

# Modeling Self-Growth with Fuzzy Cognitive Maps

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## Abstract

*One contemporary approach to self-growth is to identify an individual's risk roadmap, the set of risk factors that will inhibit their personal development. Associated with each of these risk factors are professional characteristics that can be strengthened to support the self-growth journey. To facilitate this process, a fuzzy cognitive map framework was developed to model the relationship between these professional characteristics and risk factors. Conventions are put forward for assigning relative numerical values for the relationships, for reducing the set of characteristics to master, and for identifying practices that develop them. Fuzzy cognitive mapping software leverages mathematical simulations that predict how the changes in professional characteristics will propagate through the network to mitigate the risk factors. A methodology for incorporating fuzzy cognitive maps into the self-growth process is presented and its use is exemplified through case studies. The results of the case studies led to several new conventions and strategies that help to focus an individual's attention to the key characteristics that will promote self-growth.*

## Introduction

Self-growth was first introduced as a process where individuals increase the quality of their performances through self-assessment (Leise, 2007). The concept was later formalized as a performance itself, consisting of ten key components (Jain et al., 2015). Preliminary results of this research led to the publication of *The Professional's Guide to Self-Growth* (PGSG) (Apple et al., 2018) where the process of self-growth is presented in a way that any professional can use. At the core of this model are 35 risk factors inhibiting self-growth as well as 50 professional characteristics that mitigate these risk factors to support self-growth. A complete list of the 35 risk factors and their associated professional characteristics is provided in Appendix A.

The readers of the PGSG are guided through the self-growth process by identifying risk factors on which to focus to develop the associated professional characteristics. The development of a mathematical model utilizing quantitative measurements could assist readers in this process. Since there is a feedback relationship between the risk factors and professional characteristics, a weighted, directed graph, known as a fuzzy cognitive map, models the connections between the risk factors and the professional characteristics. The fuzzy cognitive map will indicate which of the 50 characteristics may be best and most often applied to a set of risk factors unique to an individual working in a structured fashion on their self-improvement.

To develop an understanding of how the use of Fuzzy Cognitive Maps (FCMs) assist in the self-growth process, the remainder of this paper is structured as follows. First, an introduction to FCMs as well as the utilization of the

FCM to examine a single risk factor is explored. Next, a methodology for incorporating the FCM into the self-growth process is presented. The incorporation of the FCM Methodology is discussed in multiple case studies where an individual is focusing on mitigating a varying number of risk factors. Finally, general conclusions, insights regarding the FCM methodology, and next steps are discussed.

## Fuzzy Cognitive Maps as a Modeling Tool

A concept map, or mind map, represents concepts as nodes with links connecting the nodes to show causation or influence (Buzan, 2019). Similarly, in an FCM, the connecting lines between nodes are represented by arrows to indicate their causal relationship, but they are also assigned a weight to indicate the strength of the interaction between the nodes (Kosko, 1986). These weights, or impact factors, are numbers between -1 and +1. If the weight is a positive number, there is an increasing or a direct causal relationship between the nodes indicating that an increase in the one will produce an increase in the other. If the weight is a negative number, the two nodes have an inverse causal relationship and an increase in the one will produce a decrease in the other.

The term fuzzy refers to the mathematics that governs the strength of the connections. It is this attempt to give a dynamic, numerical aspect to an otherwise qualitative relationship that makes the fuzzy cognitive maps more complex than simpler mind maps or concept maps. Because two connected nodes may be quite different in what they represent and how they are measured, it can be difficult or impossible to show exact changes in one corresponding to

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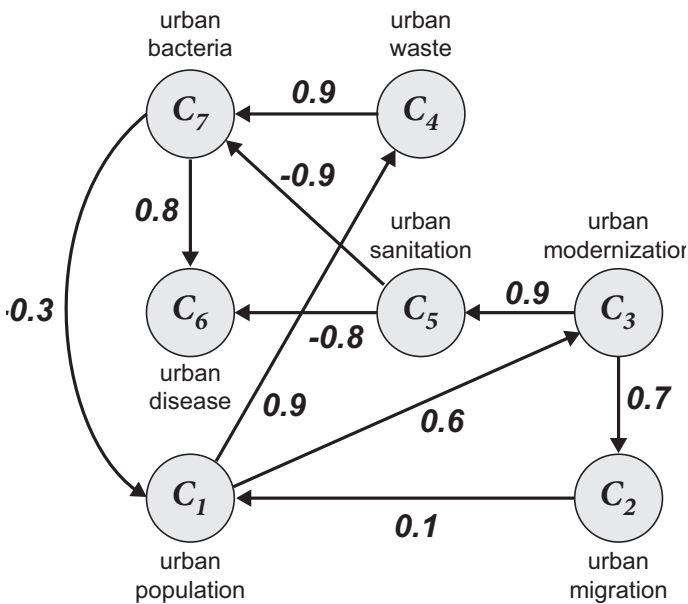
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changes in the other. So, to follow dynamic changes that can propagate throughout an FCM, percentages are used.

To illustrate this point, an example of a public health FCM (Peng et al., 2016) is depicted in Figure 1. In this FCM, the connection between node C5, the dollar cost of urban sanitation, and node C6, the extent of urban disease, shows a negative effect (-0.8). Thus, a doubling in the urban sanitation funding would produce a decrease in the extent of urban disease by 80 percent, assuming no changes in the other connected nodes.

One of the critical questions about using a FCM as a predictive model is not only what nodes to include, but how to determine the connecting strength and direction of the connection. This determination is usually done by expert

**Figure 1** Fuzzy Cognitive Map for Public Health (Peng et al., 2016)

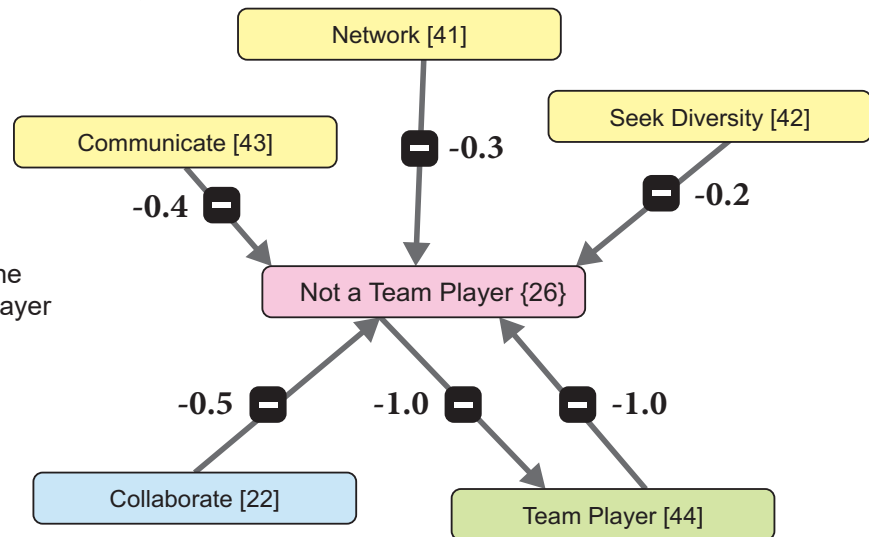


consideration of the connections. For the purposes of this work, the PGSG guided the determination of appropriate weights for the FCMs of the risk factors and associated professional characteristics. The values of the weights are based on how these characteristics were prioritized within the PGSG. The weights are inversely proportional to their order listed in Appendix A, Table 1.

While the risk factors in Appendix A, Table 1 are organized alphabetically, their associated professional characteristics are listed in descending order of influence from left to right. To determine the weights, if the professional characteristic is directly opposite of the risk factor, its weight is 1.0. If it is not, then the weights are 0.7, 0.5, 0.4, 0.3, 0.2 for each professional characteristic listed respectively. For example, the risk factor **Not a Team Player** has five associated professional characteristics **Team Player**, **Collaborate**, **Communicate**, **Network**, and **Seek Diversity**. Team Player is the direct opposite, so its weight is listed as 1.0. The other professional characteristics are weighted 0.5, 0.4, 0.3, 0.2, respectively.

Mental Modeler (Gray, 2020) is a free mathematical modeling application used to create the FCM. As depicted in Figure 2, the central node of the FCM is the risk factor **Not a Team Player**. It also displays the influence of the five professional characteristics on this single risk factor. Since each characteristic will mitigate the risk factor, all the relationships are modeled with arrows pointing to the risk factor with negative weights. Finally, as noted previously, the professional characteristic **Team Player** is direct opposite of **Not a Team Player** thus the weight is -1.0 and an additional link is added going from the characteristic back to the risk factor since as one goes up the other goes down. In general, the numbers used for the weights are chosen by the self-grower and adjusted as the growth process proceeds to optimize the accuracy of the model.

**Figure 2** Fuzzy Cognitive Map for the Risk Factor Not a Team Player



Once the FCM is built, the user inputs changes in each characteristic based on their efforts in that area. For example, using the Mental Modeler interface a user records a change in the professional characteristic(s). These changes are then used to run a simulation to predict the corresponding changes in the other professional characteristics. For example, if an individual was working to improve their Collaborate characteristic, they would enter the increase in the Mental Modeler software, run the simulation, and utilize the results to help guide their self-growth decisions.

## The FCM Methodology

The FCM is a tool that can be used to help promote self-growth. An individual using the tool can more easily determine which professional characteristics on which to focus. The Fuzzy Cognitive Map Methodology outlines the process an individual uses to identify how strengthening a professional characteristic affects the mitigation of risk factors and impact on other professional characteristics. First, the individual creates their FCM through the analysis of risk factors affecting their growth. They then identify a professional characteristic to focus upon that will mitigate that risk factor and utilize the techniques identified in *The Professionals Guide to Self-Growth* (Apple et al., 2018) to strengthen the characteristic. Finally, they will re-calibrate the changes with the strengthened characteristics and repeat the process. These steps of the FCM Methodology are delineated in Table 1 and are discussed further in what follows.

**Table 1** Fuzzy Cognitive Map Methodology

<b>Step 1</b>	Creating the fuzzy cognitive map
<b>Step 2</b>	Identify the characteristics on which to focus
<b>Step 3</b>	Prescribe techniques to strengthen characteristics
<b>Step 4</b>	Strengthen the characteristics
<b>Step 5</b>	Model the changes with a scenario
<b>Step 6</b>	Calibrate the model and repeat

### Step 1 Creating the fuzzy cognitive map

To begin, an individual alone or with the assistance of a mentor should utilize the Risk Roadmap Survey tool presented in the Professionals Guide to Self-Growth (Apple et al., 2018) to identify and delineate their risk factors. Using this list, a FCM should be created with a central node for each risk factor to be addressed. Additionally, surrounding nodes are created for each of the associated professional characteristics with arrows pointing from the professional characteristic

to the risk factor(s) they mitigate. The characteristics should be ranked in order of their impact on the risk factor and the corresponding weights indicated. There may be some overlap in the professional characteristics associated with the identified risk factors, thus inherently increasing the importance of those that will have the most effect. To offset this effect, characteristics that are connected to multiple risk factors are given a lower weight for each connection.

### Step 2 Identify the characteristics on which to focus

If the FCM contains a large set of professional characteristics, then the FCM can be used to narrow the focus. The individual should analyze the degree of a characteristic, the number of risk factors it is connected to, and the impact weights of those connections to determine which characteristic to focus upon. The lesser characteristics can be eschewed in favor of those that will dominate the overall change in risk factors.

### Step 3 Prescribe techniques to strengthen characteristics

The next step is to create an action plan that supports the development of the characteristics identified in Step 2. These action plans can be developed by the individual or with the help of a mentor. Sample techniques are provided in the PGSG. Activities that are realistic, observable, and meaningful to the individual will provide the best results.

### Step 4 Strengthen the characteristics

It has been said by Dr. Maxwell Maltz, MD in his book *Psycho-Cybernetics* (1960), that the acquisition of a new habit takes 21 days. More recent research by Lally et al. (2010) indicates that it may take from 18 to 254 days depending on the task with the new average set at 66 days. Therefore, an individual who wants to mitigate a risk factor must develop the associated set of professional characteristics by working on their action plans until they become a habit. It is important to keep detailed records of any activities to assist with quantifying the change in the skills later.

### Step 5 Model the changes with a scenario

To quantify this step, which is called fuzzifying the data, the individual needs to create a scale for the changes that have taken place. Historically, fuzzification was the process of assigning terms to numbers, working with the terms, then defuzzifying them back to numbers (Tsipouras et al., 2008). For example, if the characteristic was developed for 1 to 3 weeks then the

change could be +0.3, if the characteristic was developed for 4 to 6 weeks then the change could be +0.6, if the characteristic was developed for 7 to 9 weeks then the change could be +1.0. Some FCMs just use labels such as low, medium, and high for the fuzzy variables. The scenario is then run using the software and the resulting change in the risk factors is calculated.

current state of their risk roadmap. Changes can then be made to the risk factors and their weights determined in Step 1, the action plan prescribed in Step 3, and the scale used to determine change in Step 5 when repeating the process.

### Step 6 Calibrate the model and repeat

The results of the scenario should be compared with the personal experience of the individual and the new

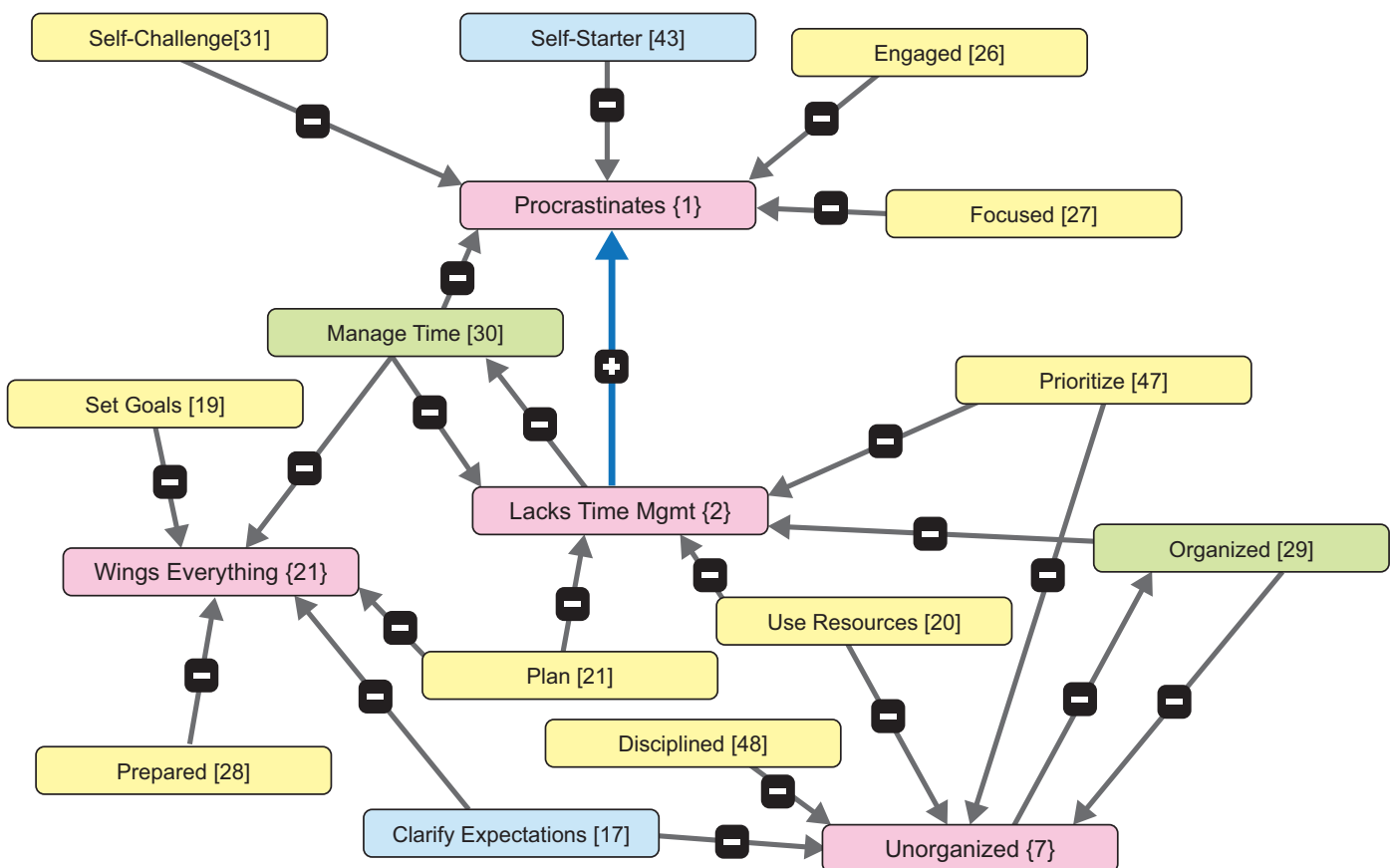
### Case Studies

To highlight the use of this methodology in the context of self-growth three case studies are presented. The first is presented here, while the remaining two are discussed in Appendix B.

**Table 2** Excerpted Risk Factors and Associated Professional Characteristics

Risk Factors	Associated Professional Characteristics				
Lacks Time Management {2}	Manage Time [30] (-1.0)	Plan [21] (-0.5)	Prioritize [47] (-0.3)	Organized [29] (-0.3)	Use Resources [20] (-0.2)
Procrastinates {1}	Self-Starter [46] (-0.7)	Self-Challenge [31] (-0.5)	Manage Time [30] (-1.0)	Engaged [26] (-0.3)	Focused [27] (-0.2)
Unorganized {7}	Organized [29] (-0.3)	Clarify Expectations [17] (-0.5)	Disciplined [48] (-0.4)	Prioritize [47] (-0.3)	Use Resources [20] (-0.2)
Wings Everything {21}	Clarify Expectations [17] (-0.5)	Plan [21] (-0.5)	Prepared [28] (-0.4)	Set Goals [19] (-0.3)	Manage Time [30] (-0.2)

**Figure 4** FCM for Case Study 1





### Case Study 1: A Professional Working on Four Risk Factors with Linked Interactions.

To put the methodology into practice, imagine a professional who aims to reduce the role of four risk factors in their life: **Lacks Time Management**, **Procrastinates**, **Unorganized**, and **Wings Everything**. The creation of the FCM (Step 1) denotes that these four risk factors are related to a cluster of 14 unique professional characteristics as depicted in Table 2. These excerpted risk factors come from the full table in Appendix A Table 2.

Five of the professional characteristics (**Prioritize**, **Organized**, **Uses Resources**, **Plan**, **Clarify Expectations**) each mitigate two risk factors, thus have arrows to both in the FCM in Figure 4. **Manage Time** mitigates three of the risk factors as indicated by the three arrows connecting to the three risk factors. Again, all the connections from a professional characteristic to a risk factor are negative, that is as an individual increases the professional characteristic, there is a decrease in the risk factor. There is a direct positive link made between the risk factors **Procrastinate** and **Lacks Time Management**. This positive link means that a deficiency in time management skills exacerbates procrastination.

During Step 2 of the FCM Methodology, the individual, in possible consultation with a mentor, examines which of the professional characteristics have the most connections and/or the greatest weights. The individual will decide to work on the professional characteristic that will have the greatest impact. In this FCM, both **Manage Time** and **Organized** have the maximum impact value of -1.0 on the risk factors **Lacks Time Management** and **Unorganized**, respectively. In addition, **Clarify Expectations** have multiple high impacts (-0.7 and -0.5) on the risk factors **Wings Everything** and **Unorganized** respectively. Finally, although only mitigating the **Procrastinates** risk factor, **Self-Starter** has the highest impact at -0.7. Thus, the individual determines that they will work on four professional characteristics, **Self-Starter**, **Manage Time**, **Clarify Expectations** and **Organized**.

Step 3 of the FCM methodology, the individual works with their mentor to determine action plans to address the growth of the professional characteristics. In this case study, the individual the individual commits to the following action plans for each of the professional characteristics:

- **Self-Starter**: at the start of each day, write down one goal for the day (something simple that could be done in under two hours)

- **Manage Time**: keep a pocket calendar and make an entry for each scheduled meeting
- **Clarify Expectations**: for each assignment, write down three criteria, asking their supervisor questions as needed
- **Organized**: for one project each week, break it down into a three to five step methodology

After two months of working on the action plans (Step 4), the individual produced the following results with the corresponding increase in improvement to be entered into the FCM software in parenthesis:

- **Self-Starter**: they had written down a task to complete nearly every day (+1.0)
- **Manage Time**: only some meetings were scheduled (+0.5)
- **Clarify Expectations**: liked to ask questions, but sometimes forgot to write down the questions or the answers (+0.5)
- **Organized**: it seemed tedious to break down a project on paper, so it was only done for two projects (+0.25)

The improvement values were placed into the FCM and the scenario was run (Step 5). The results showed a 1% reduction in **Lacks Time Management**, no change in **Wings Everything**, and a 6% reduction in **Procrastinates**. Surprisingly, there was a 4% increase in the risk factor **Unorganized** using this constellation of responses. Re-running the scenario with a greater improvement score in **Organized** reduced the risk factor **Unorganized** by 3%. Thus, the individual decided to do more to strengthen the **Organized** professional characteristic (Step 6).

Two additional case studies are discussed in Appendix B. Case 2 is a simpler situation where the individual addresses two risk factors. Case 3 is more complex where the individual address five risk factors.

### Conclusions and Insights

An examination of the list of risk factors and professional characteristics shows that the more risk factors an individual wants to improve, the more complex is the resulting FCM. The analysis of these types of combinations reveals that increasing the scope of the risk roadmap leads to an untenably large list of characteristics upon which to work. It was one of the objects of this study to find a way to reduce the number of professional characteristics in a complex map by only working with the highest impact characteristics. To this end, a frequency analysis of all the

professional characteristics from PGSG was conducted to determine which are most often listed as mitigating a risk factor, that is, which professional characteristics have the greatest impact to the risk factors.

As delineated in Table 3, the professional characteristics that impact the greatest number of risk factors are Think Critically, Self-Efficacy, and Take Risks, all associated with seven risk factors. Self-Assess, Clarify Expectation, Life Vision, and Leverage Failure are all associated with impacting six risk factors. This list suggests that individuals with very broad self-growth plans, or no plans to reduce specific risk factors, should start with these characteristics to achieve the most overall improvement.

**Table 3** Frequency of the 50 professional characteristics used to address the 35 risk factors ("Number" is as assigned in PGSG)

Number	Professional Characteristic	Frequency
#2	Think Critically	7
#15	Self-Efficacy	7
#32	Take Risks	7
#13	Self-Assess	6
#17	Clarify Expectations	6
#18	Life Vision	6
#32	Leverage Failure	6

An individual should develop only those characteristics with the highest impact factors and/or greatest degree to optimize reduction in the risk factors in question. The relative ranking of the elements is based on the individual's personal experiences and intuition. Of course, simpler ways of assigning numbers could be applied, for example using trivalent logic  $\{-1, 0, 1\}$  (Taber et al., 2007). It is interesting that in the case studies discussed in Appendix B, which model cases with two and five risk factors, the characteristics with the greatest impact were not included in Table 3. On the other hand, as the FCM became more complex, as in the Victoria case, the list of characteristics with the highest impacts does more closely resemble the list seen in Table 3.

It is also important to note that as the FCM became more complex, there was a penalty for not showing at least medium ( $\geq +0.5$ ) scores in improvement of a characteristic. In two of the case studies, when the characteristic had low improvement, one of the risk factors increased in value, that is, it worsened. This effect could be discouraging to a student or professional working alone on their self-growth. To this end, a teacher/mentor would be beneficial

to encourage the self-grower to persist to completion on the actualization goals set up. This follows the dictum "plan the work; work the plan." The mentor can help the individual to operationalize the methods to work or activate the identified professional characteristics. While the PGSG clearly identifies which professional characteristics are connected to each, actualizing the plan to develop them will be different for each self-grower. The mentor needs to be able to offer the mentee specific and personalized methods. If the mentee doesn't want to do an activity, then they should ask for a substitute, but in all cases the teacher/mentor needs to request to see proof that the action was taken, and a self-assessment was made.

With the creation of FCMs, it is possible to measure and track an individual's self-growth. A FCM could be created linking all 35 risk factors and all 50 professional characteristics. This large map would show a massive amount of complexity that may be of more theoretical interest than functional interest for the self-grower. Further, extensions of this work might include a community-wide re-valuation of the professional growth characteristics for each risk factor. If years of research indicate a modified order is merited for some risk factors, that change should be noted in subsequent editions of the PGSG. Another possible extension of this work would be to create a collection of possible ways to operationalize various professional characteristics within the goals of each mentee. This list could never be exhaustive but having a minimal number of approximately five ways with which to start would be a valuable resource for new mentors as they try to help others overcome risk factors.

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## Appendix A

The first column of Table 1 alphabetically lists the 35 most common risk factors with the number from original listing in *The Professional's Guide to Self-Growth* (Apple et al., 2018) in curly brackets. The next five columns list the top five associated professional characteristics in ranked order left to right. The number from the original listing in *The Professional's Guide to Self-Growth* in square brackets and the recommended weight for use in the FCM in parentheses.

**Table 1** The 35 Most Common Risk Factors and their Associated Professional Characteristics.

Risk Factors	Associated Professional Characteristics			
<b>Afraid of Failure {6}</b>				
Take Risks [32] (-0.7)	Leverage Failures [34] (-0.5)	Persist [33] (-0.4)	Manage Frustration [37] (-0.3)	—
<b>Anxious {3}</b>				
Manage Frustration [37] (-0.7)	Prepared [28] (-0.5)	Maintain Balance [35] (-0.4)	Adapt [38] (-0.3)	Leverage Failures [34] (-0.2)
<b>Coasting/Unchallenged {19}</b>				
Self-Challenge [31] (-0.7)	Set Goals [19] (-0.5)	Take Risks [32] (-0.4)	Leverage Failures [34] (-0.3)	—
<b>Differential {30}</b>				
Assertive [24] (-0.7)	Self-Confident [49] (-0.5)	Self-Efficacy [15] (-0.4)	Take Risks [32] (-0.3)	—
<b>Financial Constraints {23}</b>				
Problem Solver [9] (-0.7)	Think Critically [2] (-0.5)	Manage Time [30] (-0.4)	Use Resources [20] (-0.3)	Information Processor [6] (-0.2)
<b>Fixed Mindset {9}</b>				
Open Minded [11] (-1.0)	Adapt [38] (-0.5)	Self-Challenge [31] (-0.4)	Take Risks [32] (-0.3)	Self-Assess [13] (-0.2)
<b>Frustrated {35}</b>				
Manage Frustration [37] (-1.0)	Leverage Failures [34] (-0.5)	Persist [33] (-0.4)	Problem Solver [9] (-0.3)	Self-Efficacy [15] (-0.2)
<b>Ineffective Problem Solver {14}</b>				
Problem Solver [9] (-1.0)	Think Critically [2] (-0.5)	Information Processor [6] (-0.4)	Inquisitive [16] (-0.3)	Take Risks [32] (-0.2)
<b>Ineffective Reader {22}</b>				
Reader [7] (-1.0)	Information Processor [6] (-0.5)	Think Critically [2] (-0.4)	Inquisitive [16] (-0.3)	Contextualize [3] (-0.2)
<b>Ineffective Writer {24}</b>				
Writer [8] (-1.0)	Think Critically [2] (-0.5)	Organize [29] (-0.4)	Clarify Expectations [17] (-0.3)	Take Risks [32] (-0.2)



<b>Insecure Public Speaker {28}</b>				
Speak Publicly [45] (-1.0)	Communicate (43) (-0.5)	Prepared [28] (-0.4)	Organized [29] (-0.3)	—
<b>Irresponsible {34}</b>				
Responsible [50] (-1.0)	Committed to Success [36] (-0.5)	Take Risks [32] (-0.4)	Assertive [24] (-0.3)	—
<b>Isolated from Others {20}</b>				
Network [41] (-0.7)	Team Player [44] (-0.5)	Communicate [43] (-0.4)	Seek Diversity [42] (-0.3)	Collaborate [22] (-0.2)
<b>Lacks Discipline {4}</b>				
Disciplined [48] (-1.0)	Prioritize [47] (-0.5)	Focused [27] (-0.4)	Work Hard [25] (-0.3)	Engaged [26] (-0.2)
<b>Lacks Mentors {16}</b>				
Self-Assess [13] (-0.7)	Ask for Help [40] (-0.5)	Network [41] (-0.4)	Communicate [43] (-0.3)	—
<b>Lacks Support System {25}</b>				
Network [41] (-0.7)	Ask for Help [40] (-0.5)	Assertive [24] (-0.4)	Use Resources [20] (-0.3)	Adapt [38] (-0.2)
<b>Lacks Time Management {2}</b>				
Manage Time [30] (-1.0)	Plan [21] (-0.5)	Prioritize [47] (-0.4)	Organized [29] (-0.3)	Use Resources [20] (-0.2)
<b>Life-Long Learning Not a Priority {15}</b>				
Learner Ownership [1] (-0.7)	Contextualize [3] (-0.5)	Generalize [4] (-0.4)	Reader [7] (-0.3)	Information Processor [6] (-0.2)
<b>Minimal Meta-Cognition {27}</b>				
Meta-Cognitive [5] (-1.0)	Reflect [10] (-0.5)	Think Critically [2] (-0.4)	Validate [23] (-0.3)	Focused [27] (-0.2)
<b>Minimalist {32}</b>				
Set Goals [19] (-0.7)	Life Vision [18] (-0.5)	Self-Efficacy [15] (-0.4)	Work Hard [25] (-0.3)	Clarify Expectations [17] (-0.2)
<b>Needs Affirmation {31}</b>				
Self-Assess [13] (-0.7)	Validate [23] (-0.5)	Reflect [10] (-0.4)	Meta-Cognition [5] (-0.3)	Open to Feedback [12] (-0.2)
<b>Negative Attitude {12}</b>				
Positive [14] (-1.0)	Self-Efficacy [15] (-0.5)	Self-Starter [46] (-0.4)	Leverage Failures [34] (-0.3)	Maintain Balance [35] (-0.2)
<b>No Life Vision {11}</b>				
Life Vision [18] (-1.0)	Self-Motivate [39] (-0.5)	Clarify Expectations [17] (-0.4)	Committed to Success [36] (-0.3)	Responsible [50] (-0.2)

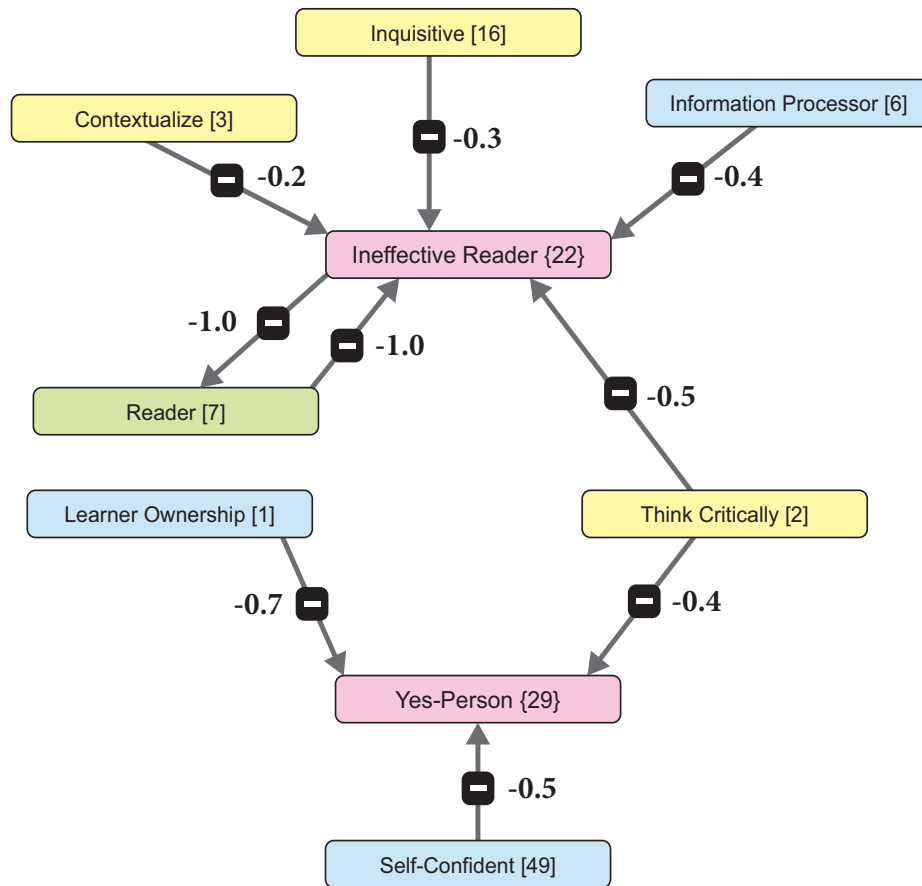
<b>No Sense of Self-Efficacy {5}</b>				
Self-Efficacy [15] (-1.0)	Self-Confident [49] (-0.5)	Life Vision [18] (-0.4)	Self-Assess [13] (-0.3)	Speak Publicly [45] (-0.2)
<b>Not a Team Player {26}</b>				
Team Player [44] (-1.0)	Collaborate [22] (-0.5)	Communicate [43] (-0.4)	Network [41] (-0.3)	Seek Diversity [42] (-0.2)
<b>Not Open to Feedback {18}</b>				
Open to Feedback [12] (-1.0)	Self-Assess [13] (-0.5)	Communicate [43] (-0.4)	Open-Minded [11] (-0.3)	Positive [14] (-0.2)
<b>Personal Factors {17}</b>				
Self-Efficacy [15] (-0.7)	Leverage Failures [34] (-0.5)	Life Vision [18] (-0.4)	Problem Solver [9] (-0.3)	Positive [14] (-0.2)
<b>Procrastinates {1}</b>				
Self-Starter [46] (-0.7)	Self-Challenge [31] (-0.5)	Manage Time [30] (-0.4)	Engaged [26] (-0.3)	Focused [27] (-0.2)
<b>Uncommitted {8}</b>				
Committed to Success [36] (-1.0)	Life Vision [18] (-0.5)	Responsible [50] (-0.4)	Set Goals [19] (-0.3)	Persist [33] (-0.2)
<b>Unmotivated {13}</b>				
Life Vision [18] (-0.7)	Self-Motivate [39] (-0.5)	Set-Goals [19] (-0.4)	Committed to Success [36] (-0.3)	Clarify Expectations [17] (-0.2)
<b>Unorganized {7}</b>				
Organized [29] (-1.0)	Clarify Expectations [17] (-0.5)	Disciplined [48] (-0.4)	Prioritize [47] (-0.3)	Use Resources [20] (-0.2)
<b>Self-Evaluator {10}</b>				
Self-Assess [13] (-0.7)	Positive [14] (-0.5)	Open to Feedback [12] (-0.4)	Open Minded [11] (-0.3)	—
<b>Self-Limited Thinking {33}</b>				
Think Critically [2] (-0.7)	Contextualize [3] (-0.5)	Generalize [4] (-0.4)	Inquisitive [16] (-0.3)	Meta-Cognitive [5] (-0.2)
<b>Wings Everything {21}</b>				
Clarify Expectations [17] (-0.7)	Plan [21] (-0.5)	Prepared [28] (-0.4)	Set Goals [19] (-0.3)	Manage Time [30] (-0.2)
<b>Yes-Person {29}</b>				
Learner Ownership [1] (-0.7)	Self-Confident [49] (-0.5)	Think Critically [2] (-0.4)	Self-Efficacy [15] (-0.3)	—

## Appendix B

### Case Study 2: A Student with Two Risk Factors

A student wishes to reduce the role of two risk factors in their life: **Ineffective Reader** and **Yes-Person**. From PGSG it was found that these two risk factors could be remediated by a cluster of seven skills, one of which, **Think Critically**, mitigates both of these risk factors. Based on the convention listed above, this common skill **Think Critically** is given a weight of -0.3 for both risk factors. The characteristic **Reader** is given the maximum weight of -1.0, and an additional back relationship, because it is the direct opposite of the risk factor **Ineffective Reader**. The top characteristic for **Yes-Person**, **Learner Ownership**, is given an impact value of -0.5. Less important characteristics are given weaker weights to complete the FCM.

Figure 1 Fuzzy Cognitive Map for Case 2



From the FCM (Figure 1), the student decides to first focus on improving the highest weighted characteristics: **Reader**, **Learner Ownership**, and **Think Critically**. Even though **Self-Confident** has a substantial effect on **Yes-Person**, this was considered too difficult to work on directly, but improvements could still be made because of success in the other areas. The student worked with their mentor to operationalize the development of the characteristics. To work on **Reader**, the student agreed to read one graphic novel of their choice every week for two months. To work on **Learner Ownership**, the student plans to intentionally disagree with someone once a week and record the results in a journal. To work on **Think Critically**, the student will exhale and wait three heart beats before replying when asked a direct question. After two months, the student returned to the mentor with detailed records of their actions. They had read six graphic novels, so **Reader** was scored as +0.5. They reported disagreeing with someone on three instances, so **Learner Ownership** was scored as +0.25. They had thought the assignment to wait three heart beats before speaking was silly and did not do it so **Think Critically** was scored as zero. The values of change were placed into the fuzzy cognitive map and run as a scenario. The results showed a 1% reduction in the risk factor **Ineffective Reader** and a 3% reduction of the risk factor **Yes-Person**. Comparing these results with the FCM revealed the weight of **Learner Ownership** was too high and should be lowered. The teacher proposed a new technique for **Think Critically** and the student agreed to continue reading graphic novels and playing the devil's advocate for the time being.

### Case Study 3: Example of Victoria Working on Five Risk Factors with Linked Interactions

Victoria is hypothetical student seeking support from her academic advisor. Her advisor has Victoria peruse the list of risk factors in the PGSG to determine which risk factors to focus on. Victoria's risk roadmap contains five risk factors: **Lacks Discipline**, **Lacks Time Management**, **Unmotivated**, **Ineffective Writer**, and **Lacks Mentors**. These five risk factors are best mitigated by a set of 21 unique professional characteristics (Appendix A). Three of these professional characteristics (**Prioritize**, **Organize**, and **Clarify Expectations**) are degree two, meaning they help to mitigate two of her risk factors. The remaining professional characteristics are only connected to a single risk factor. **Discipline**, **Manage Time**, and **Writer** are given a maximum impact of -1.0 because they are the direct opposites of **Lacks Discipline**, **Lacks Time Management**, and **Ineffective Writer**, respectively. Also note, that **Clarify Expectations** is awarded a low-level impact on both its connected risk factors because this professional characteristic is listed last in each grouping. In addition, **Organize** has a medium level impact on one risk factor and a low level impact on the other connected risk factor.

Once the fuzzy cognitive map shown in Figure 2 was created, the recommendation for Victoria was to master the eight professional characteristics: **Manage Time**, **Organize**, **Plan**, **Prioritize**, **Set Goals**, **Self-Assess**, **Persist**, and **Ask for Help**. Victoria was advised to disregard the remaining 13 because they all have medium to low impact on their connected risk factors. To operationalize these characteristics the mentor asks Victoria to make use of a planner and record her class times, work times, and study times in it and bring in to back in a few days so it can be determined if the schedule is realistic and functional. Also, the mentor asks her to set four goals, two near-term and two long-term, write these goals down in the planner and discuss what she needs to make these goals happen in the time set aside. The mentor asks Victoria to report on these goals as they are in progress using the strength, improvement, insight, SII assessment format, to model self-assessing (Wasserman & Beyerlein, 2007). At each meeting, the mentor asks her to *plan the work and work the plan* to model persistence. This model includes getting the materials, skills, and advice that are necessary to complete her four goals. At the end of each week, they review what has been done and her status with the four goals, using this data to run scenarios and update her FCM.

Figure 2 Fuzzy Cognitive Map for the Victoria Case Study

