of the intervention was weight loss and prevention of cardiovascular disease. The intervention provided a toolbox of behavioral strategies for improving dietary quality and increasing physical activity intervention. The Look AHEAD study remains an influential long-term health intervention because of the wealth of data it generated and the multiple behavioral components it tested. Many spin-off studies analyzing the data have been conducted, including identifying its most effective BCTs [9]. Thus, BCT coding of this intervention will show a snapshot of what insight can be derived from health intervention studies using the BCT coding.

We reference the BCT coding of the Look AHEAD study conducted in a recent review article [9]. The authors of the review study reported that they identified 43 BCTs from 14 clusters in the Look AHEAD study. We are presenting the BCTs they identified under the *8. Repetition and substitution*, *12. Antecedents*, *13. Identity*, and *15. Self-belief* clusters (see Table 2). These BCTs are associated with motivating the self (*13. Identity* and *15. Self-belief*) and preparing the surroundings so that they can cue behaviors (*8. Repetition and substitution* and *12. Antecedents*).

The BCTs used in the Look AHEAD study primarily aim to encourage participants to take certain actions like jogging and help them conduct them frequently. However, they do not necessarily advise participants to take actions more efficiently (e.g., recommend jogging in the morning because it will burn more calories than at night) or select a more efficient action (e.g., recommend swimming rather than jogging because swimming is a more intense exercise that can help burn more calories). The BCTs adopted in the Look AHEAD study can be useful in the education space primarily to increase the frequency of learning behaviors, given that little attention was placed on the qualitative aspects of health behavior like enhancing the effectiveness of a workout plan.

Table 2. BCT coding of the Look AHEAD study. Content of the last column is adapted from the coding data of [9].

Cluster	BCT label	Definition	the Look AHEAD study
8. Repetition and substitution	Behavior substitution (8.2)	Prompt substitution of the unwanted behavior with a wanted or neutral behavior.	Encourage to increase their lifestyle activity by methods such as using stairs rather than elevators, walking rather than riding, and reducing use of labor-saving devices (e.g., e-mailing colleagues at work)
12. Antecedents	Restructuring the physical environment (12.1)	Change or advise to change the physical environment in order to facilitate performance of the wanted behavior or create barriers to the unwanted behavior (other than prompts/cues, rewards and punishments)	Add positive activity cues. In order to become more active, it is important to have an environment which supports activity. Storing an exercise bike in the basement or garage is a sure way to "forget" to use it. Setting up the environment to "cue" us to exercise will increase activity.
	Avoidance/ reducing exposure to cues for the behaviour (12.3)	Advise on how to avoid exposure to specific social and contextual/physical cues for the behavior, including changing daily or weekly routines	Add positive activity cues. In order to become more active, it is important to have an environment which supports activity. Storing an exercise bike in the basement or garage is a sure way to “forget” to use it. Setting up the environment to “cue” us to exercise will increase activity.
13. Identity	Identification of self as role model (13.1)	Inform that one’s own behavior may be an example to others	Will set a good example for your family, friends, and community. Many of us live in a family or a culture that is inactive and eats a high-fat diet. You will face challenges as you work at doing things differently. But you will also set a good example of what it is like to live a healthier lifestyle, which can be inspiring and encouraging to everyone around you
	Framing/reframing (13.2)	Suggest the deliberate adoption of a perspective or new perspective on behavior (e.g. its purpose) in order to change cognition or emotions about performing the behavior (includes ‘Cognitive restructuring’)	Practice talking back to negative thoughts. Catch yourself thinking negative thoughts. Write them in your Keeping Track book. Practice stopping them and talking back with positive thoughts related to goals you can reach
15. Self-belief	Verbal persuasion about capability (15.1)	Tell the person that they can successfully perform the wanted behavior, arguing against self-doubts and asserting that they can and will succeed	"I can try going for a walk and stop if it gets too cold."
	Focus on past success (15.3)	Advise to think about or list previous successes in performing the behavior (or parts of it)	Think about what you’ve achieved and hope to achieve, think about your successes, what changes in your eating and activity do you feel proudest of?
	Self-talk (15.4)	Prompt positive self-talk (aloud or silently) before and during the behavior	have participants’ say out loud in their own words, self-motivational statements about why they will benefit from participating

CATEGORIZING EDUCATION INTERVENTIONS WITH THE BCT TAXONOMY

We demonstrate the applicability of the BCT taxonomy in education by using it to categorize several interventions that were recently tested across hundreds of online courses [27]. Specifically, we will examine the *mental contrasting with implementation intentions* intervention, *plan-making intervention*, *social accountability intervention*, and *value relevance intervention*. We selected these interventions to try out the BCT taxonomy for two main reasons. First, they represent an emerging trend in education to use technology to reach large numbers of students without sacrificing the fidelity of materials [49, 58, 23]. The selected interventions were implemented as field experiments on a large scale, reaching 250,000 participants who were globally distributed. Although these interventions were implemented in MOOCs that reached millions of people, they could just as well be added to widely adopted learning management systems in in-person, residential colleges. Second, the selected interventions have strong similarities in their goal, context, and design, and yet they target different psychological and meta-cognitive mechanisms, which the BCT taxonomy can help distinguish. All four interventions aim to raise student persistence in a self-directed learning environment. They prompt course participants to complete a brief, one-off writing activity at the beginning of the course.

Mental Contrasting with Implementation Intentions

The mental contrasting with implementation intentions (MCII) intervention was originally developed by psychologists to support effective goal pursuit and attainment [14]. The MCII intervention activity has two parts: first, participants identify positive outcomes of goal achievement and obstacles to achieving a goal and elaborate on them in writing by vividly imagining how they would be like (MC); second, participants generate specific if-then plans for how to overcome the identified obstacles (II). In the first field experiment testing MCII at large scale [24], learners in the control condition, which typically provides participants with an innocuous task to serve as the baseline in psychology experiments, wrote down their expectations for the course and their plans for taking the course. Overall, we identified four BCTs in the experiment by coding the instructions provided to participants.

The mental contrasting component is associated with the *Imaginary reward (16.2)* BCT, because participants are instructed to imagine positive outcomes. The specific instructions were:

> Here are the two positive outcomes that you associate with watching most of the lectures in this course:
> {First positive outcome} {Second positive outcome}
> Now elaborate on these outcomes in writing by imagining each as vividly as possible. What would it be like? [Big text box]

However, neither identifying obstacles nor imagining what encountering them might be like maps onto any BCTs in the taxonomy.

The II component is associated with the *Problem solving (1.2)* BCT, because participants make plans specifically for the identified obstacles, and additionally with the *Action planning (1.4)* BCT, because ‘Implementation Intentions’ are explicitly mentioned in the notes for this BCT definition. The specific instructions were:

> Write an if–then plan for each of your chosen obstacles like this: "If [obstacle occurs], then I will [actionable solution]."
>
> - Obstacle 1: {First obstacle} Write your if–then plan: [Text box]
> - Obstacle 2: {Second obstacle} Write your if–then plan: [Text box]
> - Write an if–then plan for when and where you intend to watch the lecture videos: [Text box]

Surprisingly, we found that the activity in the control condition is also associated with BCTs, specifically *Goal setting (outcome) (1.3)* and *Action planning (1.4)*. This finding suggests that the experiment actually compared different combinations of BCTs. An excerpt from the instructions in the control condition:

> This is an opportunity for you to specify concrete expectations and consider how you plan to manage your time. It also helps to be clear about why the course is relevant to you.
>
> - What are two things you expect from this course? [Big text box]
> - What are your plans for taking this course? How much time would you like to spend on it each week? [Big text box]

Plan Making Intervention

Yeomans and Reich's study [57] tested planning interventions with different components. They compared planning, planning-plus, and control conditions. In the planning condition, participants wrote down their specific plans to take the course, including where and when to engage with the learning content and how to handle potential obstacles during the course. In the planning-plus condition, participants were informed about the planning's usefulness and advised to make plans and follow them while taking the course in addition to the tasks in the planning condition. They also received the plans they wrote with the label of "your plans for this course." Participants in the control condition did not see any of these instructions.

We identified two BCTs in Yeomans and Reich's study [57]. First, the planning prompt guided participants to make specific plans which we coded *Action planning (1.4)*. In addition, we coded *Problem solving (1.2)* for asking for strategies to deal with potential obstacles (the last question in the quote below). Definitions of these BCTs can be found in Table 1. The instruction and question participants were shown are the following:

> We want to know about what plans you have made to complete this course. In the space below, write down some of your plans to learn. For example, try to specify:
>
> - When and where do you plan to spend time engaging the course content?
> - What specific steps you will take to ensure you complete the required course work?
> - How will you respond to obstacles that you might encounter during the course?

The planning-plus condition had some extra instructions in addition to the planning condition, including displaying the written plans to participants and sharing the importance of planning in goal achievement. Displaying the plans could be coded as *Commitment (1.9)* (definition in Table 1) in that it is intended to confirm the plans with participants. Teaching participants about how effective planning is for goal achievement, and encouraging participants to write and keep plans during the course, do not match any BCTs in the taxonomy. Overall, our BCT coding indicates that the planning-plus condition may not be different from the simple planning condition according to the BCTs in the two conditions. As a matter of fact, the study reported that there was no statistically significant difference between the two conditions in terms of completion rates.

Value Relevance Intervention

The value relevance intervention in Kizilcec and colleagues' study [27] was built upon self-affirmation, "any affirmation of some important aspect of the self" (p.291) [36], originally proposed by Claude Steele [46]. In the intervention, course participants in the value relevance condition were asked to identify the values that are important to them and how taking the online course can help them pursue these values. Self-affirmation is an established coping strategy that is especially useful in adverse situations (e.g., when a person feels inadequate, like a failure) [46]. The BCT taxonomy includes it in its definition of *Valued self-identity (13.4)*, which is "advise the person to write or complete rating scales about a cherished value or personal strength as a means of affirming the person's identity as part of a behavior change strategy (includes 'Self-affirmation')." The activity in the intervention is as follows:

> Please select the 2 or 3 values that are more important to you.
> What are two things you expect from this course? [Options: Relationships with family or friends, learning for the sake of learning, business/managerial skills, Sports and athletics, Religious/spiritual values, Musical ability/appreciation, Creativity, Physical attractiveness, Spontaneity/living life in the moment, Artistic skills/aesthetic appreciation, Sense of humor, Romantic values]
>
> Now consider the 2 or 3 values that are most important to you: {First value} {Second value} {Third value}
> How does taking this course reflect and reinforce your most important values? Please write at least a paragraph. Focus on your thoughts and feelings, and don't worry about spelling, grammar, or how well written it is. [Big text box]

Social Accountability Intervention

The social accountability intervention in Kizilcec and colleagues' study [27] encouraged course participants to seek out social support at the beginning of the course. It advised course participants to find someone they care about or who cares about them, and share their goals and plans for the course with them. In terms of BCTs, this intervention is *Social support (unspecified) (3.1)*, which is "advis[ing] on, arrange or provide social support (e.g., from friends, relatives, colleagues, buddies or staff) or non-contingent praise or reward for performance of the behavior. It includes encouragement and counseling, but only when it is directed at the behavior. Note: attending a group class and/or mention of 'follow-up' does not necessarily apply this BCT, support must be explicitly mentioned; if practical, code 3.2, Social support (practical); if emotional, code 3.3, Social support (emotional) (includes 'Motivational interviewing' and 'Cognitive Behavioral Therapy')."

As stated in the definition, social support can be categorized into practical support and emotional support. The social accountability intervention is less focused on the content of social support. Instead, it focuses more on connecting course

participants with others and using this social connection to help course participants persist in the course. In the field experiment, course participants assigned to the control condition were not provided with any instructions. The intervention instructions were as follows:

> Did you know that it can be much harder to stay engaged in an online course than in an in-person class? This is partly because nobody is holding you accountable for making progress towards your goal.
>
> Now is the best time to think about who can hold you accountable.
>
> 1. Write down the names of one or more friends, co-workers, family members, or acquaintances who could hold you accountable. *Tip*: Pick people who you don't see too often but whose opinion matters to you. [Text box]
> 2. Now plan for what you are going to tell them about the course and your goal. *Tip*: Ask them to regularly check in with you about your progress in the course. [Text box]
> 3. Finally, write down how and when you will tell them about this. For example, will you talk in person or on the phone, or send them an email or text message? Be sure to choose a time and place that works. [Text box]

In sum, we identified six BCTs across the four interventions (Table 3). Two planning-related interventions, the MCII intervention and the plan-making intervention, consist of different combinations of BCTs, although both involve goal-setting and planning. Moreover, both the value relevance intervention and the social accountability intervention use only one BCT each, although the length of their instructions is similar to the planning-related interventions. This may be because they were developed by social psychologists who scaffold the social and identity-based processes into multiple sub-steps. Here all of them are needed for the intervention to be effective and individual sub-steps alone cannot bring about behavior change.

Table 3. Summary of BCTs found in recent education interventions in [27]: mental contrasting with implementation intentions (MCII), plan making (PM), value relevance (VR), and social accountability (SA).

BCT No.	BCT label	MCII	PM	VR	SA
1.2	Problem solving	✓	✓		
1.3	Goal setting (outcome)	✓			
1.4	Action planning	✓	✓		
3.1	Social support (unspecified)				✓
13.4	Valued self-identity			✓	
16.2	Imaginary reward	✓			

We identify multiple implications for the design of education interventions from coding these interventions with the BCT taxonomy. First, some conditions were not different from the behavior change perspective in terms of the BCT taxonomy, such as the simple planning and planning-plus conditions in the plan-making interventions from Yeomans and Reich's study [57]. This may explain why the completion rates in these two conditions were not statistically different. Second, BCT coding suggests that the control condition may not be designed properly to measure baseline learner behavior. For example, the control condition in the MCII intervention study also contained BCTs related to goal-setting and planning. Therefore, comparing an experimental condition such as MC-only with the control condition identifies the difference between the effects of the combination of (*Goal setting (outcome), (1.3)* and *Action planning (1.4)*) on one hand, and the use of *Imaginary reward (16.2)* on the other. Third, some intervention components did not have corresponding BCTs, suggesting that they may not directly influence behavior change. For example, coming up with potential obstacles, unlike imagining future rewards, does not motivate people. Without preparing solutions to the obstacles, it may not have a direct contribution to behavior change (but still serve as a scaffolding step). Another example is informing people about the effectiveness of strategies suggested in the intervention, such as planning and finding someone to hold oneself accountable, does not have a corresponding BCT. Although they motivate course participants to employ strategies, they promote the behavior of using the strategies, not the target behavior of engaging in learning activities.

THE BCT TAXONOMY FOR LEARNING AT SCALE

In the Learning at Scale community, research, where the primary contribution is not developing an intervention itself, could still benefit from the BCT taxonomy. Incorporating BCTs can enhance participants' behavioral outcomes (e.g., participants engage with materials more frequently), and it can also increase the number of participants for field experiments (e.g., more people decide to join a study by clicking on the survey link provided in an email). Study materials can be reviewed with the BCT taxonomy and refined accordingly. As a demonstration, we coded email content used in a study by Borrella and colleagues recently published at Learning at Scale [5]. The study predicted which learners were at risk of dropping out of a MOOC and sent motivational emails to them. We code the *Feedback on outcome(s) of behavior (2.7)* BCT in their intervention design, as three different messages were emailed based on the number of graded assignments learners completed; the least engaged learners received version 1, while the most engaged learners received version 3. All messages contain *Verbal persuasion about capability (15.1)*, which is defined as "tell[ing] the person that they can successfully perform the wanted behavior, arguing against self-doubts and asserting that they can and will succeed." The third version employed *Material incentive (behavior) (10.1)*, "inform[ing] that money, vouchers or other valued objects will be delivered if and only if there has been effort and/or progress in performing the behavior" as it implied that certificate will be given as a reward. Our detailed BCT coding is shown in Table 4.

LEVERAGING BCTS FOR INTERVENTION DESIGN

The BCT taxonomy provides not only a proven mechanism for categorizing interventions in education, but it can also provide guidance for developing interventions. Studying the long list of different BCTs can inspire changes to existing interventions, such as adding or exchanging a component. It can also provide evidence-based guidance in the development of novel education interventions. In this section, we illustrate BCT-guided intervention extension and design processes. Here we focus on interventions that address attrition in education.

Enhancing Interventions with BCTs

Some established interventions in education could be enhanced by adding further BCTs. For example, the large-scale education interventions we reviewed with the BCT taxonomy

Table 4. BCT coding of the messages used in a study by Borrella et al. [5].

Email content (relevant BCT)
Version 1 We know you are interested in SC1x, but we haven't seen you around in the course much. (*Feedback on outcome(s) of behavior (2.7)*) Can you tell us what is holding you back and how we can help you? [Big blue button with link to an open response survey] (*Problem solving (1.2)*) You can still catch up with the course, you know? The Midterm will open on February 7 and is worth 35% of the final grade, so give it a shot. We know you can make it! (*Verbal persuasion about capability (15.1)*)
Version 2 We know you have missed some Graded Assignments, (*Feedback on outcome(s) of behavior (2.7)*) but don't worry, it is not a big deal! You can still catch up and get your SC1x certificate. Take a shot at the Midterm Exam! It is worth 35% of the final grade. We know you can make it! (*Verbal persuasion about capability (15.1)*)
Version 3 We can see that you are working hard on SC1x. (*Feedback on outcome(s) of behavior (2.7)*) Sometimes it may be challenging, but it will be worth it! You are learning a lot and the SC1x certificate will be useful in your career. (*Imaginary reward (16.2), Material incentive (behavior) (10.1)*) Good luck in the Midterm Exam, we know you can make it! (*Verbal persuasion about capability (15.1)*)

in the previous section are entirely self-directed. Although course participants are prompted in the intervention activities to make plans, motivate themselves, and connect with social support, the intervention provides limited advice on how to accomplish this and does not offer any feedback. To give a more specific example, the aforementioned planning-related interventions ask course participants to write about the strategies they would use to cope with potential obstacles while taking the course. Yet no advice was provided on how to cope with obstacles. More guidance could be added to scaffold identifying obstacles and planning how to address them: for instance, the intervention activity could ask more guiding questions to help identify obstacles. Here are two relevant BCTs (their definitions in parentheses) with examples of guiding questions:

Information about antecedents (4.2) ("Provide information about antecedents (e.g. social and environmental situations and events, emotions, cognition) that reliably predict performance of the behavior.")

> Example: Think about situations when you study for the course. Do you have any regular routines for when you study for the course? For example, before watching a video lecture, what do you do and where? Now think about situations in the past when you tried to study for the course but ended up not doing it. What made you decide not to study? Do you see any common hurdles that prevented you from studying?

Behavioral experiments (4.4) ("Advise on how to identify and test hypotheses about the behavior, its causes and consequences, by collecting and interpreting data.")

> Example: To make learning part of your daily routine, it helps to identify anything that discourages you from keeping up with learning. Write down what makes you (not) feel like watching video lectures. Keep a record of when you skipped a lecture or watched it.

There are numerous BCTs that participants can use as coping strategies. The simplest way to take advantage of them is to share information about potentially useful BCTs with course participants.[1] For example, interventions can explain how changing the environment can be effective to persevere until a personal goal, such as course completion, is achieved. This is captured by two BCTs, one about the physical environment and another about the social environment. Here are their definitions with examples of guiding explanations:

Restructuring the physical environment (12.10) ("Change, or advise to change the physical environment in order to facilitate performance of the wanted behavior or create barriers to the unwanted behavior (other than prompts/cues, rewards and punishments).")

> Example: It is best to put away anything that distracts you during study times. Do you frequently check your phone? Then it's best to place it far away from you while studying, somewhere that you cannot see or reach.

Restructuring the social environment (12.10) ("Change, or advise to change the social environment in order to facilitate performance of the wanted behavior or create barriers to the unwanted behavior (other than prompts/cues, rewards and punishments).")

> Example: How do you spend time with friends? You can form a study group with one or more friends and share how you are progressing.

BCT-inspired interventions can also be seamlessly added to existing self-regulated learning interventions (e.g., [21, 25]). Although the former promotes goal-directed behavior (e.g., engage in learning activities to complete an online course) while the latter enhances learning effectiveness (e.g., sharpen study skills to maximize learning outcomes), they are similar in terms of the psychological processes they target. We can find comparable BCTs for established strategies for self-regulated learning, such as those put forward by Zimmerman's model of self-regulated learning [61]. We illustrate this close correspondence in Table 5. For example, *strategic planning* in self-regulated learning involves making study plans specifying learning objectives and strategies (e.g., to understand 'random variables' in a statistics course, read relevant book chapters first, and then do problem sets at the end of the book chapters). Likewise, *Action planning (1.4)* refers to making plans about how to perform target behaviors in detail (e.g., have a 30-minute reading time sitting on a garden bench after breakfast). Whenever self-regulated learning strategies are facilitated in a study session in interventions, learning behaviors themselves (i.e., engaging in learning activities) can be reinforced by applying the BCTs that correspond to the self-regulated learning strategies. For example, when asking students to make study plans for the purpose of increasing learning effectiveness, we can also ask when and where to implement the plans to keep them engaged in the learning process.

Creating Interventions with BCTs

The BCT taxonomy can serve as an evidence-based foundation for developing new interventions in education. The rapid adoption of technology in education has created more opportunities for interventions that are scalable, interactive, and continuous. An increasing number of interventions for education make use of technology, ranging from something as simple as emails [29, 5] and mobile text messages [7, 23] to web-based learning management systems [10]. This has made it possible to adopt

[1] Note that sharing study strategies without additional reinforcement activities may not be an effective way to improve outcomes [25].

Table 5. Self-regulated learning strategies in Zimmerman's model adapted from [61] and examples of their corresponding BCTs. The definitions of each self-regulated learning strategy are obtained from [41].

Activity	Strategy	Definition	Selected BCTs
Forethought phase			
Task analysis	Goal setting	Selecting the goals the student take into account	Goal setting (behavior) (1.1), Goal setting (outcome) (1.3), Review outcome goal(s) (1.7)
	Strategic planning	Selecting an action plan and choosing the strategies that are needed	Problem solving (1.2), Action planning (1.4)
Self-motivation belief	self-efficacy	Students' belief about their capability to perform the task	Re-attribution (4.3), Verbal persuasion about capability (15.1)
	Outcome expectation	Beliefs about the probability to success in the task	Incompatible beliefs (13.3), Comparative imagining of future outcomes (9.3)
	Task value/interests	Relevance of the task for the personal goals	Valued self-identity (13.4), Identity associated with changed behavior (13.5)
	Interest	Liking for the task	Pros and cons (9.2)
	Goal orientation	Students' beliefs about their learning purposes	Framing/reframing (13.2)
Performance phase			
Self-control	Task strategy	Use of specific tactics related to the task	Problem solving (1.2), Instruction on how to perform a behavior (4.1)
	Imaginary	Mental organization of the information	Conserving mental resources (11.3), Mental rehearsal of successful performance (15.2)
	Self-instructions	Self-given instructions about the task	Self-talk (15.4)
	Environmental structuring	Creating an environment that facilitates learning	Restructuring the physical environment (12.1), Restructuring the social environment (12.2), Avoidance/reducing exposure to cues for the behavior (12.3), Distraction (12.4), Adding objects to the environment(12.5)
	Help seeking	Asking for help when needed	Social support (practical) (3.2), Social support (emotional) (3.3)
Self-observation	Metacognitive self-monitoring	Online cognitive process that assess the performance	Feedback on behavior (2.2), Feedback on outcome(s) of behavior (2.7)
	Self-recording	Keeping a record of the actions for a latter analysis	Self-monitoring of behavior (2.3), Self-monitoring of outcome(s) of behavior (2.4)
Self-reflection phase			
Self-judgment	Self-evaluation	Students' assessment of their performance based on their assessment criteria and modulated by their performance level goal	Self-monitoring of outcome(s) of behavior (2.4), Review behavior goal(s) (1.5)
Self-reaction	Causal attribution	Self-explanations about the reasons for success of failure	Information about antecedents (4.2)
	Self-satisfaction/affect	Affective and cognitive reactions produced by the self-judgements	Monitoring of emotional consequences (5.4), Self-reward (10.9), Rewarding completion (14.5)
	Adaptive/defense	Will to perform the task in the future and to activate learning strategies	Prompts/cues (7.1), Reduce negative emotions(11.2), Situation-specific reward (14.6) Vicarious consequences (16.3)

BCTs that have been primarily used in person with specialized, dedicated assistance from healthcare professionals. We present examples of technology-based intervention designs with the goal of cultivating a strong habit of studying at regular times:

Monitoring. An intervention can monitor progress in habit formation and provide feedback on whether the target behavior is undertaken as planned (i.e., spending time on learning). This intervention design is based on the following BCT:

- *Feedback on behavior (2.2)* ("Monitor and provide informative or evaluative feedback on performance of the behavior (e.g. form, frequency, duration, intensity).")

Association. To form a strong habit, the target behavior needs to be tied to another daily routine (e.g., having a study time right after walking the dog) or external stimulus (e.g., 8 pm on Thursdays is the start of a designated study period) [6, 31]. To this end, an intervention can prompt participants to remind them that it is time to study and provide action items. Positive reinforcement can be provided if participants start studying following the reminder, but not if they study at random times during the week. A message can be sent at the planned time to encourage participants to put in more effort to keep the promised study time. This design takes inspiration from the following BCTs:

- *Associative learning (7.8)* ("Present a neutral stimulus jointly with a stimulus that already elicits the behavior repeatedly until the neutral stimulus elicits that behavior (includes 'Classical/Pavlovian Conditioning').")
- *Habit formation (8.3)* ("Prompt rehearsal and repetition of the behavior in the same context repeatedly so that the context elicits the behavior.")
- *Reward approximation (14.4)* ("Arrange for reward following any approximation to the target behavior, gradually rewarding only performance closer to the wanted behavior (includes 'Shaping')).")
- *Situation-specific reward (14.6)* ("Arrange for reward following the behavior in one situation but not in another (includes 'Discrimination training').")
- *Prompts/cues (7.1)* ("Introduce or define environmental or social stimulus with the purpose of prompting or cueing the behavior. The prompt or cue would normally occur at the time or place of performance.")

Scaffolding. An intervention can start off by suggesting a very brief study session and gradually increase the duration or frequency of study times. For example, participants can be initially prompted to spend 15 minutes engaging in learning activities after walking the dog on Tuesdays and Thursdays. In the following weeks, the prompted study time increases to 30 minutes. Once participants start successfully incorporating

study time into their routine, prompts gradually decrease in frequency to avoid developing a dependency on the intervention instead of forming a habit. This design is inspired by these BCTs:

- *Graded tasks (8.7)* ("Set easy-to-perform tasks, making them increasingly difficult, but achievable, until behavior is performed.")
- *Reduce prompts/cues (7.3)* ("Withdraw gradually prompts to perform the behavior (includes 'Fading')")

SUMMARY AND CONCLUSION

In this synthesis paper, we highlight connections between interventions in education and in public health by adopting a behavioral science perspective. Interventions in both contexts aim to change individuals' behavior: education interventions promote behaviors that are conducive to learning, while public health interventions promote healthy behaviors. Both types of target behaviors are goal-oriented and require a longer-term commitment. Throughout the paper, we use concrete examples, such as lifestyle interventions for weight loss and education interventions to improve student perseverance in online courses, to compare commonalities and differences between interventions and contexts in these domains.

Building on the similarities between education interventions and public health interventions, we present the behavior change taxonomy (BCT) taxonomy—a widely accepted standard for classifying intervention strategies in public health research—as a tool to synthesize previously conducted interventions and to design new interventions in education. There are several benefits of using the BCT taxonomy in education research. As a BCT is a unit of an intervention strategy that brings about a behavior change, identifying and classifying active components in interventions can be done at a fine-grained level. At the same time, as BCTs are clustered into higher-order psychological mechanisms, examining an intervention in terms of BCTs provides an overview of the principal psychological components the intervention operates on. Moreover, there have been many efforts to further develop the taxonomy to reflect special needs of certain target behaviors (e.g., the CALO-RE taxonomy for physical activity) and new technology-enabled possibilities for interventions (e.g., personalization and gamification).

We discussed how to approach student attrition in online education from a behavior change perspective and provided an example of a BCT coding conducted by public health researchers for the Look AHEAD study, one of the most influential, longitudinal lifestyle health intervention studies. We then classified recent education interventions in online education based on the BCT taxonomy to demonstrate how these education interventions can be further broken down into BCTs. We argued that adding BCTs to enhance how learning behaviors are supported in current education interventions is not complicated. Finally, we also showcased how to develop BCT-driven design ideas for an intervention that helps people stay engaged in learning activities over extended periods of time.

This review inspires several suggestions for future research. First, we see an opportunity to synthesize interventions in education using the BCT taxonomy and to identify effective BCTs in different learning contexts, as has been done in public health research. To be clear, learning is a complex process, and the behaviorist view cannot fully represent the complexity of learning, but we can consider learning processes as a series of discrete behaviors to better understand how learners behaviorally engage with learning activities. This enables us to develop interventions to support learners effectively.

Second, the BCT taxonomy could be tailored to and validated in education. Some BCTs that are specifically about health (e.g., *Information about health consequences (5.1)*) could be modified and more BCTs related to technology could be added given the prevalence of digital learning tools. The BCT taxonomy can be improved to capture techniques that have been found to be effective in educational research. For example, identifying obstacles to goal achievement is a well-known technique that is not listed in the current BCT taxonomy. The closest BCT is *Problem solving (1.2)*, but the definition mentioned is "Note: barrier identification without solutions is not sufficient." The BCTs tailored for education can be evaluated for their effectiveness in educational contexts with micro-randomized trials [30], which is a common experimental design used in health intervention studies.

Finally, but importantly, educators and researchers need to be aware of the ethical concerns around the behavior change approach. For instance, nudging such as sending a text reminder to course participants can be unethical for several reasons, including forfeiting individual agency (for a detailed discussion by Sunstein about the ethics of *nudging*, see [47]). When designing and implementing interventions based on BCTs, we, therefore, recommend taking ethical guidelines into consideration [34].

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