

# Personalized Adaptive Learning v 1

# **Platform Version: 2**

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# **Realizeit - Personalized Learning**

For some time now intelligent systems have been used to underpin advances in many fields such as medicine, engineering and financial analysis. We rely on this intelligence when we travel in an aircraft, undergo a procedure in a hospital and in countless ways in an everyday context. CCKF is now applying similar intelligence in a fundamental area - to underpin education and learning.

The origins of Realizeit lie in a desire to provide the means for individuals to have a 'better' learning experience, using an intelligent and adaptive on-line system that will help each learner to achieve personal learning objectives at a pace to which they are suited and to the greatest possible extent.

# 2 The Vision

CCKF began with a vision of a new generation of learning experience that would deliver truly personalized learning using a platform that could adapt to the individual but also adapt and evolve itself as it was used. The system would be content agnostic and would consider the lifelong learner as its target user.

Realizeit is the result of this vision. It is a platform that contains an intelligent learning engine that can take any target knowledge space or skill set, accompanied by any content, and provide an adaptive learning experience for an individual.



The components of the learning engine have been developed as a result of proprietary research carried out by CCKF to identify the best mathematical models to use to achieve the required goals.

# **3** Themes

A number of themes have remained constant through the development of Realizeit:

- 1. The requirement to adapt to the learner.
- 2. The requirement for the system to self-improve i.e. the system adapts itself as more people use it.
- 3. The requirement to be and remain content agnostic content from any suitable subject area and source can be 'ingested' and used or authored natively within the system.
- 4. The requirement to fulfil the lifelong learning agenda. Learning is for all the system is not limited to a particular age group or occupational group.
- The requirement to connect different knowledge domains. Interconnections exist between different subject areas at all levels and a true learning system needs to be aware of a student's competencies across all domains.
- 6. The requirement to break traditional boundaries work within or without an organization, traverse multiple sources of content; integrate and unify different curricula and skills.
- 7. The requirement for predictive analysis, based on deeply granular evidence, to improve performance, predict achievement, improve the efficiency of learning delivery, and pinpoint appropriate remedial action.

# 4 The Intelligent Learning Engine

At the core of the Realizeit Unified Learning Model is a Learning and Analytic Engine composed of complex artificial intelligence methods coupled with cognitive methods. This works in harmony with an evidence harvesting methodology, the engine providing sophisticated decision making to determine optimum pathways for each learner. The Engine integrates the Target Knowledge with the Content components of the system.



The Learning and Analytic Engine utilizes a number of complementary techniques and components:

- Content and learner profiling methods to identify the most appropriate content to achieve an objective
- Probabilistic methods for the identification of varying ability measures for learning content within the system
- A complex evidence harvesting methodology that informs the systems and enables it to determine the state of knowledge of the learner
- A powerful, dynamic engine that can transform in real-time the learning paths for each individual as they learn, and as their individual learning objectives change, are achieved, and are superseded

The Learning and Analytic Engine determines the optimum path through the knowledge elements for each learner, using the prerequisite relationships that have been established, the knowledge state and other profile information that is available for the learner, and the profile of the learning content. Each pathway is a dynamic one, that is re-evaluated and adjusted at every step in the process, taking account of new evidence that is generated through learner interactions of every kind.

Realizeit intelligently plans and directs the individual's progress towards the learning objective, allowing each learner to work at an appropriate pace and providing relevant feedback at every learner attempt. Realizeit personalizes learning by delivering suitable material to a learner at an appropriate time. The system learns about the learner, identifying weaknesses and providing guidance and remediation when it is required.

# 5 The Knowledge Space

The system identifies target knowledge spaces, with learning content set against each 'knowledge item' in this space. Each knowledge item can encompass concepts, skills or competencies of any kind. A knowledge space could encompass humanities, social sciences, STEM subjects, language learning, leadership training, advanced continuing education for high performing staff, skills training of any kind such as negotiation skills, communication, treasury management, an employee orientation course, occupational health and safety information - in fact any area of knowledge or skill set requiring learning.

The platform supports a fully connected graph of knowledge items. This graph will be used to plan different paths through the required learning objectives. The path chosen by the system will depend on the individual learner. In addition, this visual representation of the path allows for immediate visibility of the learner's achievement and progress at all points in the path.



The knowledge pathway is mapped and continually reconstructed as the learner proceeds through the learning objective or course.

The system ensures that different areas of learning exist in a fully interconnected knowledge space. That is, each course does not need to stand alone. Interconnections between knowledge and skills in one course can be connected to those in another. In this way the system will build on its knowledge of each learner - the more they use it the more the system knows about their learning styles and strengths and weaknesses. Thus, a comprehensive profile is built up for each learner, and this information can be used at any time to assist in performance evaluation.

Prerequisite relationships among different areas can be established which define the possible pathways that can be followed in terms of career development. In this way each individual can determine a learning

pathway, and clearly see the achievements that will be required in order to progress and achieve their objectives.

In this way the aim of continual education can be realized - lifelong learning becomes a reality.

#### 5.1 Learning objectives

Realizeit draws a distinction between 'curriculum' (what is going to be learned / achieved) and 'content' (how it is to be learned). This provides numerous advantages in relation to the delivery of different courses. For example, content can easily be 'rephrased' in order to create a new course 'on the fly'.

We define a curriculum as a set of related knowledge items, down to as granular a level as is desired. In fact the more granular the items the easier it will be to reuse them in different contexts. This granularity allows the institution to track all competencies and learning outcomes at a detailed level for every student. A curriculum can be as big or as small as is appropriate in a given case.



A learning 'objective' can be a full curriculum or course, or, more typically, can be a subset of the items in a curriculum. An objective can even span different curricula - combining items from different subject or skills areas to create a new course for delivery - a process that will take no more than a few minutes.

This ability to easily customize courses for delivery can prove invaluable. Learning does not need to be delivered in large chunks that have been predefined as courses, but can be quickly customized to encompass only the content that is relevant and necessary.

The separation of curriculum and content means that alternative versions of learning material can be set against a single knowledge item, catering for different learning styles and allowing a course builder to provide necessary localization.

#### 5.2 Search function

A course creator can search the system for the skills or knowledge that is required. The search will return all of the relevant curricula and potential learning objectives that exist in the system. From the search results a learning objective can be created in a matter of seconds. Once the target item is selected from the results, the system establishes all of the prerequisite knowledge that the learner will need, and dynamically and automatically combines these items to create the new objective.



The resultant objective can be assigned to a group of learners or to an individual, and immediately becomes available to them.

In this way location ceases to be an issue - an instructor can assign one or more objective and, the next time the learner logs on to the system the objectives are available to be learned, with appropriate prompting and guidance provided.

The power and flexibility of the system enables an institution to address many issues and opportunities:

- The adaptive capabilities of the system means that appropriate content can be delivered to high performing individuals to assist in their development and growth.
- The system is truly self-paced each individual learner is guided through the system in a manner, and at a pace, that is appropriate to their capabilities and based on their readiness at each step.
- Individuals can be enabled to plan their own development and extension of their skills through the use of the system, thus increasing their engagement. Learning objectives beyond the current program or course they are engaged in can be selected (or created) with little effort.
- The system can be used anytime and anywhere. Geographical and time zone difficulties are not an issue, and visibility of each learner's progress is instantaneous as they go through a course.
- New courses can be created dynamically and automatically by using existing material and the logical connections that exist between elements of the material.
- Localization to address particular needs of indigenous communities can be catered for without the need to create separate courses in each case.
- Learning can be specifically directed to immediate requirements, allowing remediation to be applied where it is needed.

# 6 Learning Pathways

The system's intelligent learning engine uses real-time evidence to identify learning achievement. As a result, the individual is guided on a personal learning journey which identifies suitable content and appropriate learning pathways, with the focus of all decisions being the selection of the most appropriate content for the learner at any given time.

Each step in the path is determined by a mathematical model that considers factors such as predicted achievement at a knowledge item, importance of the item in relation to the objective and the history of the learner in relation to this item.

The system monitors its own decision making so that it adapts itself and can learn about the things that work best for each particular learner.

# 7 Evidence Accumulation

The continuous accumulation of evidence is a key contributor to the power of Realizeit to enhance learning. This accumulation is happening at every stage in the use of the system. Whether the system is determining the learner's knowledge, the learner is working through a lesson, practicing questions, reviewing material, attempting a test or any other activity, the data recorded relating to the learner's interactions are adding to the evidence base.



All of the decisions made by the system relating to the learner's pathway, predictions of the learner's likelihood of success at an item, the content to be presented or adaptations to that content are driven by the *totality of this evidence* in real time, not by single measurements of ability taken at a specific point in time.

# 8 The Learning Cycle

The learning cycle for an individual within Realizeit can be summarized as

follows:Decide what I need to learn.

- Find out how much of it I know already.
- Determine the optimum path to achieving this learning.

I can then begin a cycle of learning, which encompasses a continuum of evidence gathering by the system in which the pathways are constantly re-evaluated based on the up-to-date evidence, leading to further learning along the (possibly altered) pathway.



This process continues until the learning objective has been achieved.

#### 8.1 Determining the Learner's Knowledge

Before an individual learns an objective, the system can determine the extent of their knowledge, using a powerful process that makes use of an underlying mathematical model to determine their state of knowledge.

The determine knowledge function can be run across a full course or across any objective or subset of nodes within a curriculum, or across curricula - the system will select appropriate questions across the appropriate knowledge space.

The mathematical model determines the nodes that will most effectively obtain the desired information relating to the learner's knowledge and ,within this, will judge the efficacy of each question type available for the node to reliably determine the knowledge state. The system seeks to extract the maximum amount of information while asking as few questions as is possible to achieve the goal.

As a result of this process, the system has an understanding of the learner's state of knowledge, and the visual representation of the outcome is available for the learner and instructor.



Determining the learner's knowledge gives the system the opportunity to figure out what is already known, so the learning process can become more efficient and is now about bridging the knowledge gap.

#### 8.2 The Learning Conversation

When the system has determined the state of the learner's knowledge, the learning process begins. The student is continually presented with information that is dynamically generated at each step to accommodate the objectives that have been set, the point at which the learner previously finished, the possible next steps with recommendations and appropriate prompts regarding activities such as assessments (which might have a deadline associated with them), gaps in the learner's knowledge (suggesting the need for practice or remediation as appropriate).

The Learning Engine facilitates this conversation by supporting the underlying functionality required to address the complexities involved in the three questions:

realize <mark>it Products</mark>	My learning	<u>My groups</u>	Accourt							
Milestones										
Guidance <u>steps</u> Progress <u>Advanced</u>										
Progress 37 mins Time spent so far										
You have queried the marking of one question. Press Questions to examine this question.										
The last learning material you covered was some time ago when you abandoned a review lesson on <u>Law of Independent Assortment</u>										
You have completed the learning for this milestone to a standard of 29%. Your current standard for "Law of Segregation" is not high enough (need at least 50%). Why not revise the material for "Law of Segregation"? Revise										
Weaker items∗										
Item		Kno	owledge te							
Law of Independent Assortment		259	%							
Law of Segregation		269	6							
Dihybrid Crosses		299	%							
Stronger itoms										

- Where am I? The system indicates to the learner their progress in relation to the learning objective.
- What do I know? The system indicates the learner's state of knowledge down to a granular level.
- What should I do next? The system uses all of the evidence that has been gathered to determine the most appropriate next step for the learner.

As each objective is pursued the system responds intelligently, guiding the presentation of content to deliver the learning that will achieve the objective.

The system learns from each learner attempt and provides immediate feedback to the learner, identifying the possible gaps in the learner knowledge, assessing the next step required, choosing and delivering learning material in response to the learning experience. The evidence gathering and feedback during delivery of the learning leads to a greater probability of success, as both system and learner are able to gauge learning progress along the pathway.

#### 8.3 The Learning Page

As the system directs the learner along a pathway, the system profiles the content available at each node against the individual, so that the learning material can be adapted to provide the optimal presentation and delivery for each learner, based on the accumulated evidence.

The learner can see the system's view of their knowledge state at each node, and can initiate learning at any time.



Lessons are broken into 'learning bits' of different pedagogical types (e.g. introductions, learning material, worked examples, summaries, interactive examples, tests etc.) so that appropriate bits can be assembled by the system and used in different learning scenarios, altering for different learners. In this way the system actually automatically adapts the path through the bits that the learner follows within a lesson.



In addition the learner can amend the path through the lesson - for example asking for further examples if they feel they have not grasped a concept fully or would like some more practice. The system will then insert a new instance of the 'learning bit', generating new values for examples and questions where relevant.

The learner can also be given access to any resources that have been associated with the current knowledge item - scanning a document, running a presentation, accessing a URL, playing a movie etc., as indicated in the description below.

Additional resources can be added at multiple levels - by a course designer, by an individual instructor or by a learner. An instructor can decide whether or not to make a resource that has been uploaded available to the learners.

The system tracks each user action throughout the lesson, adding to the evidence base as questions are answered and responses detected. Time spent at different activities is also recorded as part of the evidence gathering. Usage of each resource is tracked, and the system includes these metrics in its evaluation of content.



#### 8.4 Rich Content & Resources

A rich repository of learning material exists at every node in the knowledge space. This can include multi-media resources - videos, sound files, URLs, documents, presentations etc., as well as actual lessons and questions.

Alternative versions of any content can also be made available.

Instructors can add to the repository of resources at any point.

Learning content can be authored directly within the system and, in addition, existing content can be ingested for use. This can come in many different formats - SCORM packages, PDF files, XML etc.

The system uses profile matching to find the most suitable piece of content for an individual to use, at all times trying to maximize the chance of a successful delivery. It can evolve content profiles through observations as it figures out when the content should be used and when it should not.

Each piece of content that is served by the system will have been tailored to the individual. The engine also provides the infrastructure to allow the content to be interactive and adaptive, as all elements of the content are not generated at the start - the system generates and serves them in response to learner actions during the learning process.

Realizeit contains a fully integrated authoring system that contains a rich toolset to allow an author to determine the pedagogy to be used, and to leverage the ability of the learning engine to adapt and personalize the content for each individual.

#### 8.4.1 Importing content

Content can come from various sources, or can be authored natively in the system. Sources will vary in their popularity and their amenability to fully automatic import. It should be noted that in general no source will contain the full spectrum of items that the Realizeit system can deal with.

PDF files are probably the lowest baseline standard for importing. They contain material that has not been processed nor prepared for electronic delivery. It has all been organized for traditional printing. As such the import of PDF material could be viewed as a starting point for an electronic alternative - instead of a complete solution, as the methodologies employed between print and electronic deliveries vary.

SCORM packages are one of the accepted standards for the publication and delivery of eLearning material. They represent a good fit with the Realizeit system as the system used SCORM as its starting point - but had to extend the standard as it was insufficient to its needs.

XML is another popular structure for content. Content in an XML format can be read and processed to determine a logical structure and content organization. XML could be considered as a cross between PDF and SCORM as it provides the structural organization that might be found in PDF but none of the interactions that might be present in SCORM.

#### 8.4.2 Variable Question Generation

Traditionally digital learning systems have provided banks of static questions to present to a learner. Furthermore, there has been an over-reliance on multi-choice questions which are really only suited to lower-order skills, can be ineffective in gauging partial knowledge and provide a reasonably high chance of guessing the right answer.

	Type of question: Enter answ	er							2
Question type	Enter answer	TRUE FALSE True or False	123 Ordering N	atching	Grouping	Composite parts	Point and click	Attachment	Allowed and the second
Context	No question context details hav	e been specified yet.	<u>Create</u>						
Edit Question (The fo	llowing information will be disp	layed as the questior	n to the learner)						🖌 🖸
🗏 Source 🗼 🗄		H 🚓 🗐 🥔	BIU#	₩ X <sub>2</sub> X <sup>2</sup>		EE	👍 🚑 🤧	Ying 📄 🚍	38
	Normal  Font	Size 🗨	 А. т. Д. т.						
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									<b>_</b>
Suppose an investo	or enters a hedge fund with a \$	A1 at the beginnin	g of year 1, and	in that year t	the fund is dow	n <mark>P1</mark> %			
What is the value o	f the fund ?								
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A unique question generation component exists within Realizeit. This component provides the generic data structures that are used to represent question forms. The author of a question creates a form or 'template' which can be used by the system to generate any number of instances of the question, rather than specifying static questions.

Variable and adaptive questions allow students to attempt questions which will be generated in real time with different variable values, thus ensuring that the learner has an almost infinite number of chances to practice a question, all with the assurance of knowing that the same question will not be presented again. These variable questions are not tied to a specific content delivery, but can be re-used in different contexts throughout the system - in a lesson, when determining knowledge, when practising, in a test.

In addition the system enables a wide range of question types such as input answer, ordering, matching, mathematics input, point and click and attachment. Composite questions can also be constructed which can include any combination of available types.

Furthermore, the delivery and use of each question is monitored by the system. This allows the system to model the expected behavior of learners for each question. The results of this process are used to determine the likelihood that a particular person can answer a question correctly, along with a prediction of the length of time this will take.

These models are used by the system to adapt the questions it offers to learners and are also fed back to authors as the system can identify "bad" questions (e.g. too high a chance of guessing the answer, questions that weaker students answer better).

#### 8.5 Practice and Revision

The learner can choose to practise answering questions at any time, and may be prompted by the system to do so depending on the current knowledge state. The practice questions will at all times be tailored to the individual, and will be based on the personal achievement level at this point in time. Practice can be repeated any number of times, and the questions will be re-generated to ensure that different versions are presented each time, providing continual reinforcement of the relevant concepts.

#### 8.6 Collaboration

Learners can be given access to information relating to the progress of their friends or colleagues. They can immediately see which other people are at the same point in the knowledge space, which people have already completed the element on which they are currently working, what their colleagues are currently doing and other information depending on the access provided.

Points of interaction are also provided to allow learners to interact e.g. discussion forums, surveys etc. This interaction can be monitored and controlled by an instructor.

#### 8.7 Testing and assessment

Realizeit contains a comprehensive assessment engine that integrates seamlessly with the learning cycle and processes within the system, but can also operate largely independently.

All assessments carried out in the system provide evidence that is applied to affect a learner's state of knowledge. An instructor can use the system to automatically create an assessment to cover areas of one or more knowledge space; an assessment might be created for the current objective or it might be designed to cover everything in a knowledge space.

The system uses a genetic algorithm to automatically determine the suitable places from which questions should be drawn for an assessment. The system will then determine an appropriate range of questions to ask. The selection of questions is made to satisfy a required standard that can be absolute or relative to an

individual or group standard. The system can also balance the expected time that questions should take to ensure that an assessment is appropriate for a particular time frame.



The system will automatically draw its questions from content that has been created in the system. An instructor can allow separate assessments to be generated for individuals in a cohort (optionally forcing the same structure or not) or can choose to use the same instance of the assessment for all learners.

The content rendering engine within the system is used to deliver the assessment, and will automatically score and mark the questions as they are completed. Scores, data and other metrics are made available to learners and instructors as appropriate. More importantly, each question that is answered provides evidence to influence the system's awareness of a learner's state of knowledge. Consequently, any weaknesses become immediately apparent after an assessment.

The assessment engine can be used as part of the normal learner cycle, used to administer actual assessments, practice assessments or generate worksheets for learners, for example.

Criteria such as level of difficulty, number of attempts allowed, ways in which the questions should be grouped etc. can all be specified.

## 9 The Instructor

Realizeit provides the instructor with the means to manage cohorts of learners with potentially different learning paths and levels of performance. An instructor gains access to all of the evidence used by the system to determine its belief in the abilities of the students. This level of data provides the instructor with the knowledge needed to manage their own intervention, if required.

As a result, weaknesses or problems for individuals and for groups of learners quickly become evident and can be addressed.

Furthermore an instructor has the ability to set objectives for the learners and let the system resolve the dependencies amongst and between objectives. In a similar manner an instructor can create assessments to cover any areas with a few button clicks.

#### 9.1 Monitoring learner performance

The instructor has access to detailed evidence of performance and engagement for learners.



Overall progress, achievement and ability levels for a group of students is readily available. This is available at as granular a level as is needed, so that the instructor can identify specific areas where the group has a weakness, and can adjust their teaching accordingly.

In addition, the same level of granular evidence can be seen for each individual, with the result that the instructor can recommend further content for a student, set additional sub-objectives in the system, prompt practice of questions for a given topic, or whatever intervention is most appropriate.

#### 9.2 Assessing learners

The instructor can quickly and automatically create tests and assessments to include as part of the learning process. Again the instructor simply has to identify the topic or area that needs to be tested and all the rest is done by the system.

If so desired criteria such as level of difficulty, number of attempts allowed, ways in which the questions should be grouped etc. can be specified. The teacher can also decide if each learner is to get the same assessment - the system can, for example, be instructed to set a test for each learner with a difficulty level appropriate to each individual.

The instructor can also preview any assessment that has been constructed, and reconstruct it if they are not happy with everything.

#### 9.3 Learning material

The instructor has access to a unified set of knowledge that integrates the learning material with other teaching resources that may be used. The instructor can easily add or customize learning material. This can range from something as simple as adding a link to an external resource, to adding notes in a document or presentation format, to including a video, and to authoring questions that can be used to assess learners. A instructor can quickly learn how to incorporate generalization capabilities in questions, so that each student will be presented with different questions.

## **10 Evidence based Learning**

Realizeit represents a new paradigm of learning, providing an ongoing and evolving continuum of assessment. The system is a manifestation of an evidence based agenda, as it naturally gathers pieces of evidence and uses them to affect its belief in the ability of learners. Its ability to identify potential changes to curriculum prerequisite networks allows it to influence curriculum design and delivery.



Instant access to cumulative metrics is available at all times for cohorts of learners or for individual cases. Not only is this data available to the instructor or organization, but it is also used by the system to evaluate the effectiveness of individual pieces of content in achieving the learning objectives. In addition the system's analytics are used to question curricular assumptions, using accumulated evidence to indicate strengths and weaknesses of prerequisite relationships between knowledge items. Thus the organization can work to improve the quality of the courses it delivers using evidence gathered from its own learners' usage of the system.

This approach is possible due to the Realizeit system's use of continuous assessment, ensuring effective granular evidence.

#### **10.1 Performance evaluation**

The system utilizes all interactions with the learner as a form of assessment result, or evidence, in conjunction with innovative algorithms and tools to ensure that a complete and immediate picture of the individual's ability and progress is available and is used at all times. This is in contrast to traditional approaches to assessment which simply measure the learner's knowledge and ability at a particular point in time, with the consequence that decisions are made based on assumptions that are out of date.

The Analytical Reviews interface automatically mines the accumulated data and searches for specific correlations and relationships. If relationships are found the data is further analyzed to find all information within the data that may be correlated with the observed relationship. The analytical reviews generate visualizations and dashboards which allows the relationships and derived information to be easily digested.

There are four analytical review interfaces within Realizeit:

- Overall review this considers data across all courses and sessions within the system for an institution
- Course review this is similar to the above review but is restricted to all instances of a single course
- Instructor review this review looks at instructor performance
- Course Development review this review considers the learning material and resources available with the system



#### **10.2 Analytic Engine – Evidence Harvesting**

The Analytic engine component has been created to enable granular Evidence Based Learning Practice to be achievable quickly, easily and reliably. One capability of an evidence based learning system is the performance of gap analysis for learners and organizations.

The system ensures that the achievement gap is closed through evidence based accountability, increased flexibility in learning delivery, and a choice of learning suitable for each individual learner, so that every learner can achieve their true potential. Realizeit provides a continuum of assessment in order to identify deficiencies in the knowledge level of learners, providing timely remediation in order to assist student retention. It now becomes possible to leverage technology in order to transform the learning experience of every individual.