ETM
ENGINEERING & TECHNOLOGY MANAGEMENT

Title: Scenario Analysis Using Fuzzy Cognitive Mapping in Adaptive Learning for Students with Disabilities and Special Needs – A Consultative Perspective on Pursuing Adaptive Learning for Special Needs Students

Course: ETM 543/643 Front End Management for New Product Development

Year: 2015

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Report No.: 3

Abstract

The focus of this paper explores the future of education, concentrating on the adaptive learning aspects for children with special needs and disabilities. A future need exists for a flexible and adaptive interactive learning environment that transcends beyond the classroom, encompassing inputs and influences from a student's whole network (Educators/specialists, Parents, advocates, Transportation/life aids, and therapists). Scenarios for an adaptive learning environment are constructs of using a hybrid approach which encompasses scenario analysis and fuzzy cognitive mapping (FCM) techniques. FCM methods have been used successfully in many futures studies in various industries to identify challenges, but have rarely been applied to the educational industry. A panel of educational experts and practitioners were interviewed to identify the driving factors and uncertainties for a realistic future vision of the adaptive learning environment for special needs students. Utilizing subject matter experts, an informal cognitive mapping workshop ensued to visualize the relationships, impacts, and causalities between each pair of drivers, which generated causal maps that have been aggregated into an FCM structure. Morphological analysis was used to quantify and simulate the impacts of hypothetical scenarios on the future vision. The results of the FCM analysis provide guidance and insight into where the subject matter experts and champions for those with disabilities can channel their resources for maximum impact in 2025. Scenarios that have been created facilitate debate and pose questions that when answered can remove some uncertainty surrounding the future for adaptive learning for special needs adolescents and adults.

Contents

1.0 Project Introduction

The goal of this paper is to present a comprehensive approach and synthesis of various methods for assessing the future of adaptive learning (AL) for special needs and students with disabilities. Research shows the current trend for institutions in the adaptive learning community tends to concentrate on solution space. The complex questions of the perceived reality of adaptive learning for special needs students is built into the conceptual framework and model encompassing the use of multi-dimensional research methods and available tools to equip experts, educators, parents and policy makers in evaluating future trends in the education sector for special needs students. Feedback from subject matter experts (SMEs) through a series of surveys and workshops derived key factors, concepts, and scenarios impacting the future of adaptive learning for special needs students. Additionally, insights and knowledge from academia through literature review to identify strategic methods of thinking, such as Scenario Planning (SP) and Scenario Analysis (SA) to examine uncertainties on this topic. The use of the PESTEL analysis framework examined factor influences pertaining to the future of adaptive learning for special needs students from varied perspectives. Mental Modeler, R, and other software comprised the tolls that were utilized to extract the necessary data that was analyzed to assess relationships among concepts. In addition to leveraging these tools to investigate relationships within the collected data, we also discovered other examination methods such as Morphological and Multivariate approaches to explore and derived statistical meaning and linear correlations. Interpretation of the resultant data provided a functional framework capable for generating multi-combination outcomes of scenarios upon manipulating the consequential concepts.

1.1 Problem Statement

Education has and will continue to undergo several changes in the future, as it is an iterative cycle, similar to the rapid changes that technology exhibits maturity and generates new insights into education sciences. Key element of research for the improvement of learning in the educational system includes but is not limited to the research in the concept of adaptive and flexible learning. In the review of educational literature research, concepts of adaptive learning include changes to institutional structures, teaching methodologies, and both social and cultural behaviors among several other key factors of influence. All of these attributes and factors will be influenced on some level by economics, government processes and legislation, and general environmental concerns, technology and information infrastructures.

While the subsect of *special needs* education is subject to the same factors of influence as *general education*, the needs for the special needs students is more magnified and in terms defined by Alan Newell, extraordinary [4]. Solutions for general education applications may not be applicable to many special needs learners based on physical or emotional limitations as well as great variances in individual goals and needs. Adaptive learning capabilities and eventual products for special needs students and adults must be flexible and available for a larger support structure than typical educational aids. There is a substantial need which is the reason for the overall problem statement: *outlining scenarios for the flexible and adaptive learning environment of a special needs learner that reaches beyond the classroom and incorporates inputs and influences from the learners entire environmental network.*

To illustrate the variance of potential challenges faced by those with special needs in education, three personas are provided below:

> *George is a 14 year old young man with that qualifies on the autism spectrum for special needs services. He has the ability for limited communication when focused and excels at strategic or puzzle based activities. Recently, George has been through several different classrooms as he has shown tendencies to become extremely frustrated, even violent to himself and others, when overwhelmed or uncomfortable. As a result, a new aide has recently been assigned to George as well as some coping items including sound cancelling headphones and a weighted blanket.*
>
> *Susan is a nine year old girl with Downs Syndrome and is typically good natured and full of smiles. Susan loves to be around other children and does not understand why she is sometimes not included in their groups. Although she does have some cognitive challenges and in general is behind her classmates, Susan likes to learn new things. However, similar to others her age, she is easily distracted and does not always focus well.*
>
> *Pat is a sixteen year old boy that suffered several injuries in a car accident five years ago. With the brain trauma, Pat functions cognitively like a child that is two and his educators are focusing on choosing activities with the help of several push button devices. In addition, Pat is confined to a wheelchair and has only significant use of his right hand. Recent funding developments have seen Pat begin a new regiment of physical therapy including the use of a new motorized wheelchair.*

1.2 Objective

The goal of this project is to provide insight and guidance through scenario analysis, leveraging FCM techniques in the context of a future vision for adaptive learning in the special needs educational field that are necessary to progress and enhance the overall experience and make further strides in making teaching efforts more efficient while benchmarking and providing students and adults with special needs, a higher quality of life. Incorporating an expert panel for advice and their needs, provides the researchers with the level of detail that allows for construction of a robust FCM model, which is used to simulate the future vision while iteratively alternating the starting state of carefully vetted inputs/factors. The FCM model analysis provides quantitative and qualitative results for multiple plausible scenarios.

The following is the expectation was set for the output of the analysis:

1. Cognitive map showing relationship, impacts and casualties of the concepts/nodes
2. Identification of two major factors defined by uncertainty and importance to serve as axes structures in building a graphic picture of multiple plausible scenarios

3. A variety of potential futures that show breadth and magnitude of factors' impact

1.3 Overview

This project delves deeper into understanding the fuzzy front end (FFE) of developing means and methods to meet the needs of the future as it relates to education and learning characteristics for special needs students that may also have disabilities. At the forefront of this project is a notion to make a global attempt at understanding the needs as a whole for the system but the research has been conducted in the Pacific Northwest. The approach utilized is comprised of a structured scenario analysis process coupled with a quantitative method for describing causal conceptual models. Ultimately, this research will present results in a set of scenarios to frame the landscape project where this specific educational tract will be 10-years from now.

A literature review and field research have afforded the team an opportunity to build scenarios of what the future of adaptive learning for students with disabilities in the Pacific Northwest may look like using methods described throughout this paper. The end product is to arrive at scenarios that are projected out ten years that cover a wide range of possible futures. These scenarios are not meant to be used to estimate what is likely to occur, rather they are meant to provide a method of analyzing what the best response is in future situations and what the resulting consequences will be positively or negatively impacting the industry [6].

To gain an understanding of the overall issue and challenges that can be attributed to the problem statement, several resources have been scrutinized as part of a qualitative research approach in order to achieve the following:

1. Better define the key driving factors and concepts.
2. Increase knowledge in implementing scenario analysis/planning with Fuzzy Cognitive Mapping (FCM).
3. Learn how to leverage scenario analysis tools in assessing futures of adaptive learning impact to disabilities and special needs students.
4. Expand the research scope by examining alternative approaches in addition to scenario analysis in evaluating futures of adaptive learning for disabilities and special needs students.

Determining the details around what critical factors are and who key players in influencing the special needs learning environments in the future are, is the focal point of this evaluation. With a generally larger support structure including educators and specialists, parents and advocates, medical professionals, transportation and life aides, and numerous others, a consistent learning path becomes difficult to develop. Establishing a deliberate path towards an optimal solution has become an integral piece of the scenario development work using cognitive mapping techniques and expert interaction. In the midst of uncertainty regarding special needs learning, utilizing scenario planning techniques helps to develop a strategy that may eventually lead to future products and services that would be beneficial in this market. The use of expert interactions and general research have been combined in an effort to determine what critical factors are most important and are influential as well as their interdependencies, being either positive or negative. Clearly documenting the factors that influence the confidence levels of the interdependencies have developed the strategy and delivered the most useful scenario options with a vision of what should happen. As prescribed in similar studies, there will inevitably be numerous available options; scenario analysis selection will be determined by the factors' magnitude and certainty to impact adaptive learning for special needs students.

2.0 Literature Review

Over the last decade, a myriad of research articles have been generated as they relate to academia regarding the use of Scenario Planning and Analysis as a way to quantify uncertainties. Leveraging these academic sources provided several articles focusing on various types of research paradigms including qualitative, exploratory, and descriptive to understand the application of Scenario Planning (SP) and Scenario Analysis (SA). Searches were conducted on a wide variety of keywords, authors, and titles by the team. The results were then examined for their relevance using the abstracts and the overall research data that has been conducted. It was learned and understood that the relevant articles related to the topic analyzed would be obtained from a number of resource databases including but not limited to HBR.org, Google Scholars, and PSU electronic libraries to offer an understanding of SP/SA application.

2.1 Scenario Planning and Analysis

To understand Scenario Planning and Scenario Analysis, the term "scenarios" must first be defined. Scenarios are stories or "snapshots" of what might take place in the near future. Decision makers use Scenario Planning and Scenario Analysis as tools to evaluate what to do at the present time, based on various possible futures. The futures options are a reflection of an exploratory study of current trends or changes observed in area of interest. Scenario Planning and Scenario Analysis are general categories of a technique referred to as Creative Visioning. Creative Visioning is a distinct approach utilized to provide information about the future. Figure 2.1 below reflects other industry accepted methods and tools for thinking about the future such as *Projecting and Forecasting*, *Assessment* of potential impact, and *Exchange*. Unlike these methods, SP and SA do not indicate what the future will look like. Rather, SP and SA invigorate creative approaches of thinking that assist stakeholders in being catalyst for breaking out of established patterns of assessing situations and planning actions in order to adapt effectively to the future.

Creative Visioning is an approach intended "to challenge existing mental barriers to make use of creative intuition and construct visions or plans for a desirable or preferred future." It is a

response to the "...human tendency to be bound by what we already know" [5]. Visioning is used to discover interconnections between events, especially macro-events on micro-environments. Techniques include imaging, scenarios and futures history writing.
Projection and Forecasting are techniques that produce relatively precise quantitative predictions. This approach requires historical precedents, regularities of cause and effect, data availability and short time periods. Some consider forecasts appropriate for single variables: prices, population etc. [2], rather than complex phenomenon. The method of arriving at the answer may be complex and is usually not transparent to decision makers. Methods include: Delphi techniques, trend extrapolation, computer modeling and cross-impact analysis.
Assessment of Potential Hazards is an approach for identifying the possible impacts of a new policy or practice. The method requires prior determination of criteria and indicators for assessment. Common techniques include environmental and social impact assessments.
Exchange and Dialogue Methods aim to release people from socially imposed and unexamined expectations. The method enables people to understand other group's plans and visions and stimulate dialogue. Techniques include discussions of literature, self-assessment, games and simulations.

Figure (2.1): Future visioning techniques

As highlighted in the textbook "New Products Management" by authors Crawford and Benedetto, chapter 5 provides the foundation for correct use of scenario analysis as a tool. The text uses scenario analysis to understand potential problems a customer may have in the future that the customer does not know about currently. Ultimately, the initiative is to stay one step ahead of the customer by using scenario analysis. The textbook offers these steps when using scenario analysis for product development; "First, paint a scenario; second, study it for problems and needs; third, evaluate those problems and begin trying to solve the most important ones." [21] Scenario analysis methodology was applied not for the purposes of product development but rather to create future scenarios from expert opinions and then analyze these scenarios using a specific set of factors. These scenarios are used in conjunction with mathematical models, which are discussed later in the analysis. Scenarios can be used as inputs into the strategic planning process as hypothetical alternative futures, design to question, and spur debate, which should lead to a more thorough and robust product, service or technology.

The seven step deductive approach to building scenarios outlined by Schwartz is a structure that has been modified for this project [19]. Schwartz's steps are:

1. Define the topic/problem and focus of the scenario analysis.
2. Identify and review the key factors/environmental influences on the topic.
3. Identify the critical uncertainties/Model Review
4. Define scenario logics (often using scenario matrices).
5. Create/flesh out the scenarios.
6. Assess implications for business, government, and the community.
7. Propose actions and policy directions.

The scope of this project is bound by the effort to understand the methods and tools that begin to inform ideas about the future and thus do not include steps six and seven.

2.2 Educational Futures Research

Future studies are the practice of attempting to gain foresight and understanding of influencing factors and possible outcomes for a given topic. It is understood that future studies explore multiple perspectives and alternatives in the form of scenarios. Research for future studies is typically carried out by an academic institution, enlisting the knowledge and insight of scholars, experts and practitioners in the chosen field to compile data to aid in the mapping process and provide a deeper understanding of the specific topic. Future studies have a broad application, and are commonly used in long term horizons such as environmental, technological, social, socio-economic, and cultural studies, among others. The world futures studies federation (WFSF) is one example of a scholarly organization practicing futures studies on a global scale [24]. Gidley has identified five traditional futures ideological methods dating back to the 1960, (1) Critical-normative, (2) Cultural-interpretive, (3) empowerment-activist, (4) integral/trans disciplinary and (5) empirical-positivist [12]. Futures and foresight is an established practice in higher education for researchers and policy makers [10],[23].

Typical education futures studies involve identification of trends, both macro and micro and meso that influence and impact future visions of education. Data can be gathered through a combination of expert interviews, creative workshops and /or a survey [16]. Recent technological advances in mobile computing provide an opportunity to analyze the future impacts of ICT on education. The results and output of said research can be a framework and guide of the landscape and factors that are perceived to impact education, which can be used to create scenarios to aid in planning and policy making.

However, despite the investment and the effort in educational futures, there are still considerable research gaps, as discussed by Gildey in "The Evolution of Futures in School Education." Gildey argues that much of the existing futures knowledge and practices focuses only on subjective (interior) and objective (exterior) individual dimensions, with a large vacuum present in the understanding of the social interior and exterior aspects of education [11].

Vincent-Lancrin used futures studies to build 6 scenarios for a university based on observed trends from Organization for Economic Co-operation and Development (OECD) countries. Figure 2.2 shows a simple 2x2 graph illustrating the six scenarios, (1) Traditional, (2) Entrepreneurial, (3) Free Market, (4) Open & Lifelong, (5) Network and (6) Diversity. The X and Y axis of the chart are generated based on the uncertainty of the future state/directions of institutions and the social perception of how individuals and society approach learning [23]. This figure can be used as a valuable tool to pose interesting and unanticipated questions to established ideologies and institutions.

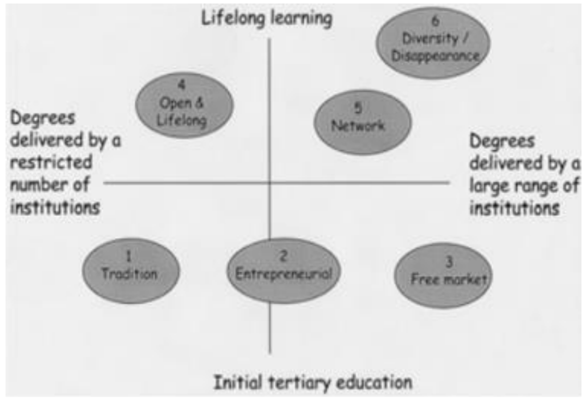


Figure (2.2): Six futures scenarios for universities

Rosca uses a PESTEL analysis for futures of higher education in Romania [8], where the major changing factors from Political, Social, Technological, Economic, Legal and Environmental are identified and described.

Exceptionally comprehensive and useful research from the European Commission Joint Research Center (JRC) is relevant to this research application. The JRC has conducted multiple exercises to create a vision of the educational future of the region for 2020 and 2025 [22],[26]. To gain a better understanding, the research team set out to map the learning strategies and changes for the next 10 years, and developed a vision of the future, based on the social-economic trends and challenges. From this exercise they were able to extract strategies for each scenario developed and propose them to the stakeholders involved in the process. Using a combination of workshops, online consultation, and group cognitive mapping, the researchers worked over a two year period with teachers (13), experts (16) and policy makers (15) to identify d*rivers and trends*, *what should change,* and *what needs to change to achieve the vision*. This resulted in several maps reflecting the vision in relation to changes, learning, and education; however, these maps were never quantified. The subsequent information was grouped into twelve factors using a cluster analysis (Figure 2.3), which were then ranked in importance and feasibility to the vision.

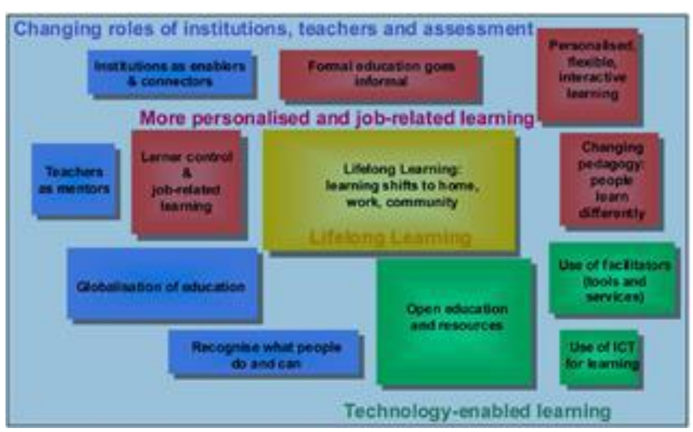


Figure (2.3): Twelve factor cluster analysis

The tweleve identified factors were renamed and altered to conform to specific adaptive learning and special needs subjects to blend the current practitioner's perspective with the literature review. An interesting observation that was discovered from the above figure is that the factors with the highest importance tend to correlate with low feasibility. Project feasibility can be linked to certainty or uncertainty and risk. For scenario analysis, a 2x2 chart could be utilized representing on one axis a more personalized learning and role of institutions could be the other axis; similar to Larcin's 2x2 in Figure 2.2

While casual conceptual and cognitive maps are common tools found in literature, fuzzy cognitive map models are somewhat uncommon; however, precedence exists for applying FCM as a tool to quantify the relationships between concepts/factors and to generate scenarios in education and learning. Kandasamy applies FCM techniques to understand child dropout rates in the Indian education system, as it relates to the impacts of the parents decisions, views and choices on the child's education [25]. Cole provides another example of FCM applied in education, where the researchers study the relationships between learning and distance education [13] (Figure 2.4).

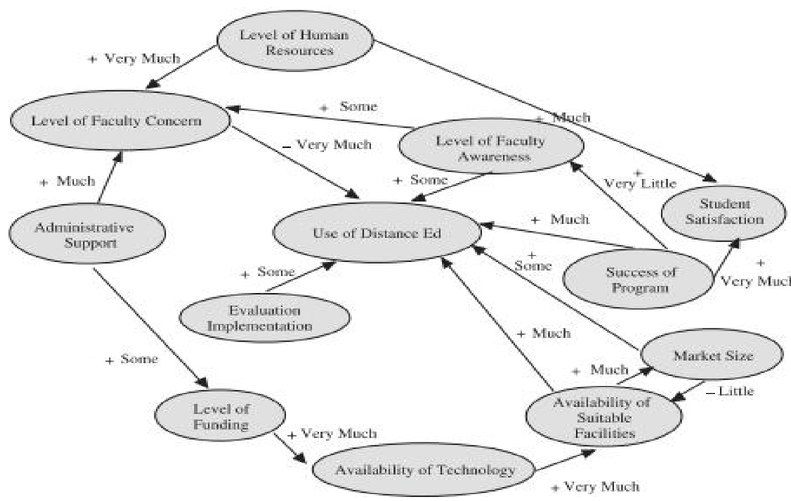


Figure 2.4: Group FCM of the use of distance education

FCM's are interference networks used for knowledge representation and reasoning. They are used for analyzing complex systems by combining fuzzy logic and neural networks [15]. FCM's can be used in multiple ways which include *explanatory*, *prediction*, *reflective* and *strategic*, and for this research project the *prediction* function of FCM will be used. Due to its overall simplicity and graphical representation, this type of mode is easy to understand. This model allows for the integration of stakeholder views into product (scenario) development, which is key for this research project as multiple experts views' were gathered to build the scenarios [21].

FCM has multiple characteristics that make it suitable for scenario development. The research supports FCM as being a proven method for gathering information easily due to its intuitive cognitive design which allows people to use the tool with no formal training or structure [21]. Inputs for FCM are gathered by respondents relating factors to one another by drawing arrows between them and then identifying if the factors have a negative or positive impact. This allows qualitative and unclear inputs to be related to one another in a network that then can be mathematically analyzed. The network of inputs can be used to identify consequences and effects of certain inputs and how they will affect the scenario's identified.

3.0 Tools and Methodology

This section identifies the tools used based on the literature review and information presented in Front End Mgmt New Product Development: ETM 543 course taught at Portland State University. These tools include interviews, workshops, the Mental Modeler, Fuzzy Cognitive Mapping and Scenario Analysis/Planning. The key drivers and 12 factors that are used as inputs for these tools come from the literature review [22] validated and ranked through expert surveys (Appendices D1). Finally this section provides an outline of the process flow for the execution of this project and a layout of the plan.

3.1 Methodology/Process Flow

To gain a more succinct understanding of the global issues that surround adaptive learning as it pertains to special needs students, a clear roadmap was necessary to adequately understand the fuzzy front end (Figure 3.1). Performing extensive research to analyze what has been concluded and conducted in the field to date was the first step in the methodology for constructing a solution to FFE of this problem. In order to achieve a starting point, follow-on research and journals were examined to learn further how scenario planning and scenario analysis is applicable to cognitive mapping and the relationship with educational factors and drivers that can be better understood in this environment. After better understanding what work has been performed in the industry the next step in the process was to meet directly with subject matter experts.

Once the research was performed the natural next step was to reach out to the professionals and parent advocates that have the experience and working knowledge of the real challenges that are faced constantly. A survey was created and conducted to gain a higher-level vision of where the adaptive learning should be headed by 2025. After brainstorming sessions using various methods, an initial list of questions was developed. It was further refined with input from select subject matter experts before it was sent out to various professionals and parent advocates. A digital survey was created utilizing a frequently used online software program. Having this level of detail was necessary to assist in the fuzzy cognitive model (FCM) and cognitive mapping workshops that took place after the survey. The mental model exercise that takes place to better understand the cognitive mapping will be created utilizing a shareware program to capture and analyze the data input but the SME's. Subsequently, the survey and FCM analysis will better dictate important factors and the overall framework for the 2X2 as it relates to the various scenarios to be evaluated.

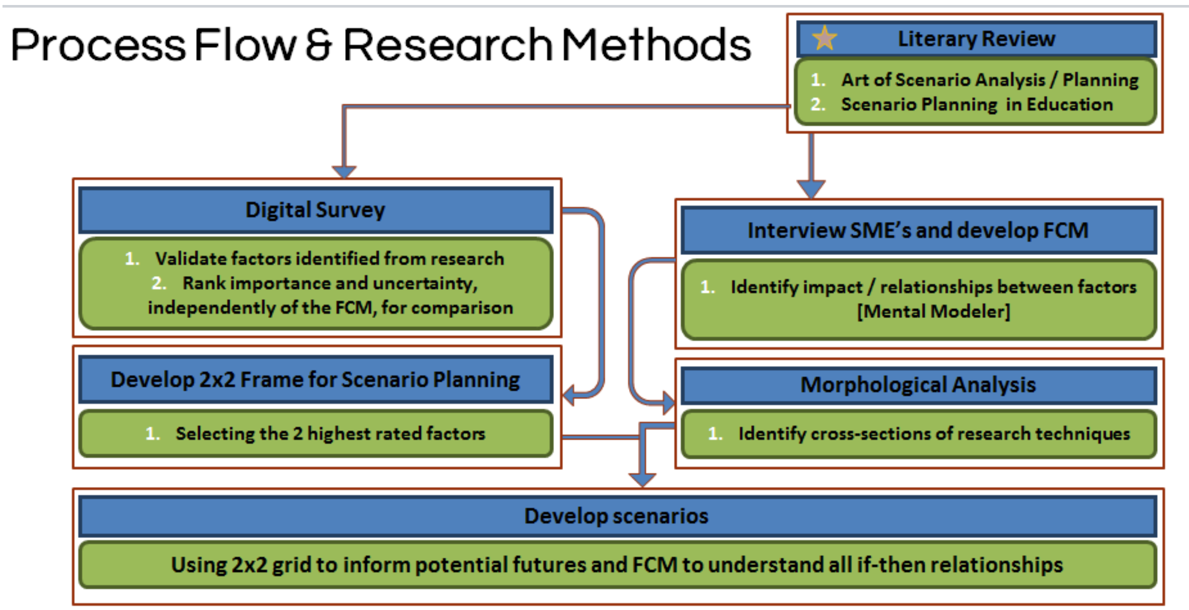


Figure 3.1: Process flow of project and objectives for each stage.

Developing the model and receiving the input from the various stakeholders will provided the level of detail necessary to begin the analysis and probe further into the morphological breakdown that has been generated in the R program.

3.2 Pool of experts

As noted above, a large portion of the translation of research into reality revolves around effective establishment of expert panels. Overall, three different, and in some cases overlapping, groups of experts were created to help with various parts of the overall project. As part of the general research, a small informal discussion with a few select special needs educators and coaches was conducted to help brainstorm key areas of interest and the ideal end state of adaptive learning ten years in the future. These areas of interest would be combined with the literature reviews to create an initial list of adaptive learning factors to be used later in the project. A second broader group of stakeholders, that all play an important part in the daily learning activities of a special needs student, were utilized to validate our research findings. Thirteen of these experts provided feedback related to critical factors through the use of the survey which is described later in section 4.1 of this document. Incorporated feedback also helped us to determine the needed confidence levels associated with how impactful those factors would be in the future of adaptive learning. Finally, a third group of six more experienced individuals were utilized in our cognitive mapping exercise. Using the improved list of factors, a roadmap of dependencies and interactions was established as described in section 4.3 leading us to the desired end state.

In all cases of stakeholder utilization, the experts consisted of a ranging mix of special needs educators, coaches, specialists, parents and special needs advocates with varying degrees of experience. The initial early review session helped the team determine the need for broad engagement and the inclusion of both educators and parents or rights advocates. Although our overall target group of experts consisted of fourteen individuals, five general archetypes were developed to reflect the overview of experience and interactions. Below is a description of these five archetypes and how they might interact with some of the special needs student personas highlighted earlier in this paper.

The educator or teacher of the special needs classroom is typically responsible for the overall lesson plan creation and management. Depending on the situation, the educator may provide oversight to a dedicated aid or directly facilitate the lesson. Unlike a more typical classroom where a single lesson plan is used for most or all of the students, a special needs classroom will incorporate both collaborative group work as well as highly specialized individualized activities. As highlighted by a distinctly diverse set of physical, mental and emotional challenges, the curriculum of a special needs student can span a vast range of learning development documented in a federally mandated Individualized Education Plan (IEP). Inclusion of highly specialized therapies and social interactions, as well as progress indicator goals, will be coordinated by the special needs educator and provided to the parents as well as the school district. These plans are legally required to be reviewed and updated on an annual basis.

The instructional or behavioral coach provides much needed support for the teaching staffs and the school districts in general. Often having previous experience as a special needs educator, this individual is available across the school district to engage and provide guidance in especially difficult cases. Supports will be provided to the educator when needed including lesson planning strategies, equipment and SW tool recommendations. The behavioral coach may be centrally located for rotation or even provide coverage within a given classroom as needed.

Individual specialized educators including physical, occupational, visual and communication therapists are a critical part of many IEPs. Based on meeting established federal or state pre-established criteria, therapy work will become a part of the student's normal school routine. Typical direct interactions between the specialist and the student are often limited due to a critically high student to specialist ratio but recommendations and strategies are included in the IEP plan for facilitation by the educator or classroom aide. These specialists are often a utilized path for the incorporation of new technologies and techniques of adaptive learning.

Parents are a significant part of any special needs students' life for obvious reasons. Parents typically manage the normal daily hygiene, feeding, transportation and other typical supports as most of us would imagine. However, in addition, parents are critical to the progression of lesson planning and behavioral practices. Parents are included in the IEP planning and goal creation as they both help to direct areas of needed focus for simple quality of life improvements but also to re-enforce the practices being taught in the classroom. Consistency is critical for success when discussing general life skills and adaptive learning.

Special needs advocates are often family members or close friends of individuals with special needs students. These individuals play an important role in advocating for services and resources that a student or classroom may normally not have available. Interactions with law makers as well as interactions and the creation of non-profit organizations help to provide supports for parents by challenging state and federal laws and funding practices.

3.3 Mental Modeler

Mental Modeler is a software tool that has been developed by Dr. Steven Gray that allows for the development and representation of semi-cognitive models [7]. This modeling software is constructed based on the FCM research, and allows for the user to identify critical factors and relate these factors to one another by identifying either a positive or negative relationship. For each relationship the user can provide a confidence level based on their own judgment. Once this information is gathered it can then be used to run different scenarios and determine “what if” scenarios to see how the system reacts to different inputs. This tool was developed to support the group decision making process through having the feature of being able to merge multiple different models. The method allows for the user to develop a single model that represents multiple people's perspectives that then can be used to analyze a decision’s potential future outcomes. Mental Modeler can be used online or it can be downloaded and used on a PC. It is free software that is currently under development. For the purposes of this research paper, a base model was developed with all the factors in it that the experts will use to identify relationships. A set of instructions was also created as an explanation on how to use the Mental Modeler which can be found in the appendix [Appendix 1A].

3.4 Fuzzy Cognitive Mapping

The first step in creating an FCM is to generate concepts from the literature review based on factors that may potentially impact the future state or scenario. Subject matter experts then use the Mental Modeler software to rate and rank the factors to create relationships between the 12 factors. These factors are rated on a scale based on impact by either setting a +++ (highly positive impact) to ---- (highly negative impact). Then, for each relationship a confidence level can be set by dragging a bar on a scale from high confidence to low confidence. Once the experts have completed their cognitive maps they are asked to email them back to this group. Each of these maps is then analyzed for inconsistencies and compared to other respondent’s maps. After receiving these inputs the Mental Modeler software combines all of the experts individual cognitive maps into a single cognitive map which is then used to determine edge weights by combining the causal maps of multiple experts and calculating the average weight for every edge of the FCM model for scenario development and analysis [1],[9],[18]. FCM and morphological analysis of adjacency matrices is then used to analyze the relationships between the factors and to better understand the effect (causality) of each factor on the overall system. Based on the final model that is then created from the experts opinions and judgments, the team is able to identify four potential scenarios that are most likely to occur which may have the greatest impact on the end state of adaptive learning in 2025.

The next step is comprised of using the Mental Modeler or/and FCM R package tool each of these scenarios are tested iteratively altering the non-fixed vector starting states until the model reaches a stable state. A robust model should result in different outcome for each scenario, and reach stability in with fewer than 25 iterations.

3.5 Quantifying the Qualitative

Quantifying a qualitative input is tricky and posed to be rather challenging. One of the strengths of the FCM method in the ability to capture qualitative user feelings about relationships in a framework that allows for quantified analysis. Calculating the FCM network of relationships is regarded as a simple form of recursive neural networks [9]. While FCMs can quantify in-between states, defining greater fuzziness, for the purpose of this research each of the concepts is simplified to state of "on" (1) or "off" (0). Networks are non-linear in nature as are the function impacts to the network relationships as one of the concepts or "neurons" changes state or value. FCMs allow a feedback loop that result in influences that spread out to related concepts as well as the back to the newly activated concept [9]. The multiplying state vector of causal activation creates a square connection matrix when the results are stymied by the model's squashing function.

Sperry and Jetter demonstrate the calculations and squashing functions of the model in the following way:

If concept C1 (highlighted in grey) in Figure 1 is activated, while all other concepts are turned off, the initial state vector is:

S = [1 0 0 0]

It is multiplied with the square connection matrix that is equivalent to the signed digraph.

	E_1	E_2	E_3	E_4
E_1	0	0	1	0
E_2	0	0	1	0
E_3	0	0	0	1
E_4	0	0	0	0

Matrix multiplication and the application of a threshold function lead to a new state vector:

$S^1 = [1\ 0\ 0\ 0]$

(In this particular example a binary threshold function that converts inputs of ⍰ 0 to 0 and inputs of > 0 to 1 is used). The resulting new state vector is again multiplied with the connection matrix. The process is repeated until stability is reached (in this case after S4), or a stop criterion is met:

$S^2 = [\ 0\ 0\ 1\ 0]$

$S^3 = [\ 0\ 0\ 0\ 1]$

$S^4 = [\ 0\ 0\ 0\ 0]$

$S^5 = [\ 0\ 0\ 0\ 0]$

This project explored changing concepts that were event focused (one-time impact) as well as longer lasting impacts in which case concepts were "clamped" in the mathematical model and always set back to its initial activation level [21].

3.6 Key factors and concept mapping

The following table contains a mapping of the factors identified from the literature review, and the terminology or concept names used in both the survey and the FCM workshops (Table 3.1).

Concept Number	FCM Terminology	Survey Terminology	Survey Factor number
C1	Broad Learning Env.	Formal to Informal Ed	2
C2	Dev Tools & Services	Development Tools	9
C3	Educator/Specialist R&R	Teacher Boundaries	4
C4	Future Learning Institutions	Role of Institution	1
C5	Future of adaptive learning		
C6	Globalization of Edu	Globalization	11
C7	Indiv. Modes of Learning	Learner Based Awareness	7
C8	Learner Based Awareness		
C9	Open Resource & Support	Provider Ed & Resources	3
C10	Social Learning	Role of Social Interaction	6
C11	Success Indicators	Progress Measurements	8
C12	Technology in Education	Role of Technology	5
C13	Transition Beyond 21	Life-long Learning	10

Table 3.1: FCM model key factors

4.0 Field Research

In addition to the literature review that was performed, the team held interviews, sent out surveys, and had brainstorming sessions with subject matter experts. Extensive field research was performed to bring relevance to the models utilized throughout this process. The survey data, mental modeler, and interviews generated in-depth insight into the industry as a whole as it pertains to adaptive learning and how improvements can transcend the current practices that have been institutionalized.

4.1 Survey

Several subject matter experts were surveyed in order to deliver the details analyzed herein. Subject matter experts made up a panel which was comprised of specialists, educators, and parent advocates. The survey contained thirteen questions, the experts were asked to rank the level of importance and the level of certainty which compared the driving factors and concepts against the future vision. Furthermore the level of importance is necessary for understanding how impactful the change is as it pertains to the factors reviewed in adaptive learning in special needs education. Level of certainty assisted in understanding how much is known for certain about a specific factors future state.

Identifying those to be surveyed and the target audience was the first step in shaping the survey questions. It was a challenge to develop the method, and sample size for which to pursue in order to receive the necessary data to understand the needs for adaptive learning for special needs students. Various local professionals in the educational sector were then emailed for further consideration. Several iterations of the questions were evaluated and finalized into the questions that have been developed, tested, and prepared for the survey.

A great deal of time and effort was spent preparing the questions to best address the needs and advances in adaptive learning. Brainstorming sessions ensued and generated dozens of possible ideas aimed at identifying elements that will have a positive impact on furthering the growth and opportunities for success for special needs students. The team pilot-tested the survey questions to identify any miscommunication and misinterpretations that might cause bias or alter the results. Ultimately, this created a smaller list of questions which were evaluated for clarity and intuitiveness because it was determined that having the survey conducted in a group environment was unlikely due to the timing required for the project results. This method produced thirteen survey questions which were designed to allow the subject matter expert to openly share their opinions and thoughts on the topic.

The survey was created in Qualtrics to streamline the process and provide the evaluators with a tool that can generate a more comprehensive report versus other programs that are currently available to the market. Ultimately, identifying the needs of the industry through the SME's will shape and define the needs of the field further developing a product to fulfill the demand of this market.

4.2 Survey Results

The survey was completed by a total of thirteen individuals, which represented varying ends of the spectrum in the categories of special needs educators, specialists and parent advocates. Figure 4.1 below depicts the breakout of roles amongst those that replied. Several key themes begin to emerge when initially observing the summary results.   It is clear that an overall, comprehensive learning capability is not only desired but required. This comprehensive environment is believed to be supported by both federal and private funded institutions as well as a more open and accepting informal set of learning sources. The need exists but there is high confidence that a global pool of shared learning, tools, and support structures should also exist. There is an underlying perception that exists that institutions and the open market can be collaborative in nature and would not need to be in competition with each other.

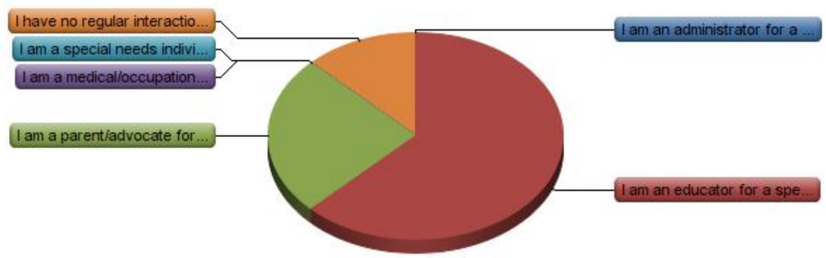


Figure 4.1: Survey response participants

Another key theme highly supported in the survey results was the need for social acceptability and self-awareness. In the special needs environment, individuals are challenged in varying areas which may include an inability to directly interact or control their environment. In all cases the experts have noted, with high confidence, that enabling this basic interaction and some degree of control is extremely important and needs to be a future area of focus. Social interaction, although varied, is also critical to an individual. Combining an overall learning infrastructure, that includes key social interaction and acceptance standards, appears to be one key constant part of any global initiative for adaptive learning environments.

Contrasting slightly with the consistent high certainty regarding the need for an adaptive and flexible learning environment with multiple sources of information, the need for structured evaluations and progress indicators is less uncertain. Although a general consensus supports the need for an Individualized Education Plan (IEP) with progress indication, a consistent standard for evaluation becomes more uncertain. Through follow-up sessions with the subject matter experts, two major factors were key drivers. First, each student may have completely different needs and capabilities from the next student so any sort of broad capability assessment becomes nearly impossible to create for both the student and the teacher. Second, time is limited with a focus on working with the students, not necessarily providing general critiques. A wide degree of varying opinions exist on what this type of progress evaluation for both the learner and the educator could look like. It should be noted, that progress indicators are normally required as part of any IEP plan.

4.3 Cognitive Mapping Workshop

In combination with the follow-up interviews, the Mental Modeler has been utilized as part of the field research. The smaller group of subject matter experts was asked to help make sense of the information derived from the survey responses and additional literature reviews in order to develop the scenario planning moving forward. To cover the various ends of the spectrum and have a more comprehensive understanding of what is important to the industry as it pertains to adaptive learning; mental models were created by a select group of six experts. “Scenarios should be collaboratively built by people with different expertise and backgrounds who are likely to have different mental models and can challenge each other’s worldviews without the limitations of groupthink.” [20] The importance of covering this array in performing the field research is that it will deliver a more realistic picture of what the market need in order to proceed to the next development phase. During the course of three different sessions it became apparent that some of the expert personas clearly differ in their interpretation and utilization of factors when creating the path to the future. In addition, a key takeaway for the research team included a significant need for clear and consistent communication combined with concise process descriptions.

A thorough step by step breakdown was created to walk the subject matter experts through the process of creating the mental model. An early example of a self-created cognitive map by one of our experts is shown below in Figure 4.2.

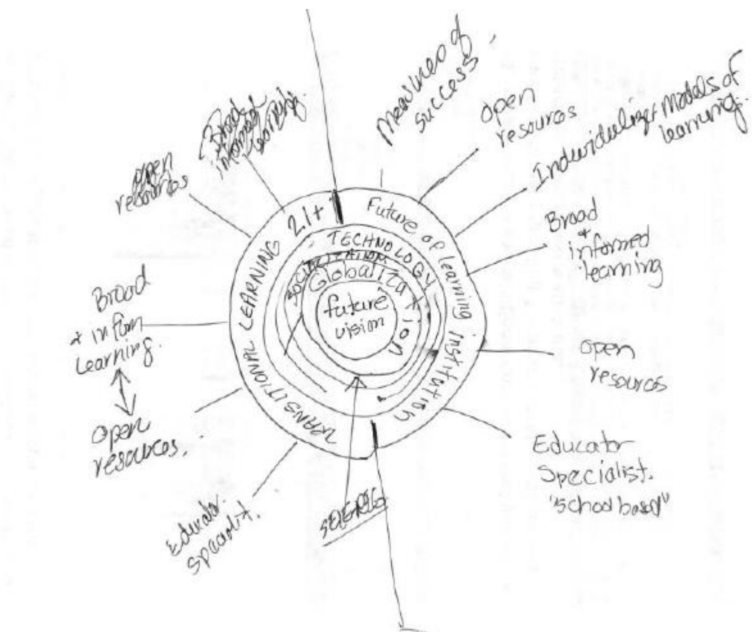


Figure 4.2: Early cognitive map

To help simplify the process moving forward, the mental models in the three joint sessions were created and setup using the website www.mentalmodeler.org [7]. Assigning interactive or dependency arrows to create the cognitive map was described in the instruction set as well as descriptions of the factors to be associated while the map was being generated. Once the interactions were modeled the degree of impact for that factor relationship was established with a wide range of high to low dependency as well as the positive vs. negative influence. These variances were depicted as +++, ++, +, -, --, and --- in the model. Unlike a straight pairwise comparison, the dependency factors do not need to be weighed against each other, rather each association path is evaluated independently.

A final characterization, although not yet utilized by the mental modeler tool, included an expert's confidence rating of each established relationship. The Mental Modeler tool does not yet factor the confidence rating into its analysis but as a side discussion we were able to compare the ratings against confidence ratings of the factors from the survey. A more detailed analysis of the confidence ratings could easily become part of next steps discussion. Following the creation of the cognitive map from each of the three sessions, some intuitive minor adjustments were needed in order to ensure highlighted pathways were not overshadowed by inadvertent dependency loops. Upon completion of the fine tuning the results were then combined in order to incorporate any variance of opinions and provide the reasonable average. A clear pathway from the current state to the future state of adaptive learning now becomes visible but easily interpreted without the use of the Mental Modeler tool.

4.4 Interviews

Taking the information provided from the survey, an updated set of interview questions were asked in combination with the cognitive mapping session. Due to a limited timeframe for project completion, the same sets of experts utilized for the cognitive mapping were utilized combining the interactive sessions. The interview was derived for clarification of the survey results and focused on interpretations of the confidence levels as well as explanations of why the factors were perceived as important. Additional discussions surrounding free form responses given during the survey were also included. Most of the experts utilized in these follow-up interview sessions also participated in the original survey. The interview followed the script of prepared questions; occasionally there was a prompt to clarify or to expand on thoughts that were being expressed. Interviews were conducted in a manner that was more of a collaborative conversation with the interviewer, where elaboration was encouraged while documenting detailed notes.

In an ideal scenario, these follow up interviews might have been better served as either a separate discussion prior to the mapping, in order to influence the model factors, or as an early part of a larger workshop activity. The case of this study, minor adjustments to the cognitive mapping factor definitions and titles were made as the sessions progressed. In general the overall factors were left intact so as to not compromise the work done by earlier teams. The overall results provided through both the follow-up interviews and cognitive mapping are being held as confidential with no direct correlation to who provided the comments or feedback. At the end of the interview the interviewee was thanked and told that they could contact a team member with any additional questions, concerns or thoughts.

5.0 Analysis

5.1 Concept ranking and PESTEL

Results of the interview for importance and uncertainty for the twelve factors and concepts (Table 5.1).

PESTEL	Twelve-Factor/Concept mapping counterpart

Political	C11- Success Indicators/Progress Measurement C9- Open Resources & Support / Provider Ed & Resources C8- Learner Based Awareness C1- Broad Learning Env. / Formal Education Goes Informal C4- Future Learning Institutions / Role of Institution
Economic	C6- Globalization of Edu / Globalization C9- Open Resources & Support / Provider Ed & Resources C2- Dev Tools & Services / Development Tools C13- Transition Beyond 21/Lifelong Learning C1- Broad Learning Env. / Formal Education Goes Informal C4- Future Learning Institutions / Role of Institution
Social	C3- Educator/Specialist R&R / Teacher Boundaries C6- Globalization of Edu / Globalization C9- Open Resources & Support / Provider Ed & Resources C2- Dev Tools & Services / Development Tools C8- Learner Based Awareness C7- Individual Modes of Learning C10- Social learning/ Role of Social Interaction C13- Transition Beyond 21/Lifelong Learning C1- Broad Learning Env. / Formal Education Goes Informal C4- Future Learning Institutions / Role of Institution
Technological	C9- Open Resources & Support / Provider Ed & Resources C12- Technology in Education/Role of Technology C2- Dev Tools & Services / Development Tools
Environmental	C9- Open Resources & Support / Provider Ed & Resources C7- Individual Modes of Learning C10- Social learning/ Role of Social Interaction C13- Transition Beyond 21/Lifelong Learning C4- Future Learning Institutions / Role of Institution
Legal	C7- Individual Modes of Learning C10- Social learning/ Role of Social Interaction C4- Future Learning Institutions / Role of Institution C3- Educator/Specialist R&R / Teacher Boundaries

Table 5.1: PESTEL Analysis

5.2 Scenario selection

Using the Likert scale results from the survey, an averaged weight of *uncertainty* and *importance* was derived, allowing each of the concepts to be plotted on a 2x2 axis chart [Figure 5.1]. By identifying the concepts of high uncertainty and high importance the research filters scenarios that should be explored when identifying potential futures. From this plot of concepts, 15 scenarios [Appendices E] were created to explore potential impacts of concept changes over time.

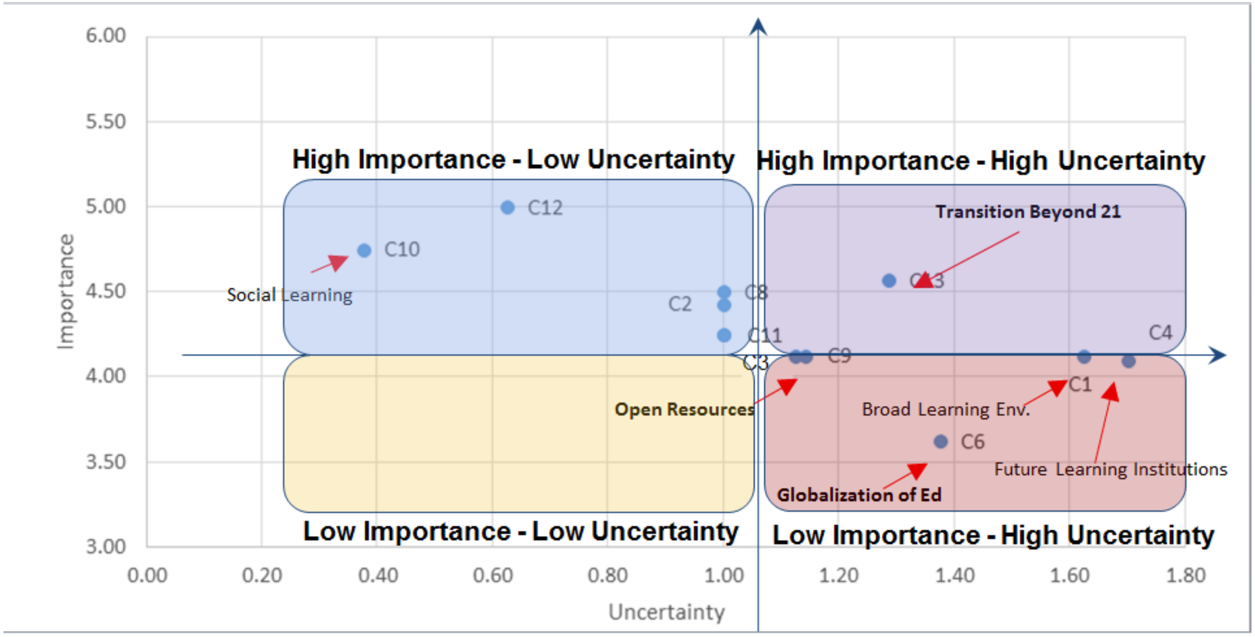


Figure 5.1: Uncertainty vs. Importance 2x2

5.3 Model Analysis Testing for robustness/stability

Analysis of the FCM model was completed using a combination of functions and packages in the R software platform [17]. In this process, the first step was to combine the three conceptual maps created in the workshops; this was achieved by aggregating the three matrices into a single adjacency matrix. The adjacency matrix can be found in Appendix C. Figure 5.2displays the cognitive map using mental modeler SW for the 3rd workshop. Maps that were generated for workshop one, two, and three can be found in Appendix C. A combined map is difficult to visualize due to the complexity of the links between nodes and as such, it has not been included in this report in graphical form.

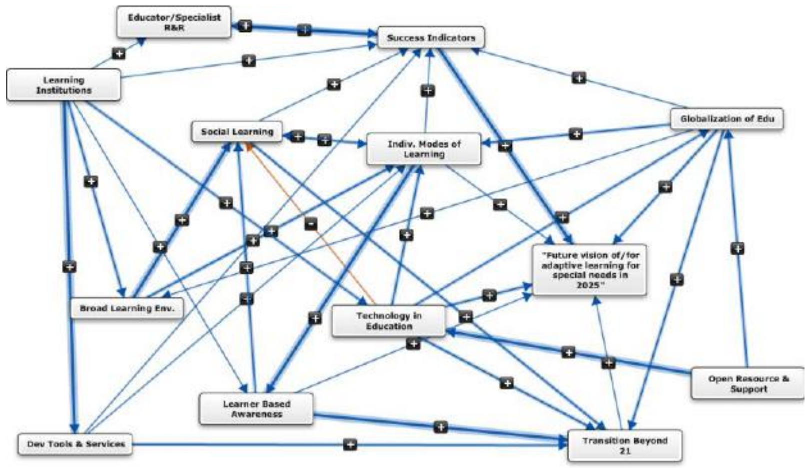


Figure 5.2: Cognitive map

Using the final combined cognitive map, an R project called "Fuzzy-cognitive-maps" was used to test the model for stability and robustness [14]. The fuzzy cognitive maps program was packaged in a "shiny" graphical user interface to allow for ease of visualization. This model was initially analyzed from two states to form a baseline for the morphological analysis. The first state was a starting vector of 1's, the second state was a starting vector of 0's. No concepts were clamped for the baseline testing. The analysis performed an iterative process of changing the starting state of each concept to a 1 or 0, and calculated the equilibrium value or eigenvalue of each concept. Values for the possible equilibrium ranged from 0-1. The model iterated through the vector changing process until all equilibrium values stabilized across all concepts. Both baseline tests stabilized to exactly the same equilibrium values for each concept in <5 iterations. Figure 5.3 and Figure 5.4 show the results of the analysis through the iterations. The final equilibrium value for each concept can be found in appendix C under morphological results table, row labeled "BL". Stabilization of the model indicates that the adjacency matrix itself is robust continuing no de-stabilizing elements. This fact allows us to continue further with the FCM analysis using scenario landscape and morphological analysis.

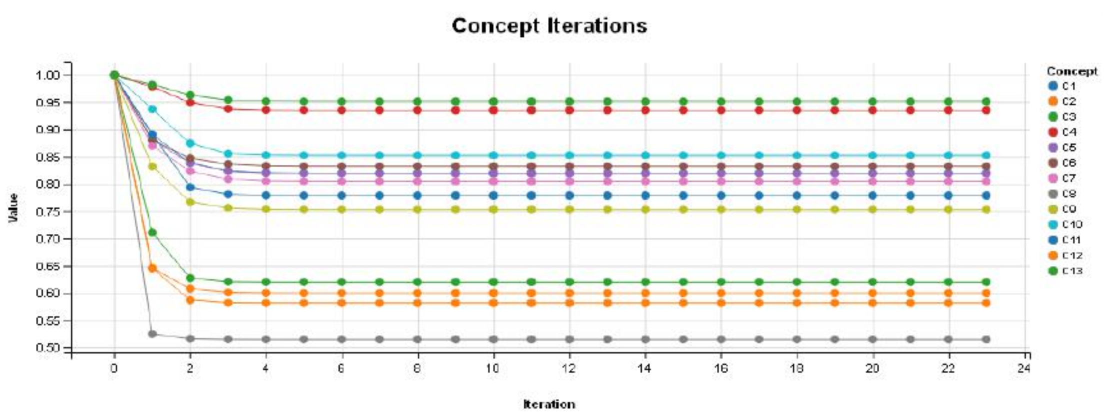


Figure 5.3: First baseline starting vector of 1's

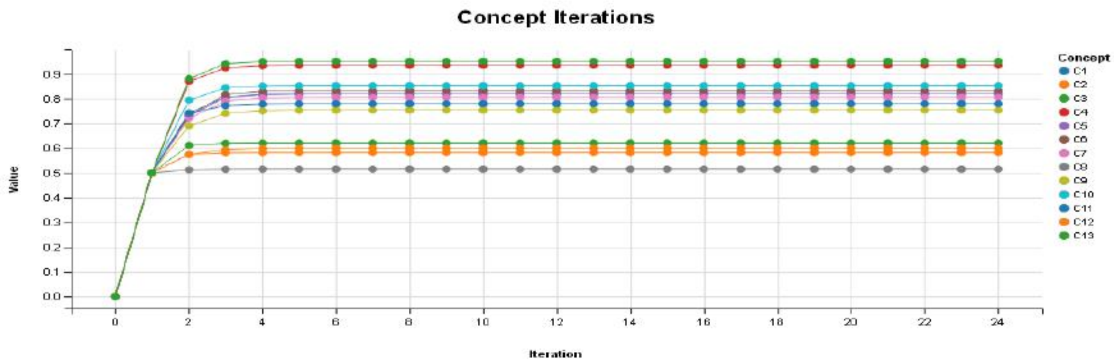


Figure 5.4: Second baseline starting vector of 0's

5.4 Multivariate Analysis of model

For the next step of the analysis a new approach was attempted to help quantify and rank the general impact of a given concept on the goal C5, "future of adaptive learning..." The philosophy behind the method developed was to explore all possible start state vector scenario combinations (scenario landscape), and use advanced analytical techniques to determine the concepts that have the most impact on the model.

The aforementioned fuzzy cognitive maps package [14] in R did not provide capability to automate this portion of the analysis. A separate R package called "FCMapper" [20], was modified/adapted to allow automated iteration of the scenario landscape through the use of vectorization and "for loops".

To create the scenario landscape, all possible combination of start vector were created using simple matrix manipulation. The total number of combinations is found by raise the total number of starting states, to the power of the number of concepts.

Total scenario combination = 3^13 = 1,594,323 combinations.

A matrix (13x1,594,323) of start state vectors was formed using either a 0,1 or "NA" (empty cell). Due to memory limitations and to reduce the time to complete the analysis 100,000 of the total combinations were sampled at random, and passed into the analysis function. To develop and test our new analytical approach to quantifying FCM models, we did not anticipate that 100% of all scenarios needed simulation, an appropriate fraction of randomly selected scenarios should suffice to determine the impact and rank the concepts accordingly.

For each loop (1 loop = scenario) of the analysis, the concepts with at 0 or 1 were fixed or clamped and the "NA" values were not clamped and thus allowed to fluctuate with the model. A histogram with the results of the analysis can be found in Figure 5.5. In the X axis the equilibrium value ranges from 0.5-1.0. The Y axis is the frequency or number of counts that a given equilibrium state was reached.

An interesting observation from this analysis and plotting is the shape of the graph/curve. Each scenario can have a distinctive shape, (1) curves representing a wide uncertainty for a given concept, (2) discrete groups indicating more certainty as in C2, C3, C8 and C12 (Dev Tools & service, Educator/Specialist R&R, Learner based awareness and support, technology in education), (3) skewed curves, indicating importance or impact to the model, which can be also seen in the correlation results. The clamped values were removed from the results as they were artificially created, the code to do this searched for a 0 or 1 and replaced with “NA” or missing value.

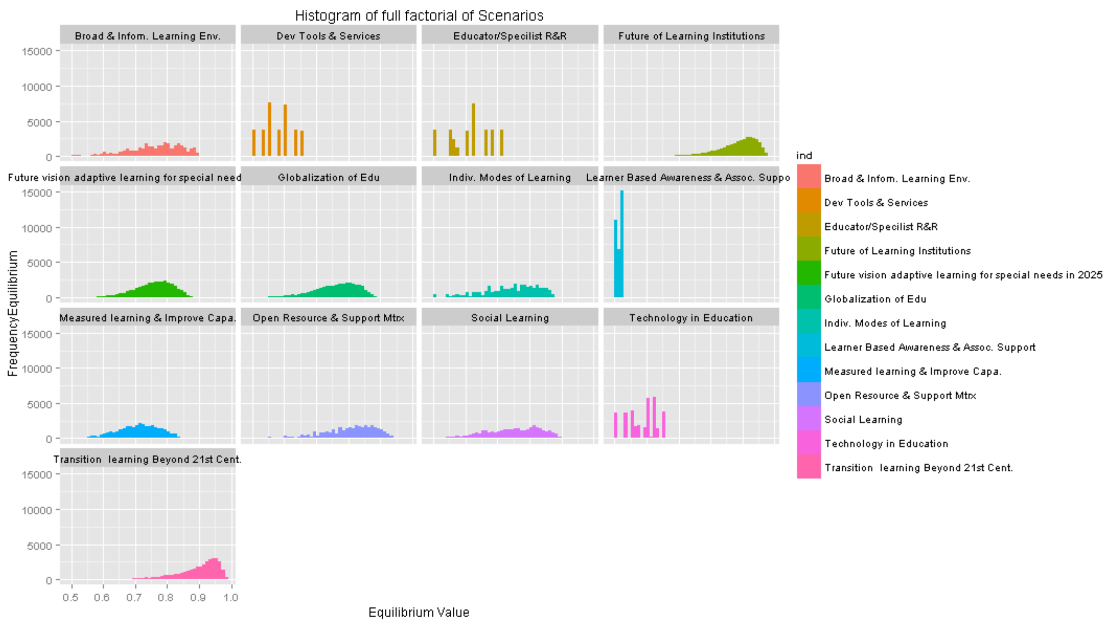


Figure 5.5: Histogram of Scenario landscape analysis, 100k randomly selected scenarios.

The precise correlation of each concept was calculated by passing the matrix containing the equilibrium values for the 100k randomly selected scenarios into the “cor” function in the base “stats” package in R [17]. A “cor” function computes the linear Pearson correlation values for each concept against the others (pairwise due to NA’s resulting in clamped values). The results of the analysis are a value of 0-1 for each concept, 0 indicates no correlation, 1 indicates perfect correlation. A higher correlation score means that a concept impacts the subject strongly. Our analysis will use the correlation scores as a means to rank importance of the model’s concepts against the goal. From the results in Table 5.2, C13 (Transition beyond 21) had the greatest impact on C5 (future of adaptive learning). The next highest impacting factors are C7, C10, C6 C4 and C1 respectively. Interestingly, C2,C8 and C8 ranked lowest, this is somewhat surprising given that the experts in the workshop were mainly practitioners and parent advocates. Our expectation was that technology and the educator would rank highly against the future of learning. Comparison of the spearman rho technique and the Pearson correlation shows almost perfect correlation between the two methods. One added benefit of using a multivariate correlation matrix is that similar impacts can be determined for each concept individually. For example, if C1 is important to the goal C5, one could extract the highest impacting factors to C1 to enable its development to allow C5 to further improve.

It is understood that the multivariate scenario landscape analysis paints a picture of the range of possible plausible outcomes. The results of next step in of the morphological analysis should fall within the ranges and curves displayed.

#	Concept	Pearson Correlation	Spearman rho	Mean	Std Dev	Survey Uncertainty	Survey Importance

		Coefficient					
C1	Broad & Infom. Learning Env.	0.74	0.74	0.75	0.08	2.38	4.13
C2	Dev Tools & Services	0.42	0.42	0.89	0.05	3.00	4.50
C3	Educator/Specialist R&R	0.31	0.33	0.74	0.06	2.86	4.13
C4	Future of Learning Institutions	0.73	0.72	0.80	0.06	2.30	4.10
C5	Future Vision of AL	1.00	1.00	0.76	0.06	-	-
C6	Globalization of Edu	0.76	0.76	0.76	0.07	2.63	3.63
C7	Indiv. Modes of Learning	0.77	0.77	0.88	0.09	-	-
C8	Learner Based Awareness & Assoc. Support	0.31	0.33	0.74	0.01	3.00	5
C9	Measured learning & Improve Capa.	0.47	0.46	0.70	0.07	3.63	4.75
C10	Open Resource & Support Mtrx	0.77	0.76	0.58	0.08	3.00	4.25
C11	Social Learning	0.62	0.61	0.58	0.09	2.88	4.13
C12	Technology in Education	0.43	0.43	0.61	0.05	3.38	4.43
C13	Transition learning Beyond 21	0.84	0.85	0.51	0.07	2.71	4.57

Table 5.2: Correlation results from scenario landscape.

Another interesting application of this analysis is to compare the survey ratings with the correlation ranking. The model and the survey did not agree as to the importance of the concepts relative to the C5 goal. There was a modest negative correlation between “survey importance” and “pearson correlation”; there was a weak negative correlation between “survey uncertainty” and the scenario landscape “std dev”. This highlights the importance of linking connections between notes that FCM captures; it should be noted that a one dimensional survey can not convey this level of detail.

Using 100k, 300k or 500k randomly sampled start vectors results in the same concept correlation ranking. We can conclude that supporting the idea that 100% of all combinations are not required to model the importance or the impact to a FCM model. ~5-6% random sampling should be sufficient to capture the correlations.

5.5 Morphological Analysis

While the multivariate analysis is a powerful tool with many uses, it can be difficult to translate its results into words and convey to the experts and contributors to the workshop and model.

To convey a sense of how impactful the starting state of each vector is, we used a morphological analysis to create a set of plausible scenarios using “what-if’s”. There were fifteen scenarios created and concept start states were defined to either 0, 1 or left to vary (NA) to reflect the desired inputs. The fifteen state vectors were then passed into the same FCM analysis tools to calculate the equilibrium values after the model stabilized. A table of start state vectors can be found in Appendices C. The table of equilibrium results can also be found in appendix C. Table 5.3 below provides a brief description of the scenarios.

Scenario 1 - Republicans win 2017 election - defund education - small government	Scenario 5 - Personal robots become a household item and provide homeschool education for students.	Scenario 8 - Removal of Technology from learning spaces.	Scenario 15 - Government initiates direct neural transfer program for learning downloads eliminating need for teachers.
Scenario 2 - Bernie wins 2017 election - socialism for everyone - big government - control	Scenario 6 - Increased Population density leads to higher student to teacher ratio	Scenario 9 - Reduced SN educational state funding, role of educator falls onto parents and family	Scenario 12 - Special needs education becomes more isolated from mainstream schools and general oversight becomes highly specialized.
Scenario 3 - Institutions move toward role of resource providers and teachers become social progress coordinators and mentors.	Scenario 7 - Removal of government laws/bills affording educational protection and support for disabilities.	Scenario 10 - The government takes legal action on uninvolved parents, creates a new program for monitoring at risk children.	Scenario 13 - Government links funding to IEP goal success, educator training milestones and parent feedback.
Scenario 4- Institutions serve as a space for expert attention and individual skill development.		Scenario 11 - Removal of specific special ed learning spaces, broader integration into social aspect.	Scenario 14 - Government adds life skills program for adults to medicaid qualifying programs.

Table 5.3: Morphological Analysis Scenario description.

To quantify the impact of each scenario against the goal C5, we used one of 2 methods. The first method (1) was to compute the delta of scenario equilibrium vs baseline equilibrium or (2) directly compare the equilibrium values for two opposing scenarios. As an example Scenario 1 and Scenario 2 were selected as opposites, republicans vs democrats winning the 2016 election. Concepts clamped at 0 for one scenario were fixed at 1 for the other scenario and vice versa. The full table of deltas can be found in the appendix C. A negative delta means a concept resulted in a worse outcome, a positive delta results in a better outcome for a given concept.

An example of an interpretation of the results using this method is, *if republicans win 2016 election, the future of adaptive learning (C5) will be 0.08 (0.11-0.3) points lower than if the democrats win. Dev tools and services (C2) will worse by 0.05 (0.27-0.22) and technology in education (C12) will be better by 0.09 (0.2-0.29) points.* The expert and research team can then engage in a further discussion as to whether the results are meaningful, expected or intuitive. Based on the acceptance of the scenario, the start state vectors chosen against a scenario can be validated.

A graphically representation was generated to communicate the results a 2x2 graph was created. The highest six impacting concepts from the multivariate correlation were grouped into two categories, (1) Learning spaces and (2) Social integration. Learning spaces was comprised of C1, C4 and C6 (Broad and adaptive learning environment, future of learning institutions and globalization of education. Social integration was comprised of C10, C12 and C13 (Social Learning, Tech in Education and Transition beyond 21). As represented on the graph, X and Y coordinates for each scenario was calculated using a simple average of the three concepts for each axis. Figure 5.6 shows the results of the 2x2 analysis, with 4 quadrants indicating impact to each axis.

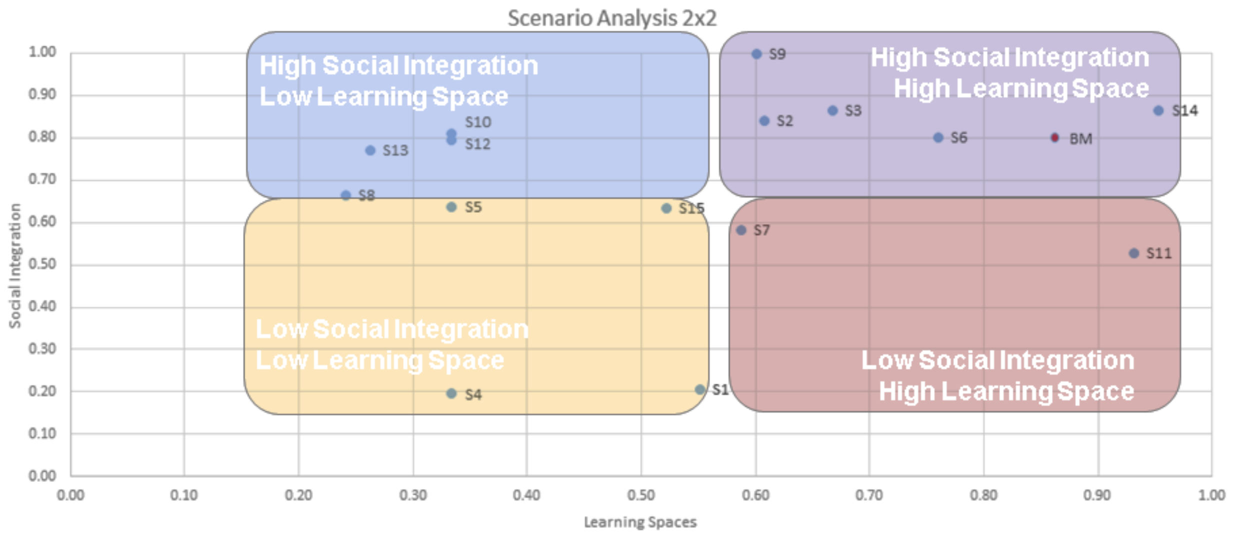


Figure 5.6: Social integration vs. Learning spaces 2x2

To realize a more progressive future of adaptive learning, scenarios that rate high on both Social Integration and Learning Space are necessary. The figure above shows five scenarios (S2, S3, S6, S9 & S14) and the baseline (BM) are located in the ideal high social integration and high learning space quadrant. Utilizing this data, a stake holder could use this is to focus resources and advocating for adaptive learning for special needs in those scenarios and clamped state functions. Interestingly enough, the difference between scenario 1 and 2 (reps vs dems) is not significant on the learning spaces axis, but is quite significant on the social integration axis - this aligns with the researcher team's intuition of plausible outcomes of the 2016 election vs future of adaptive learning and special needs.

5.6 Analysis Summary

Taking a multi-modal approach to the research and analysis gave a layered level of understanding of the topic, adaptive learning for the special needs student, and visibility to potential gaps in research or understanding. Below are lessons learned from the summary of this analysis:

(1) A survey cannot on convey/capture the complicated node interactions like an FCM, and following the survey results alone could result in serious implications by misidentifying the importance of a given input. FCM model and survey importance did not correlate positively.

(2) The FCM model was robust and stabilized to the same equilibrium states for starting vectors of 1's or 0's. All 100k combinations resulted in stabilized equilibrium states.

(3) Multivariate analysis combined with landscape scenario exploration resulted in meaningful analytical statistics that determine (a) a given concept's impact/importance (linear correlation) to every other concept or goal (C5), (b) a range of possible outcomes for each concept between

0-1, used as a proxy for certainty/uncertainty (c) a curve shape/density function or distribution of discrete outcomes for each concept, used to identify the frequency of outcomes (d) this method could be used to compare individual models for discrepancies between experts, perhaps identifying expert groups by correlation fingerprint. (e) this method can be used to give experts exact feedback as to the model's outcomes, which may facilitate faster iteration and revision of models to reflect the through mental model which is difficult to capture. (f) all morphological scenarios should generally fall within the range of the scenario landscape.

(4) The importance of each concept relative to goal C5, as listed in Table 5.4 below.

Concept Mapping	Concept	Importance Correlation Co-eff
C13	Transition Beyond 21(life long learning)	0.84
C1, C4, C7, C6,C10	Broad earning Env., Future of Learning Institutions, Indiv. Modes of Learning, Globalization of Edu, Open Resource,	0.73-0.77
C11	Social Learning	0.62
C12, C2, C9	Tech in Edu, Dev Tools & Services, Success Indicators,	0.42-0.47
C3, C8	Educator/Specialist R&R, Learner Based Awareness	0.33

Table 5.4: Concept Mapping

(5) Morphological Analysis can be used to convey complex scenario combinations simply, either descriptive or graphically using a 2x2 matrix by grouping related concepts and aggregating through a scoring model. Scenario description can be molded or tailored to each type of stakeholder (persona) without changing the model outcome. This allows better communication and translation of the model results to something meaningful for the stakeholders/personas.

6.0 Further Steps/Work

Although a reasonable process overview was conducted, there were certainly areas for further development and broader analysis. This paper has generated a detailed investigation and was created to provide industry experts and advocates with a means for comprehending scenarios that will have an influential impact of the future of adaptive learning for special needs students in general. Having already established that the needs of special needs students vary considerably, one area that was not differentiated correlates to the age of the learner. Although one of the highlighted influencing factors discusses the need for education beyond the age of twenty-one, this analysis does not emphasize how the focus of that learning style may be significantly different than that of a younger student. In order for those transitioning past the age of twenty-one to achieve success in learning and further their cognitive maturity a different set of factors is most likely needed.

A shortfall in the research is with regard to the various stages of life and corresponding expectations. More time and analysis is necessary to ensure the model is robust across all life phases. A concentrated effort for young, teen age, and adult special needs learners could be considered in the future lending further insight into how the industry as a whole can produce a more conducive and encompassing environment for the growth of those with special needs. With time, additional and more finely tuned surveys can be completed by a wider spectrum of professionals and those with a vested interest with regard to the subject matter. This level of information would create a stronger basis for more detailed interactions with additional resources not previously considered in this research which would include but is not limited to, legislators, advocacy groups, global respondents, fiscally tied political figures, various demographics and environments, social inputs, etc.

Regarding the process followed to identify the factors, interviewing stakeholders and undertaking cognitive mapping seems to make sense but with a greater structure. Highlighting the larger group of stakeholders above, a true opportunity for an interactive workshop exists. Ideally, in various geographic locations in order to differentiate various state and country practices will help to identify previously unknown factor relationships. This additional work would create the in-depth details that may be necessary to develop realistic influencing scenarios and factors that are applicable to the respective demographics. Varied analysis would provide a detailed road map that would be enveloped around the PESTEL for that specific region in the world.

Utilization of the Mental Modeler tool, or other similar software, simply provides a data analysis of the established relationships. Without interpretation, the results are limited. As such, the scenario analysis recommendations described are somewhat user defined. Although the real purpose of this process is to establish an effective FFE analysis tool, an improved next step is also needed. A future review taking a defined scenario analysis into actual product development would be a great next step and validation of these results.

Unfortunately, due to the compressed schedule and timing of the research being performed, the team was not able to circle back with the subject matter experts to discuss the results of the scenarios discussed throughout this breakdown. Further insight from the SME’s would better define the scenarios that have been created and add to or subtract from the legitimacy of the outcomes, ultimately creating finer understood details as they pertain to the scenarios or possibly mutations of them to encompasses ideas not previously expressed or described.

Further research is needed as there are currently three models. Additional development would be to use the multivariate to compare individual models for disagreements or to track the evolution over time, ultimately to understand the importance levels and how they change from model to model. The results could be used to challenge the experts to better identify a consensus by introducing a Delphi technique to gain unbiased answers and better detail.

The future work and further progress that can be adopted from the cornerstone of this paper can be realized with the additional research as it is prescribed above. Industry leading experts as well as a broader understanding from parent advocates will dictate the needs for those who require special guidance. Once a more defined and detailed analysis is completed, the scenarios that are derived will indicate the next steps with development of a new product as the FFE will be understood to a level that will allow executives and leaders in the industry to confidently allocate resources and budgets appropriately to create and accomplish the necessary mechanisms for which the market is currently lacking in order to foster an environment that will be successful for all of the entities involved from every end of the spectrum.

7.0 Conclusion

Extensive research and time has been invested in analyzing the FFE to better understand what it will take to ensure students and adults with disabilities have an opportunity to learn in flexible and adaptive environments that surpass the current expectations of local and global institutions that of which transition into the student's entire network that includes but is not limited to educators, specialists, parents, advocates, therapists, and the like. This team was able to create reasonable scenarios based on the feedback that was received through the surveys, interviews, and the FCM method utilized. The culmination of thorough literature review to better understand the subject and receive feedback from local experts was crucial to the success of this project. After several iterations a robust model was created in the statistical program of R which delivered the results from the respective subject experts that globalization of this type of education, providing an open resource for such lesson plans and mechanisms for adaptive learning, and transitioning an educational program beyond the age of twenty-one are the most important factors in establishing success in this realm of education by 2025. The conclusion of this investigation provides further insight into what these results mean for educators, how this information can be used by others with similar pursuits, and has uncovered a method utilizing FCM to understand what is important and at the forefront of the industries needs from a customer's perspective.

Even though the pool of subject matter experts was limited to the region for which this research took place, the literature review provided similar insights into the market needs for adaptive learning for students with disabilities. A common thread existed between the examination performed; there is a need to have a global connection with educators who face similar challenges with creating a lesson plan, as basic as it may sound, individual needs require time consuming road maps that if shared through an open resource on a global platform, would provide an opportunity to be more efficient as well as generate a means for adaptive learning for special needs students as they transition into the age range of older than twenty-one. Having an understanding that there is this overall need, it has defined a segment in this industry that should be developed. Other important factors have been discovered and are outlined in the aforementioned sections of this analysis, however, what initially was thought to be a more important factor, technology being utilized in these cases, ultimately were not as important as initially anticipated. The output received is not definitive but it does provide guidance with regard to future research and factors that are important to the success of the advancement of this industry over the next decade.

A well-defined model that can be utilized as a tool to evaluate various scenarios has been created throughout this process. Understanding the inputs into R while establishing fruitful information from subject matter experts is the recipe that was conducted when performing this research which has resulted in a useful and robust end product that can be used by experts, advocates, and those versed in R to create a breakdown that reflects the overall needs of a case similar to this one. However, this tool can be used in any related format that delves deeper into FCM and mental modeler. It can be used to take inputs from surveys and interviews that provide industry knowledge and needs into a useful metric for how a company or team should proceed in taking a product or a subject to the next phase gate as the team works through the FFE.

Several conclusions can be drawn from the research performed which pertain to and provide further insight into the theoretical space that FCM can transcend. Understanding cognitive mapping and describing it to the subject for which one is obtaining research from is challenging. Communicating and understanding the questions and the informational needs was an initial struggle on the project. However, as the team worked through the iterations and the workshops with the respective subject matter experts, their input became more logical and painted a vision and picture for which strong conclusions and desires for this industry were more prevalent. Being able to grasp that there are no wrong or right answers and also incorporating a nominal group technique with brainstorming justified the FCM that was created in Mental Modeler by the professionals and knowledgeable interviewees that were consulted on this project. It is anticipated that with the incorporation of other related entities that would have a vested interest in this topic, such as but not limited to, legislatures, general public, legal experts that the model would shift and become more normalized as other contextual factors are considered with regard to funding, environment, and social impacts. Much like a survey, the information provided would need to be diligently reviewed creating a scatter plot to remove outliers but ultimately, using the various levels of research methods and utilizing Mental Modeler as well as R to analyze the feedback, a robust model can be generated, providing executives with a quality report for which to proceed with and make informed decisions as they move away from the FFE into the next stages of NPD.

8.0 Acknowledgements

The team would like to sincerely thank Dr. Jetter for her continued provisions and guidance throughout the creation and iterations that were necessary to develop the models that have been generated throughout the term. The feedback was greatly appreciated and has been the inspiration for creating the tool that has been generated in our pursuit of attaining the goals of this course. It has provided the team with instruments to be utilized in future pursuits academically and in our respective careers. We would like to express our gratitude for you all of your time, consideration, and patience.

Also, we would like to thank the panel of experts for which we have worked closely with the project on for their time, involvement, and the access to the system; so that we could generate the tool that we have created for the various models. Without this opportunity, we would not have had the chance to take we have learned into practice, for which we are grateful.

9.0 References

[1] B. Kosko, Adaptive inference in fuzzy knowledge networks, in: D. Dubois, H. Prade, R.R. Yager (Eds.), Readings in Fuzzy Sets for Intelligent Systems, Morgan Kaufman, San Mateo, 1993.

[2] Blythe, M.J., Young, R., 1994. Scenario analysis: A tool for making better decisions for the future. Evaluat. J. Australasia 6(1), pp. 1-17.

[3] Crawford, Charles Merle., and Di Benedetto Anthony T. *New Products Management*. Boston: McGraw-Hill, 2011. Print.

[4] Designing for Extraordinary UsersErgonomics in Design: The Quarterly of Human Factors Applications October 1993 1:10-16.

[5] Deshler, D., 1987 Techniques for generating futures perspectives. In: Brockett, Ralph G. (Ed), Continuing Education in the Year 2000. New Directions for Continuing Education, No. 36. Jossey-Bass, San Fransisco, CA, pp.79-82

[6] Duinker, Peter N. and Greig, Lorne A. "Scenario analysis in 35nvironmental impact assessment: Imporving explorations in the future" Enviornmental Impact Assessment Review 27 (2007) pages 206-219.

[7] Gray, Steven. "Mental Modeler." *Mental Modeler*. N.p., n.d. Web. 05 Nov. 2015. <http://www.mentalmodeler.org/>.

[8] I. G. Roşca, C. Păunescu, and C. Pârvan, "Shaping the future of higher education in Romania: Challenges and driving factors," *Manag. Mark.*, vol. 5, no. 1, pp. 57–70, 2010.

[9] Jetter, A., Schweinfort, W. Building scenarios with Fuzzy Cognitive Maps: An exploratory study of solar energy, Futures, Volume 43, Issue 1, February 2011, Pages 52-66, ISSN 0016-3287, http://dx.doi.org/10.1016/j.futures.2010.05.002.

[10] J. Gidley, D. Bateman, and C. Smith, *Futures in Education: Principles, practices and potential, monograph No 5, the strategic foresight monograph series*. Swinburne University, 2004.

[11] J. M. Gidley and G. P. Hampson, "The evolution of futures in school education," *Futures*, vol. 37, no. 4, pp. 255–271, May 2005.

[12] J. M. Gidley, "Global Knowledge Futures: Articulating the Emergence of a New Meta-level Field," *Integral Rev. Transdiscipl. Transcult. J. New Thought Res. Prax.*, vol. 9, no. 2, pp. 145–172, 2013.

[13] J. R. Cole and K. A. Persichitte, "Fuzzy cognitive mapping: Applications in education," *Int. J. Intell. Syst.*, vol. 15, no. 1, pp. 1–25, 2000.

[14] K. Van Blommestein, *kevinvanb/Fuzzy-Cognitive-Maps*. R Package version 1.0 https://github.com/kevinvanb/Fuzzy-Cognitive-Maps

[15] Papageorgiou, Elpiniki I. Salmeron, Jose L. "A Review of Fuzzy Cognitive Maps Research During the Last Decade" IEEE Vol. 21, No. 1, February 2013.

[16] R. A. Slaughter, "A foresight strategy for future generations," *Futures*, vol. 29, no. 8, pp. 723–730, Oct. 1997.

[17] R Core Team (2015). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

[18] R. Taber, Knowledge processing with Fuzzy Cognitive Maps, Expert Systems with Applications 1 (1991) 83–87

[19] Schwartz P. "The art of the long view: planning for the future in an uncertain world." New York, NY: Currency Doubleday; 1996. 258 pp.

[20] Shaun Turney and Michael Bachhofer (2015). FCMapper: Fuzzy Cognitive Mapping. R package version 1.0. http://CRAN.R-project.org/package=FCMapper.

[21] Sperry, R., and A. J. Jetter. "Fuzzy Cognitive Maps to Implement Corporate Social Responsibility in Product Planning: A Novel Approach." *Technology Management for Emerging Technologies (PICMET), 2012 Proceedings of PICMET '12:* (2012): 2536-541. Web.

[22] S. Stoyanov, B. Hoogveld, and P. Kirschner, "Mapping major changes to education and training in 2025," *Inst. Prospect. Tecnológica Cent. Común Investig. Unión Eur. Línea Ftpftp Jrc EspubEURdocJRC59079TN Pdf*, 2010.

[23] S. Vincent-Lancrin, "Building Futures Scenarios for Universities and Higher Education: An International Approach," *Policy Futur. Educ.*, vol. 2, no. 2, pp. 245–263, Jun. 2004.

[24] "WFSF - World Futures Studies Foundation," 31-Oct-2015. [Online]. Available: http://www.wfsf.org/about-us/futures-studies.

[25] W. V. Kandasamy and P. Pramod, "Parent Children Model using FCM to Study Dropouts in Primary Education," *Ultra Sci*, vol. 13, pp. 174–183, 2000.

[26] Y. P. Christine Redecker, "The Future of Learning 2025: Developing a vision for change," *Future Learn.*, vol. 2, no. 1, pp. 3–17, 2013.

10.0 Appendices

10.1 Appendices – A: Mental Model

Mental Model instructions that were sent to the experts.

Directions on how to use Mental Modeler to create a Cognitive Map – This only works on PC's, it does not work on MAC's.

Opening the Model

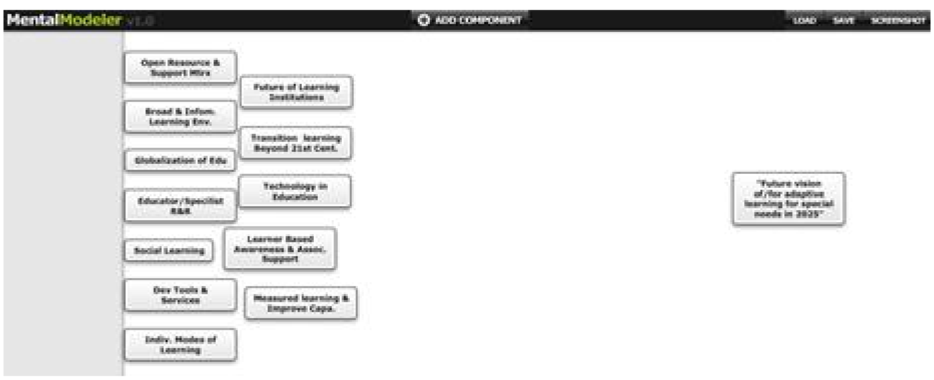
1. Save the attached .mmp file to your computer.

2. Goto http://www.mentalmodeler.org/online/

3. Click "LOAD" and select the MMP file that you saved earlier

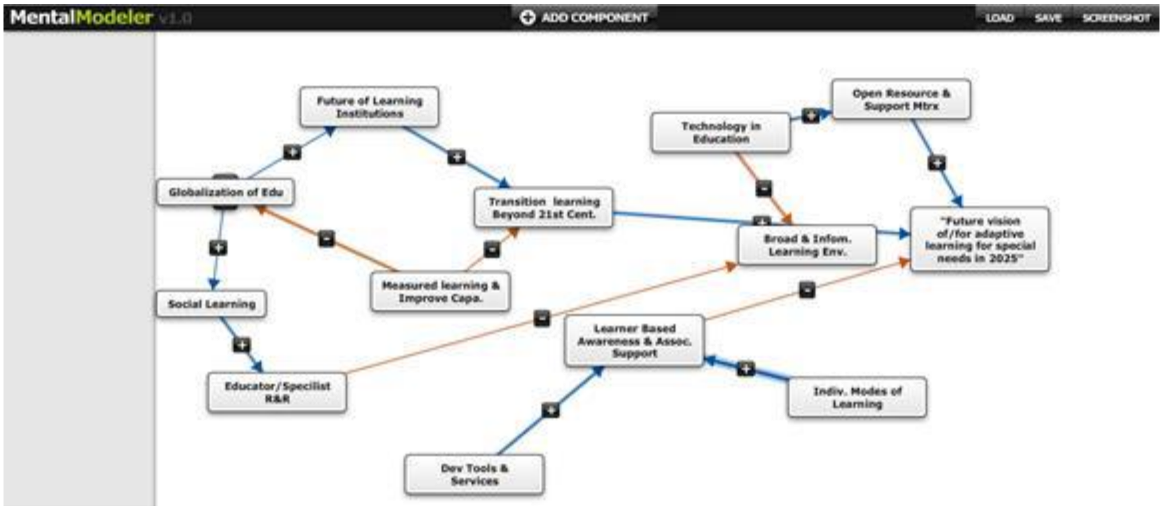
4. You should now see the model. Note that the ""future state of/for adaptive learning for special needs in 2025"" on the left is the end state. It should **not** have an effect on the factors, however factors may affect this end state.

I.e. -- Arrows may point towards the "end state" but should not be originating outward from the "end state".

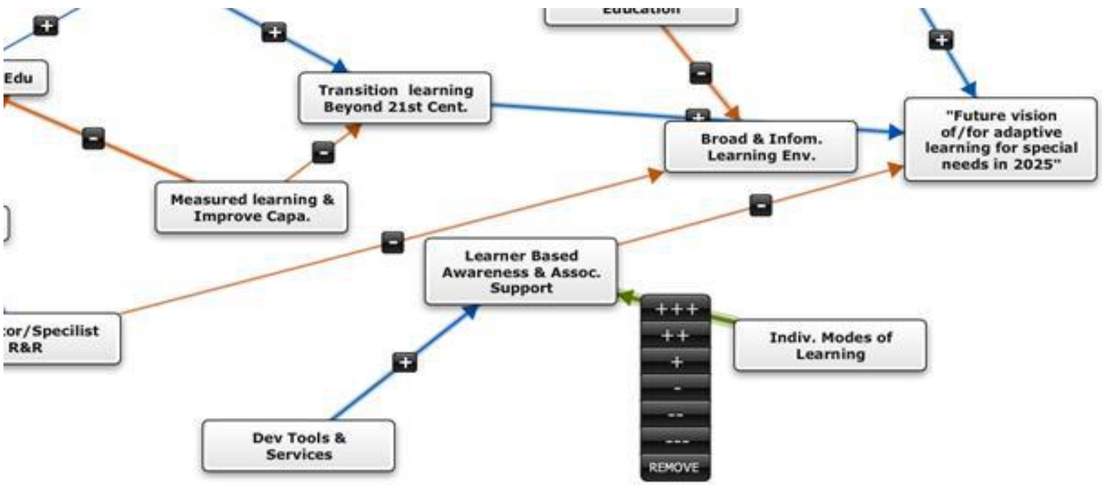


Using the Model

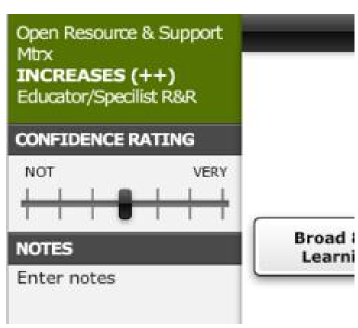
5. Hold your mouse over each factor and then **click and drag it to any location** on the cognitive map. Then **click and drag the arrow** from one factor to a factor or end state that it affects. Each factor is defined under the notes section. By doing this you are creating a Cognitive Map. Note factors can impact any number of other factors including the end state, they also can have no impact. For example your map may look something like this…



6. Select to what degree it impacts that factor. It’s a scale from Highly Positive +++ to Highly Negative ----. Continue drawing these arrows to identify the impact that factors have on one another. Once you feel you have captured the relevant impacts your cognitive model is complete!



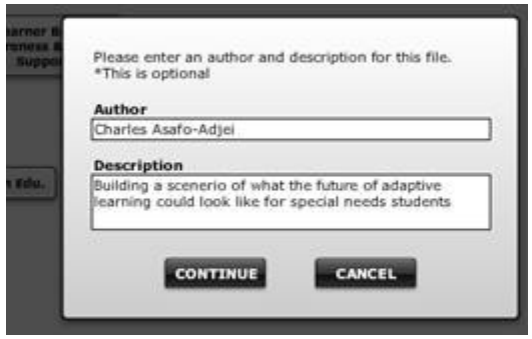
7. Then you can set a confidence for each relationship that you have identified by using the bar on the left.



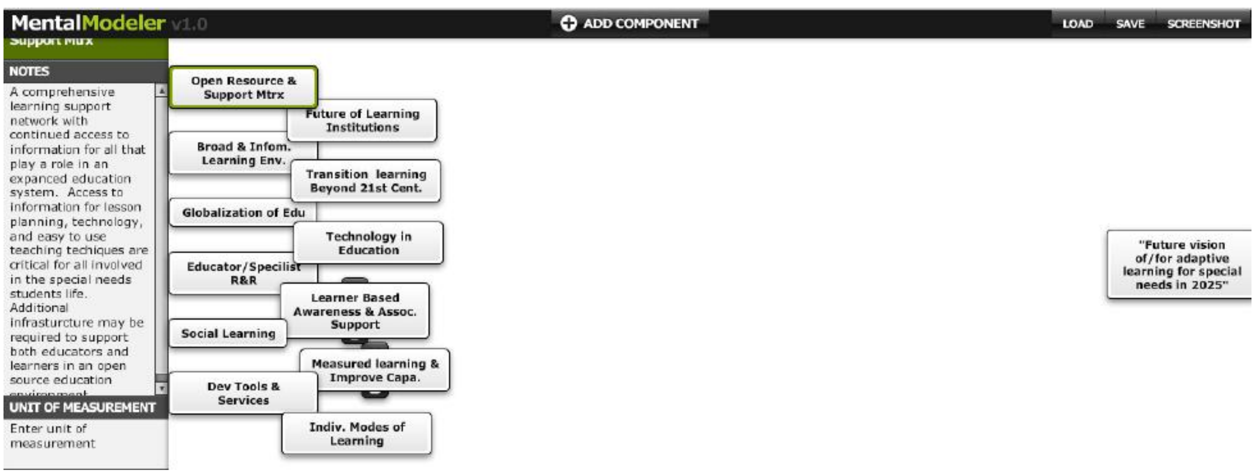
Saving the Model

8. Once you are all done drawing arrows between the relevant factors and how they impact the end state, click the "SAVE" icon and save as a MMP file.

9. Change author to your name and hit continue.



10. Save renamed MMP file and e-mail to your correspondent.



10.2 Appendices – B: Literature Review

Literature Review Table(s):

Author / Date	Topic /Focus /Purpose	Concept Theoretical Framework	Paradigm/Method	Context Setting Sample	Findings	Future Research
Muhammad Amer, Antonie J. Jetter, & Tugrul U. Diam (2013)	Development of Multi-Future Scenarios using FCM for Wind Energy Sector of a development country	FCM-based model	Mixture of Qualitative & Quantitative Research	Portland OR	Estab.3 perspectives of future vision of the national wind energy sector: · Economic Growth directly proportional to Energy Security · Formulation of favorable Gov. Policies & Gov. financial support are key priorities · Env. Climate Changes due to CO2 emissions is of concern.	· Leverage experts knowledge to highlight barriers & challenges · Diversify FCM-based scenario using various squashing func. · Incorp. Wild card events into FCM model
Peter N. Duinker & Lorne A. Greig (2005)	Scenario analysis in environmental impact assessment(EIA): Improving explorations of the future	Scenarios Analysis Method	Qualitative Research	Ontario, Canada	Current futures suggest the relevance of integrating the following into EIA scenario analysis: · Present scenarios with sharp contrast to alternative futures · Avoid creating likely scenario due to limitations on judging probabilities · Classify scenarios in terms of High, Med, Low & Almost Certain, Reasonably Foreseeable, Hypothetical · Comprehensive range of potential futures	· EIA analysts research tools and techniques for futures analysis · EIA investigate the use of scenario approaches practices
David A. Garvin & Lynne C. Levesque (2006)	Exploratory & Heuristic Study of Scenario Planning	Scenario Planning Exercise	Qualitative Research	Boston, MA	Scenario planning involve several components: · Key Focal Issue / Driving factors · Uncertainties / Framework · Scenarios / Narratives · Warning signs / Options · Five Steps planning phases	N/A
Hugh Courtney, Jane Kirkland & Patrick Viguerie (2005)	Strategy Under Uncertainty: Use of analytical tools based on level of uncertainty	Four-level Framework of uncertainties	Qualitative Research	Boston, MA	· In stable business env. Analytical tools works · Under uncertainties tools tends to break down · Four step strategic framework provide alternative to traditional method of dealing uncertainties	Further Research articles: · Strategies That Fits In Emerging Markets · Predictable Surprises: The Disaster You Should Have Seen Coming
Eva Wollenberg, David Edmunds, Luise Buck (2000)	Using scenarios to make decisions about the future: anticipatory learning for the adaptive co-management of community forests	Scenarios Analysis Method	Exploratory/ Descriptive	Jakarta, Indonesia	· scenario methods differ from other tools for adaptive co-management by providing a framework for anticipating the future. · Scenarios involving multiple stakeholders can speed up the process of information exchange and enhance adaptiveness. · Review of methods for the construction of scenarios indicates the broad scope of possibilities for using scenarios and their relevance to adaptive management.	· CIFOR has initiated in Indonesia and Madagascar on the effectiveness of scenarios as a tool for ACM.

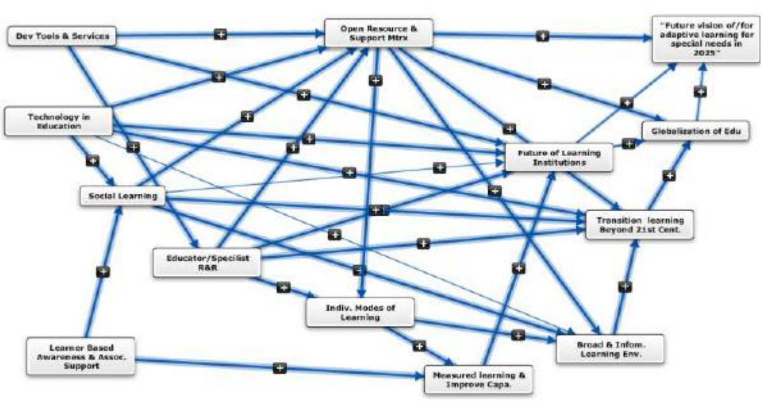
Author/Date	Focus / Purpose	Theoretical Framework	Paradigm/Method	Location	Findings	Future Research
J M Gidley (2013)	Global Knowledge Futures: Articulating the Emergence of a New Meta-level Field	Meta-field level of futures	Review of global knowledge futures/philosophical framework of futures facets	Paris, France	Four fields of study Postformal, integral, global/plantery, futures. Five typologies, (1) Critical-normative, (2) Cultural-interpretive, (3) empowerment-activist, (4) integral/trans disciplinary and (5) empirical-positivist	NA
J M Gidley, GP Hamspton (2005)	The evolution of futures in school education	Futures in education	Reviews of futures for youth in education	Paris, France	Existing futures in education focus on subjective, not objective. Large Gaps in Futures studies in education and learning - continued effort in world furtures studies required.	Psychological dimensions, Socio-cultural diversity, Cultural resources, Human futures, social systems, integral consciousness.
Vincent-Lancrin (2004)	Building Futures Scenarios for Universities and Higher Education: An International Approach	Scenario building in eduction futures	Scenario Analysis - identify system, key factors, identifying uncertainty, selecting scenarios	Paris, France	Six scenarios identified (1) Traditional, (2) Entrepreneurial, (3) Free Market, (4) Open & Lifelong, (5) Network and (6) Diversity	Enage stakeholders in scenario discussion
D. Bateman, and C. Smith (2004)	Futures Education in Australian Primary and Secondary Schools: Mapping Current Principles and Practice	Scenario analysis in sceond level education	Literature review, task analysis - Key factor analysis through expert interview	Melbourne, Austrialia	Critical factors identified: Leadership, teacher enthusiasm, teacher knowledge, Community education	Schools with FE need to lead, create professional FE bodies, partnerships between schools and universities, collaboration between schooles and communities, include AS FE teachers in global FE efforts - WFSF
I. G. Roşca, C. Păunescu, and C. Pârvan (2010)	Shaping the future of higher education in Romania: Challenges and driving factors	Scenario analysis in third level education	Expert interview, trend & driver analysis, focus groups, PESTEL analysis	Romainia	Change Factors: Socio-demographic factors - Demographic decrease, access to education, need to work during school. Technological factors - new alternatives in education, increased R&D. Economic factors - Development of services, Local development, expansion of university networks, entrepreneurial education. Political and legal factors - non-confirming legislation, poor and unprofessional policay makers, budgetary policy, privatization of education industry. Envirnomental factors - Pollutants.	Enage stakeholders in scenario discussion
Y. Punie, C Redecker(2013)	The Future of Learning 2025: Developing a vision for change	Scenario analysis in education and training	Expert interview, trend & driver analysis, focus groups, Conceptual mapping	Seville, Spain	Move towards more personalized training strategies. Professional flexibility, enabled by technology - evolution of ICT. Identified new skills and new ways of learning - life long learning	Research into new skills and new ways of learning
C. Redecker, M. Leis, M. Leendertse, Y. Punie, G. Gijsbers, P. Kirschner, S. Stoyanov, B. Hoogveld (2011)	The future of learning preparing for change	Scenario planning using Hierarchical cluster analysis	Expert interview, trend & driver analysis, focus groups, Conceptual mapping, cluster analysis - rank and feasibility	Luxembourg	Changes:Formal education goes informal Open education and resources Role of teacher Roles of institutions Globalisation of education Assessment, accreditation and qualifications Tools and services enhancing learning Epistemological and ontological bases of pedagogical methods Life-long learning Technology in education Individual and profession driven education Individual and social nature of learning	Enage stakeholders in scenario discussion - inspiring questions and debate about future
R. Miller, H. Shapiro, and K. E. Hilding-Hamann (2008)	Learning Spaces in Europe in 2020: An Imagining Exercise on the Future of Learning	Scenario building in future learning spaces using	Strategic scenario building -Expert interview, trend & driver analysis, focus groups, Conceptual mapping	Luxembourg	The emergence of new skills and competences (high impact) Demographics, health and social changes (Very high impact) Diversification of life and learning trajectories (high impact) Education system slow to adapt, Full Potential of ICT not realized (high impact) Corporate/Organizational learning mainly through informal learning (high impact) Recognition of informal learning and learning happening in serveral context for all generations (high impact) The emergence of the new millennium learners (high impact) Still limited use of ICT for learning amoung adults(medium impact)	Discuss hypotetical policy options with stakeholders
W. V. Kandasamy and P. Pramod (2000)	Parent Children Model using FCM to Study Dropouts in Primary Education	Parent Children Model using FCM to Study Dropouts in Primary Education	FCM model, expert interview, conceptual mapping, FCM	India	Parents decisions on short term finanical gain drives dropout rate. - no foresight as to damage to childs future from poor education and dropping out	How to impact parents decsisions
J. R. Cole and K. A. Persichitte (2000)	Fuzzy cognitive mapping: Applications in education	FCM of impact of distance education on learning.	Experts Brainstorming, cluster analysis, casual mapping, FCM	Bolton, MA	FCM can be used to build a robust model for education purposes - FCM can be used to build an expert model for diagnoisis and monitoring of learning - leaing to an adaptive system. FCM advantages 1. FCMs capture more information in the relationships between concepts. 2. FCMs are dynamic. 3. FCMs express hidden relationships. 4. FCMs are combinable. 5. FCMs are tunable.	Lots more opportunity in education for FCM

10.3 AppendiCES – C: FCM analysis results

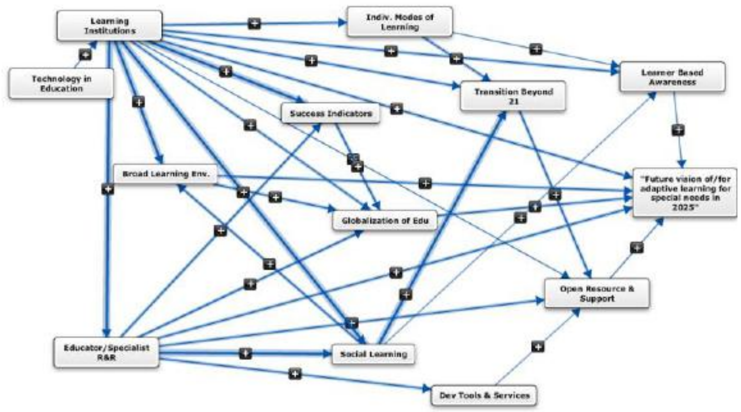
Factors:

		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
C1	Broad & Infom. Learning Env.	0	0	0	0.2	0.2	0.2	0	0	0.2	0.4	0	0	0.4
C2	Dev Tools & Services	0	0	0.4	0.4	0	0.1	0	0	0.1	0.4	0.1	0	0.2
C3	Educator/Specailist R&R	0	0.2	0	0.6	0.2	0	0.4	0	0.2	0.8	0.4	0	0.4
C4	Future of Learning Institutions	0	0	0	0	0.2	0.2	0	0	0	0	0	0	0
C5	Future vision adaptive learning for special needs	0	0	0	0.4	0	0.2	0	0	0	0	0.1	0	0.2
C6	Globalization of Edu	0	0	0	0.1	0.2	0	0.5	0	0	0	0.1	0	0.2
C7	Indiv. Modes of Learning	0.4	0	0	0.2	0	0	0	0	0.4	0	0	0	0.4
C8	Learner Based Awareness & Assoc. Support	0.6	0.4	0.5	0.2	0.2	0.2	0.3	0	0.5	0.4	0.9	0.2	0.2
C9	Measured learning & Improve Capa.	0	0	0	0.5	0.2	0	0	0	0	0	0	0.4	0
C10	Open Resource & Support Mtrx	0.6	0	0	0	0.4	0.5	0.7	0	0	0	0.1	0	1
C11	Social Learning	0.4	0	0	0.5	0.2	0	0	0	0	0.4	0	0	0.4
C12	Technology in Education	0.1	0	0	0.6	0.2	0.2	0	0.1	0	0.3	0.4	0	0.6
C13	Transition learning Beyond 21st Cent.	0	0	0	0.1	0	0.4	0	0	0.2	0	0	0	0

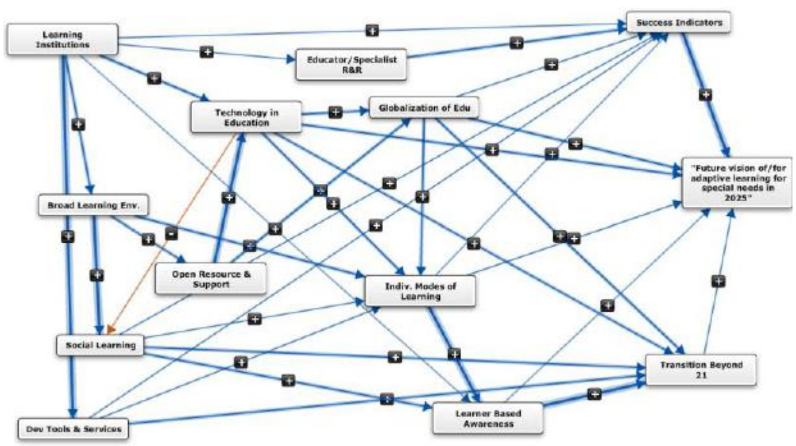
Workshop 1 - cognitive map



Workshop 2 cognitive map.



Workshop 3 cognitive map



Morphological Analysis state vectors.

Scenarios	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
1	1		0	0					1	0			0
2	0		1	1					0	1			1
3	1		0	0		1				1			1
4	0		1	1		0				0			0
5	0	1	1	0		1		1		0		1	
6		0	1				0	0	0	1	0		
7			1	1		0	1	0	1			0	

8	**0**	**1**	**1**	**0**			**1**		**1**	**0**		**1**	**1**
9		**1**		**0**		**1**	**1**	**0**	**1**	**1**		**1**	**1**
10	**0**		**1**	**1**		**0**	**0**	**1**			**1**		
11	**1**		**0**	**1**			**0**			**1**			**0**
12	**0**		**1**	**1**		**0**	**1**						
13	**0**		**0**	**0**				**1**			**1**		
14	**1**	**1**		**1**			**1**			**1**			**1**
15			**0**	**0**			**1**	**1**		**0**		**1**	

Morphological Analysis equilibrium results

Scenarios	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
S1	1.00	0.55	0.00	0.00	0.71	0.65	0.62	0.52	1.00	0.00	0.71	0.62	0.00
S2	0.00	0.60	1.00	1.00	0.79	0.82	0.84	0.51	0.00	1.00	0.80	0.53	1.00
S3	1.00	0.55	0.00	0.00	0.79	1.00	0.79	0.51	0.74	1.00	0.74	0.60	1.00
S4	0.00	0.60	1.00	1.00	0.71	0.00	0.64	0.51	0.68	0.00	0.77	0.59	0.00
S5	0.00	1.00	1.00	0.00	0.76	1.00	0.77	1.00	0.78	0.00	0.88	1.00	0.92
S6	0.66	0.00	1.00	0.82	0.76	0.80	0.00	0.00	0.00	1.00	0.00	0.50	0.91
S7	0.76	0.55	1.00	1.00	0.77	0.00	1.00	0.00	1.00	0.83	0.65	0.00	0.92
S8	0.00	1.00	1.00	0.00	0.73	0.72	1.00	0.52	1.00	0.00	0.82	1.00	1.00
S9	0.80	1.00	0.60	0.00	0.81	1.00	1.00	0.00	1.00	1.00	0.73	1.00	1.00
S10	0.00	0.65	1.00	1.00	0.81	0.00	0.00	1.00	0.72	0.89	1.00	0.62	0.93
S11	1.00	0.55	0.00	1.00	0.81	0.79	0.00	0.51	0.63	1.00	0.73	0.59	0.00
S12	0.00	0.60	1.00	1.00	0.78	0.00	1.00	0.51	0.75	0.85	0.79	0.60	0.94
S13	0.00	0.60	0.00	0.00	0.76	0.78	0.77	1.00	0.74	0.77	1.00	0.62	0.92
S14	1.00	1.00	0.66	1.00	0.84	0.86	1.00	0.52	0.78	1.00	0.79	0.60	1.00
S15	0.81	0.60	0.00	0.00	0.74	0.76	1.00	1.00	0.79	0.00	0.82	1.00	0.91
BL	0.82	0.58	0.62	0.93	0.82	0.83	0.80	0.51	0.75	0.85	0.78	0.60	0.95

Delta of scenario analysis equilibrium vs baseline equilibrium

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
S1	NA	-0.27	NA	NA	-0.11	-0.17	-0.20	-0.30	NA	NA	-0.11	-0.20	NA

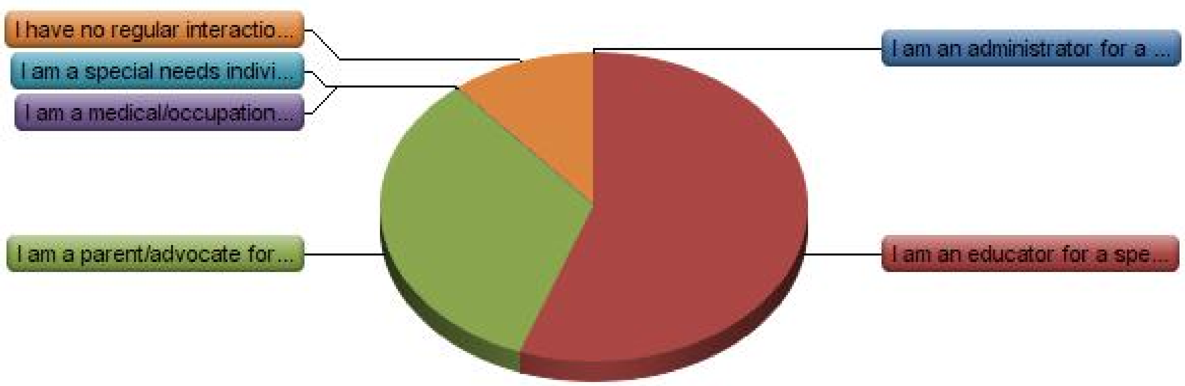
S2	NA	-0.22	NA	NA	-0.03	0.00	0.02	-0.31	NA	NA	-0.02	-0.29	NA
S3	NA	-0.27	NA	NA	-0.03	NA	-0.02	-0.30	-0.08	NA	-0.08	-0.22	NA
S4	NA	-0.22	NA	NA	-0.11	NA	-0.18	-0.30	-0.14	NA	-0.05	-0.23	NA
S5	NA	NA	NA	NA	-0.06	NA	-0.05	NA	-0.04	NA	0.06	NA	0.10
S6	-0.16	NA	NA	0.00	-0.06	-0.02	NA	NA	NA	NA	NA	-0.32	0.09
S7	-0.06	-0.27	NA	NA	-0.05	NA	NA	NA	NA	0.01	-0.17	NA	0.10
S8	NA	NA	NA	NA	-0.09	-0.10	NA	-0.29	NA	NA	0.00	NA	NA
S9	-0.02	NA	-0.22	NA	-0.01	NA	NA	NA	NA	NA	-0.08	NA	NA
S10	NA	-0.17	NA	NA	-0.01	NA	NA	NA	-0.10	0.07	NA	-0.20	0.11
S11	NA	-0.27	NA	NA	-0.01	-0.03	NA	-0.30	-0.19	NA	-0.09	-0.23	NA
S12	NA	-0.22	NA	NA	-0.04	NA	NA	-0.30	-0.07	0.03	-0.03	-0.22	0.12
S13	NA	-0.22	NA	NA	-0.06	-0.04	-0.05	NA	-0.08	-0.05	NA	-0.20	0.10
S14	NA	NA	-0.16	NA	0.02	0.04	NA	-0.30	-0.04	NA	-0.03	-0.22	NA
S15	-0.01	-0.22	NA	NA	-0.08	-0.06	NA	NA	-0.03	NA	0.00	NA	0.09

10.4 Appendices - D: Survey

Importance / Certainty

D1.1 Please select all that apply.

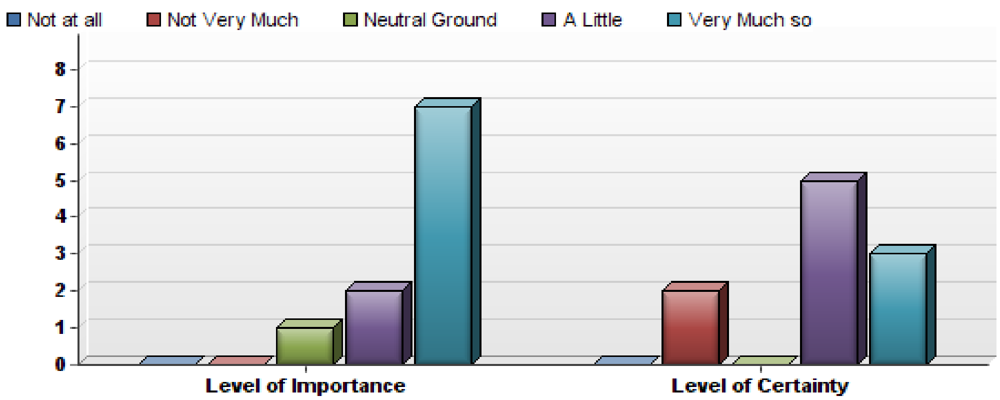
- I am an administrator for a special needs individual
- I am an educator for a special needs individual
- I am a parent/advocate for a special needs individual
- I am a medical/occupational professional for a special needs individual
- I am a special needs individual
- I have no regular interaction with a special needs individual



D1.3 Schools and broader institutions may plan a larger role in standard methodologies and support services but may also become more restrictive based on government funding. Understanding the roles of both privatized and public education institutions and how this will influence adaptive learning capabilities for special needs individuals will be important in the future.

Please rate Role of the Institution as it relates to the future of the adaptive learning landscape for Special Needs students

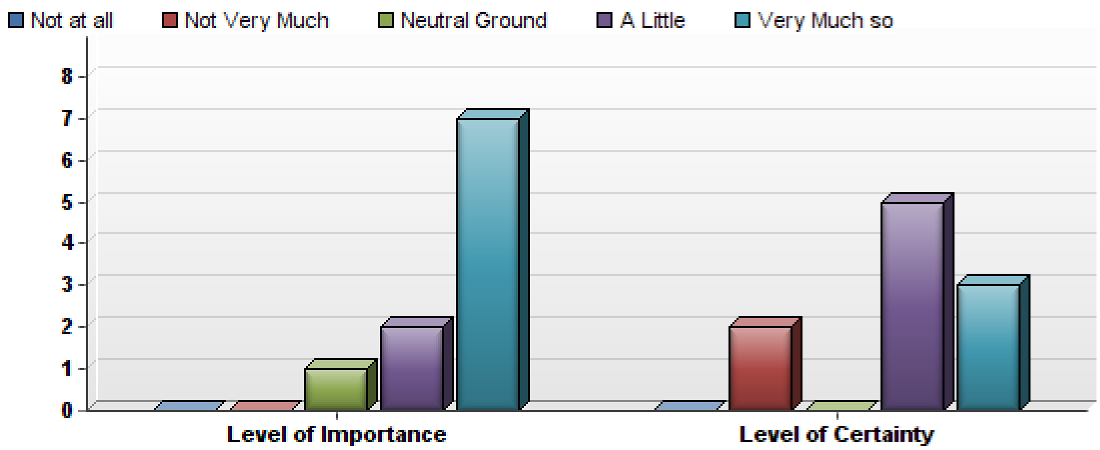
	Not at all	Not Very Much	Neutral Ground	A Little	Very Much so
Level of Importance	■	■	■	■	■
Level of Certainty	■	■	■	■	■



D1.4 Education can be defined beyond the typical formal classroom environment where true life skills are developed and supported for special needs learners. Re-defining the expectations of an adaptive learning program may take a new set of criteria and informal guidance incorporating specialists, home and health care providers, family members as well as a broader source of educational experts.

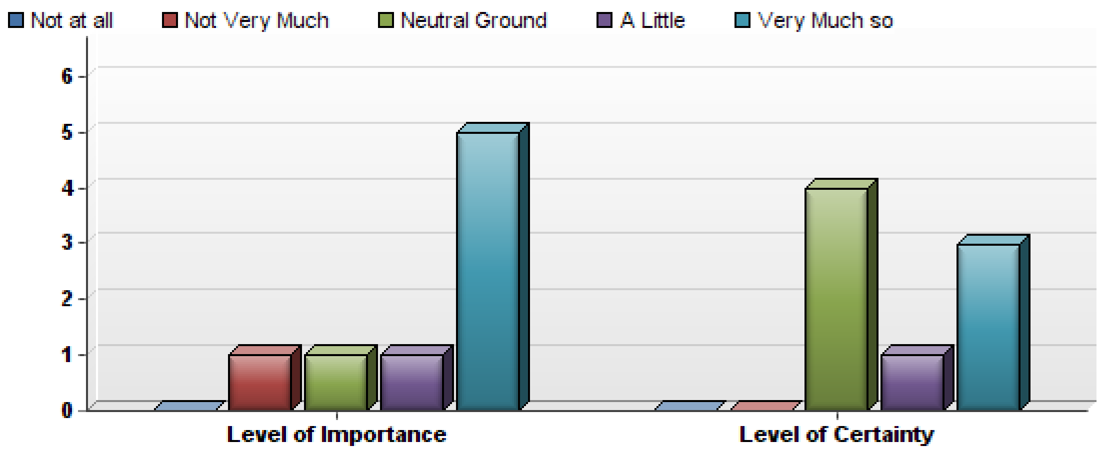
Please rate Moving from Formal to Informal Education as it relates to the future of the adaptive learning landscape for Special Needs students

	Not at all	Not Very Much	Neutral Ground	A Little	Very Much so
Level of Importance	■	■	■	■	■
Level of Certainty	■	■	■	■	■



D1.5 A comprehensive learning support network is needed with continued access to information for all that play a role in an expanded education system. Access to information for lesson planning, technology, and easy to use teaching techniques are critical for all involved in the special needs students life.	Please rate Open and Accessible Provider Education and Resources as it relates to the future of the adaptive learning landscape for Special Needs students

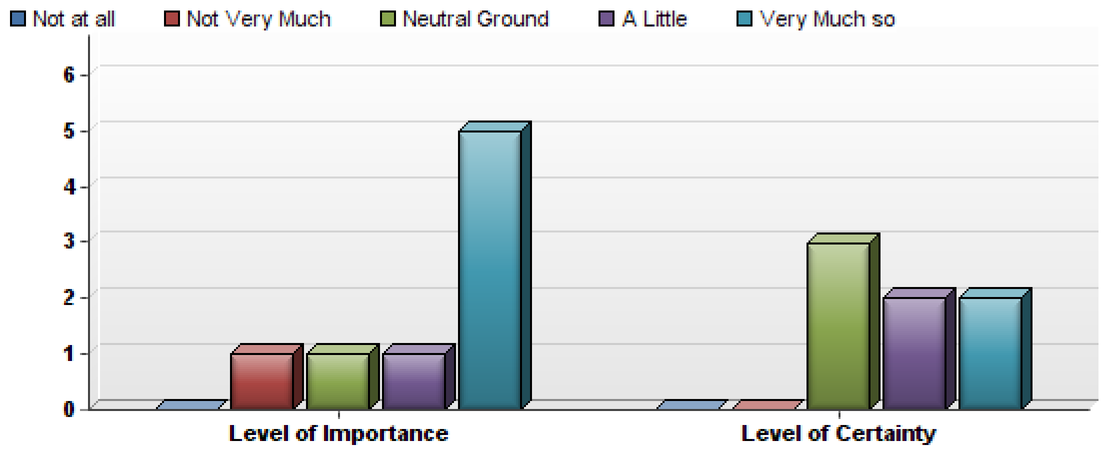
	Not at all	Not Very Much	Neutral Ground	A Little	Very Much so
Level of Importance	■	■	■	■	■
Level of Certainty	■	■	■	■	■



D1.6 The definition or role of the teacher and educator can be fairly diverse including both general instruction and the need for specialized work. In the future, clearly defining the role of educators/specialists, interaction boundaries, and time utilization (i.e. IEP and daily planning vs. hands on student work) are critical to developing a path to student success.	Please rate the Role and

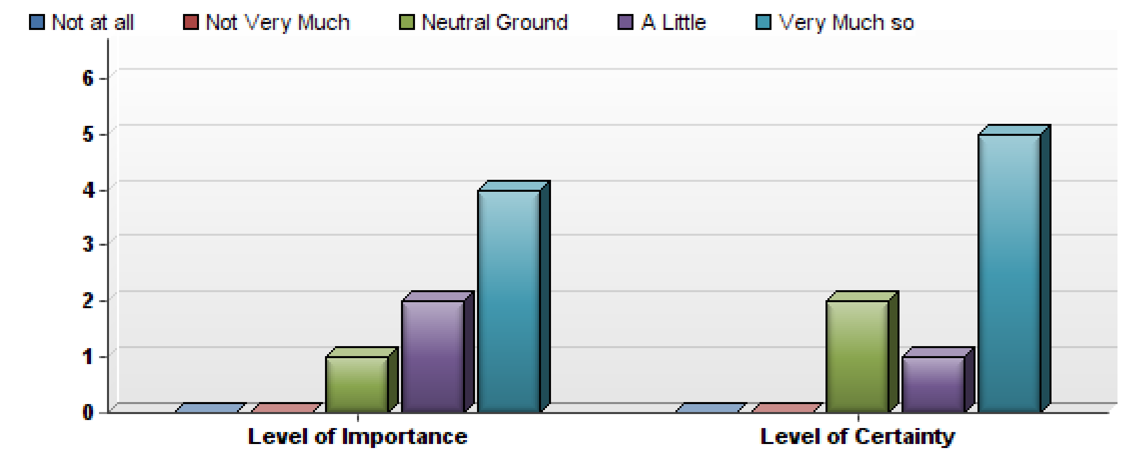
Boundaries of Teachers/Specialists as it relates to the future of the adaptive learning landscape for Special Needs students

	Not at all	Not Very Much	Neutral Ground	A Little	Very Much so
Level of Importance	■	■	■	■	■
Level of Certainty	■	■	■	■	■



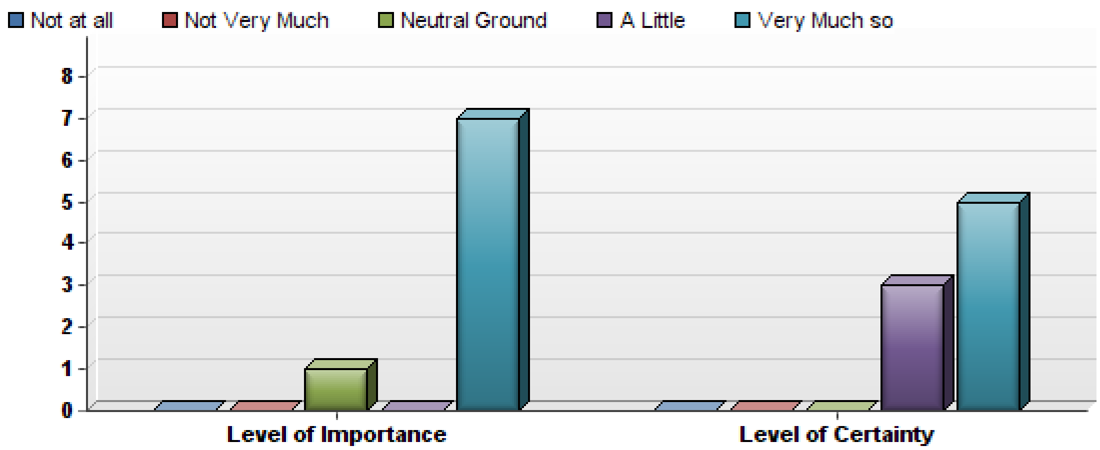
D1.7 The role of technology in education is critical and can be seen in many formats. From interactve and mechanical support items to software and planning tools, real opportunities exist to support physical, mental and social learning. In all cases, the available or future technology must be supported by an ease-of-use system for all that might be engaged. Please rate the Role of Technology in Education as it relates to the future of the adaptive learning landscape for Special Needs students

	Not at all	Not Very Much	Neutral Ground	A Little	Very Much so
Level of Importance	■	■	■	■	■
Level of Certainty	■	■	■	■	■



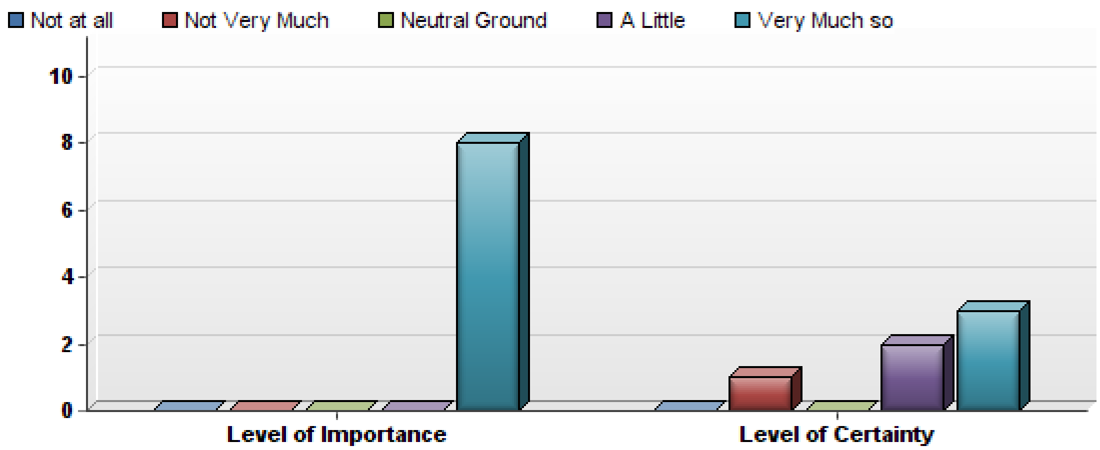
D1.8 Individualized lesson plans should be supported by a safe social environment and include an emphasis on acceptance and group interaction. Adaptive learning in the area of special needs must comprehend opportunities for inclusion with their peers but in a safe environment for all. Considerations for environmental stimulas should be comprehended with opportunities for both physical and online interaction availability.   Please rate the Role of Social Interaction in Learning as it relates to the future of the adaptive learning landscape for Special Needs students

	Not at all	Not Very Much	Neutral Ground	A Little	Very Much so
Level of Importance	■	■	■	■	■
Level of Certainty	■	■	■	■	■



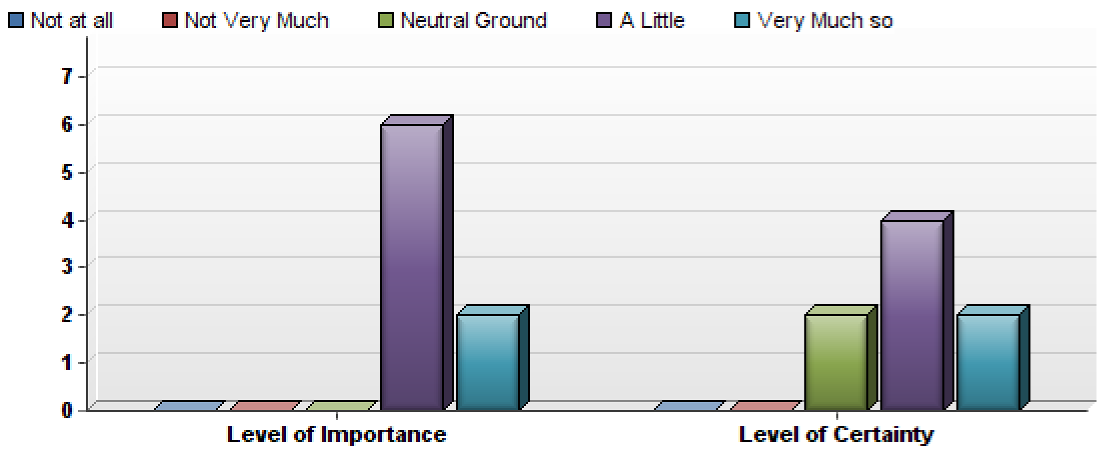
D1.9 Adaptive learning programs should be compatible with exsiting lesson planning but enable a theme of self-awareness. Inclusion of self regulated learning and a comprehension of ones environment would allow for improved life skills and a feeling of contribution in society. Key learning characteristics could include focus and behavior management tools as well as communication and critical choice areas of development.   Please rate the Role of Learner Based Awareness and Supports as it relates to the future of the adaptive learning landscape for Special Needs students

	Not at all	Not Very Much	Neutral Ground	A Little	Very Much so
Level of Importance	■	■	■	■	■
Level of Certainty	■	■	■	■	■



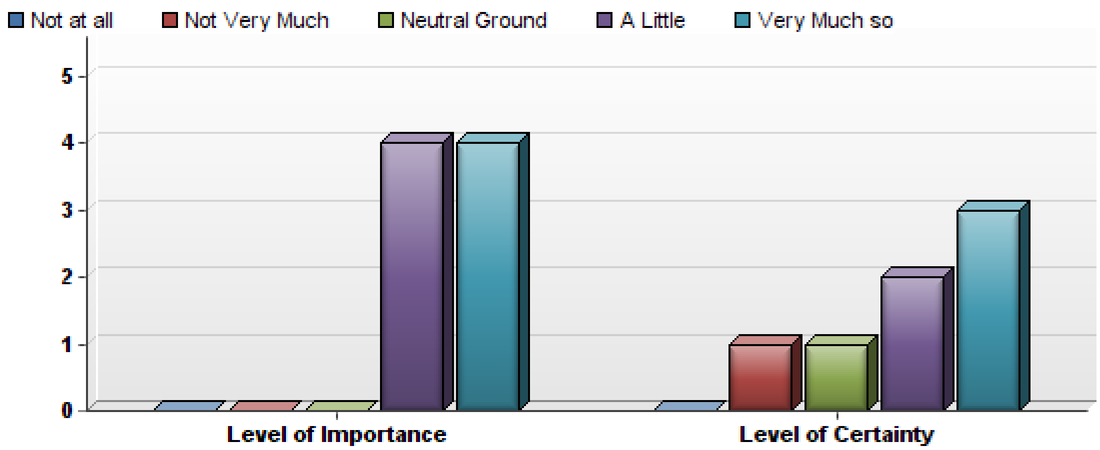
D1.10 Assessing progress and success in the area of special needs learning is sometimes difficult to express. Each individual situation may require a different measure of success for both the learner and the educators or specialists. The establishment of an improved measuring system that can both indicate progress of the learner as well as success of the learning strategy may be important.   Please rate the Role of Measured Learning and Progress Indicators as it relates to the future of the adaptive learning landscape for Special Needs students

	Not at all	Not Very Much	Neutral Ground	A Little	Very Much so
Level of Importance	■	■	■	■	■
Level of Certainty	■	■	■	■	■



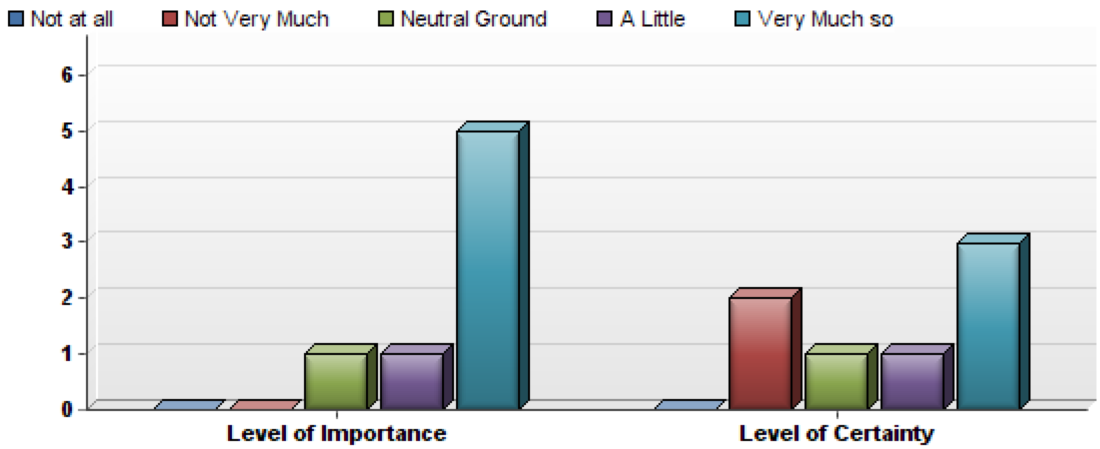
D1.11 Adaptive learning requires various tools and services to create a comprehensive plan for special need learning opportunities. Improvement of tools, both physical and software based, supportive infrastucture capabilities, and training must all be comprehended. The clear need and understanding of everyday lifestyle requirements should be comprehended in general lesson plans. Please rate the Role of Development Tools and Services as it relates to the future of the adaptive learning landscape for Special Needs students

	Not at all	Not Very Much	Neutral Ground	A Little	Very Much so
Level of Importance	■	■	■	■	■
Level of Certainty	■	■	■	■	■



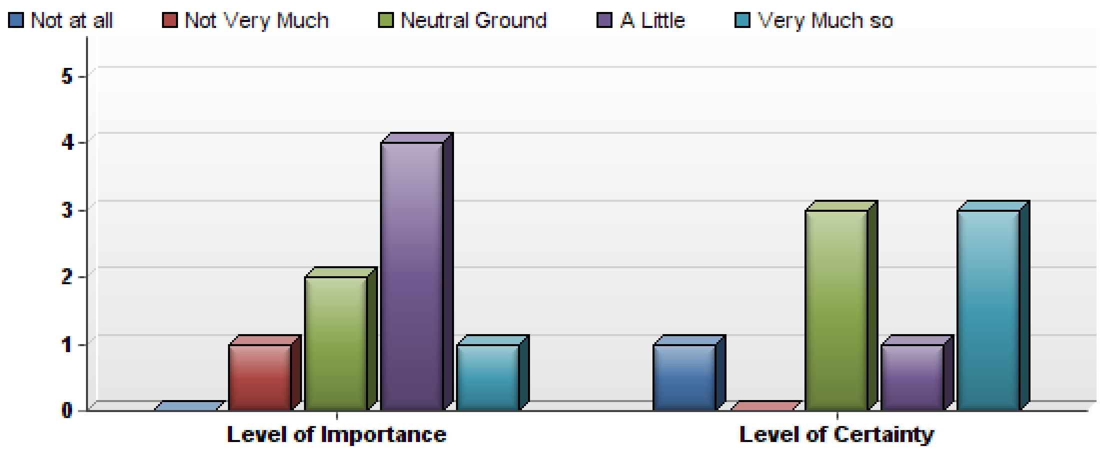
D1.11 Learning opportunities should never cease to exist. Adaptive learning in the areas of special needs individuals should continue well into adulthood promoting opportunities for skill developments and continued engagement. Additionally, learning opportunities should comprehend strategies for offsetting periodic regressions and rehabilitation.   Please rate the need for Transition Learning beyond the age of 21 as it relates to the future of the adaptive learning landscape for Special Needs students

	Not at all	Not Very Much	Neutral Ground	A Little	Very Much so
Level of Importance	■	■	■	■	■
Level of Certainty	■	■	■	■	■



D1.12 Access to adaptive learning should expand to reach any that need it. What kind of tools and infrastructure is needed to enable real time instruction and guidance. Will education become more consolidated by singular global entities or will it expand to allow for more freedom of expression and ideas. Global access to resources and personnel will help to ensure both improved performance as well as the ability to monitor for comparison. Please rate the need for Globalization of education as it relates to the future of the adaptive learning landscape for Special Needs students

	Not at all	Not Very Much	Neutral Ground	A Little	Very Much so
Level of Importance	■	■	■	■	■
Level of Certainty	■	■	■	■	■



D1.13 Please provide any additional comments that you feel we should consider regarding Adaptive Learning influencing factors for Special needs students.

10.5 Appendices – E: Scenario planning

D2.1 Aggregated Factor Influence

	Factor	Avg Focus
1	Role of Institution	3.35
2	Formal to Informal Ed	3.19
3	Provider Ed & Resources	2.97
4	Teacher Boundaries	2.89
5	Role of Technology	2.79
6	Role of Social Interaction	2.69
7	Learner Based Awareness	2.56
9	Development Tools	2.56
8	Progress Measurements	2.56
10	Life-long Learning	2.36
11	Globalization	2.00

D2.2 Certainty/Uncertainty of Factors' Future State

	Factor	Avg CERTAINTY	Avg UNCERTAINTY
1	Role of Institution	3.30	1.70
2	Formal to Informal Ed	3.38	1.63
11	Globalization	3.63	1.38
10	Life-long Learning	3.71	1.29
4	Teacher Boundaries	3.86	1.14
3	Provider Ed & Resources	3.88	1.13
7	Learner Based Awareness	4.00	1.00
8	Progress Measurements	4.00	1.00
9	Development Tools	4.00	1.00
5	Role of Technology	4.38	0.63
6	Role of Social Interaction	4.63	0.38

D2.3 Factors' level of Importance

	Factor	Avg IMPORTANCE
7	Learner Based Awareness-- Importance	5.00
6	Role of Social Interaction-- Importance	4.75
10	Life-long Learning-- Importance	4.57
9	Development Tools-- Importance	4.50
5	Role of Technology-- Importance	4.43
8	Progress Measurements-- Importance	4.25
2	Formal to Informal Ed-- Importance	4.13
3	Provider Ed & Resources-- Importance	4.13
4	Teacher Boundaries-- Importance	4.13
1	Role of Institution-- Importance	4.10
11	Globalization-- Importance	3.63