Intelligent Guided E-Learning Systems for Early Learners with Autism Spectrum Disorder

Alma BARRANCO-MENDOZA
Computing Science, Trinity Western University
Langley, BC, V2Y 1Y1, Canada

E. Christina BELCHER
Department of Education, Redeemer University College
Ancaster, Ontario L9K 1J4, Canada

Kenneth A. PUDLAS
School of Education, Trinity Western University
Langley, BC, V2Y 1Y1, Canada

and

Deryck R. PERSAUD
Infogenetica Bioinformatics, 3197 Tahsis Ave.
Coquitlam, BC, V3B 6E2, Canada

ABSTRACT

There is a burgeoning need to consider new ways of providing early educational services for young and often newly diagnosed children with Autism Spectrum Disorder (ASD) and their families. Such children do not respond naturally to linear curricular delivery, normally utilized in inclusive classrooms that predominate public education, but rather need an educational model incorporating intra and interpersonal development skills. In addition, there is an urgent need for the ability of keeping track of and addressing uneven progress in specific areas; characteristic of learners with ASD. It is suggested that a new curricular model be designed that integrates the advantages of e-learning for data management and communication exchange with the inclusion classroom learning. A multi-disciplinary approach to the problem has lead to the proposal of an alternate model using an Intelligent Guided E-Learning System, which can be of benefit to such learners, their parents, and their teachers. This system utilizes a Knowledge Representation model that incorporates the complex multidisciplinary data related with ASD, along with curricular information as well as other Artificial Intelligence techniques that guide the curriculum in a simple and directed, yet evolving, manner such that the complexity increases as the learner with ASD's understanding progresses.

Keywords: Intelligent Guided E-Learning Systems, Intelligent Systems, Autism, Inclusive Classrooms, Guided Curriculum, Multidisciplinary Knowledge Representation.

1. INTRODUCTION

In relation to the delivery of education to students with special learning needs, the most recent global question was whether or not a full inclusion model was efficacious. However, since it is already happening that question is moot, and the more salient issue now has become how educators, parents, and other professionals can work collaboratively to ensure that it be done well. The model of full inclusion is one in which all students are to be considered as fully functioning and fully valued members of the school community, with the primary responsibility for education being placed on the regular classroom teacher. In most instances this is a defensible ideology and a workable model. However, in regards to students with Autism Spectrum Disorder, the challenges require an extraordinary level of intervention. The purpose of this paper is to suggest the manner in which the marriage of technology and special education might lead to improved services for students, less stress for teachers, and a more positive learning outcome in general.

Autism, a term often associated with characters popularized in such media as the movie *Rainman* is not so easily defined or neatly categorized. Recently the term Autism Spectrum Disorder has been coined to acknowledge that individuals fall somewhere on a developmental continuum of the disorder and thus the educational intervention necessary varies. One aspect that remains constant, however, is that early and intensive intervention is of the most benefit if significant change and amelioration of the effects is to be achieved. [11] To that end then, some therapeutic interventions such as Applied Behavioural Analysis have been utilized. Said interventions are very intensive and very repetitive in nature. The rationale behind the present project is that using a computer-based system can mitigate some of the burden of the repetitiveness of the therapy. This has several benefits. One is that it removes the oft-present negative reciprocal reaction between the child with autism and the intervener. Another is the potential cost saving of not having to employ the expert intervener to monitor repetitive exercises. And another is the possibility of automatically charting progress along a carefully constructed custom designed developmental course.

Many factors contribute to the successful inclusive experience of students with special or diverse learning needs. What remains a key, however, is that the classroom teacher is primarily responsible for setting the tone of the classroom. Figure 1, illustrates one schematic for examining the various interrelated aspects of a merger of special education with regular education. [1] Clearly the role of teachers is paramount. Too many teachers however, very successful in their careers to this point, have not had sufficient experience or education to give them a sense of professional efficacy regarding the inclusion of students with special needs. While research indicates [12], [13] that pre-service teachers' attitudes can be influenced positively, it may be the responsibility of concerned and motivated school administrators to encourage the in-service professional development that teachers want and need if they are to provide the maximally inclusive experience for all of their students.

Teacher attitudes toward the inclusion of students with special needs have been studied by Bunch [6] and others. What seems to emerge from these studies is the old NIMBYism that was prevalent in the early days of what was then called "mainstreaming" or "integration". Another factor noted in that research is that teachers often indicate they do not perceive that their principals give them adequate support in making inclusion work.

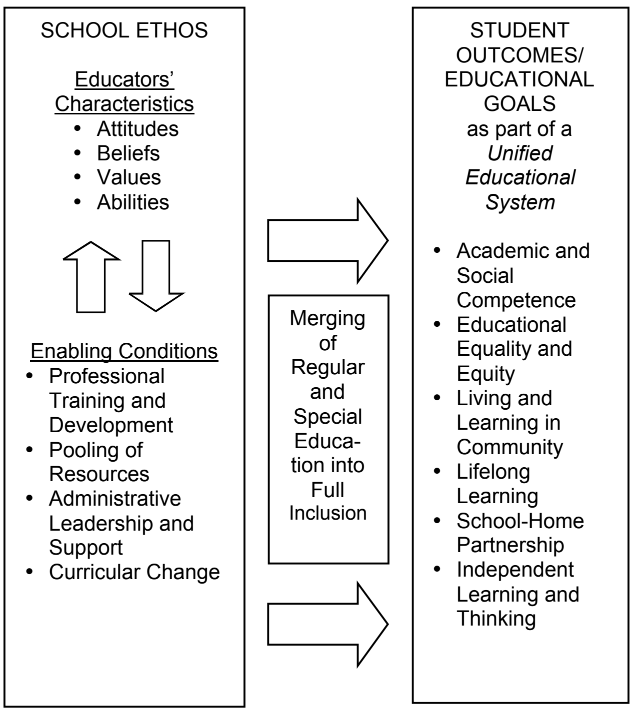

Figure 1. Factors influencing positive inclusive outcomes. Adapted from: J. Andrews and J. Lupart, J. **The inclusive classroom: Educating exceptional children.** Scarborough, ON: Nelson, 2000.

Considering all that has been said, it is currently evident that even with best intentions, integrated learning has not met the 'full' inclusion of human needs for ASD children. The reasons for this are complex, but fall mostly into the reason of inclusion being foremost geared to the perceived good regarding the rest of the class majority. Thus, the word inclusion does not denote full acceptance or allow for special needs teaching in any grand scheme or significant way. Often this premise actually furthers exclusion of the ASD learner, who is not always incorporated as a full peer in the social and intellectual parameters of the classroom, but is included in the spatial design and structure of the classroom, rather than being 'fully' included in all aspects of the life and learning it holds for other students. Although there are many frustrations and legitimate needs noted by teachers who find themselves in this predicament, the outcome for the ASD student remains less than a parent would hope for.

Part of the reason for this is that even though earlier cited models met the institutional '*systemworld'* [15] needs of schooling a student, these models did not equip the student with the social inter and intrapersonal needs for living outside or inside of the classroom (the '*lifeworld*') sufficiently. Knowledge may be dispersed, but applying it in a way meaningful to the learner as a future part of society has been found wanting. In the light of this gap, it is suggested that the guided e-learning system has much to offer.

2. METHODOLOGY

Understanding Autism Spectrum Disorder and its Treatment

As mentioned earlier ASD is a complex behavioural and cognitive disorder. The Centre for Disease Control has recently reported that 1 in 150 children under 8 year old in the USA are affected with this disorder [10] and males are three times more likely to be affected than females. The exact cause for ASD is not yet known, however there is strong evidence that there is a genetic predisposition for this condition involving at least 5 to up to 12 different genes. [14]

This disorder presents a wide variety of symptoms raging from mild to disabling. The symptoms that are the central focus of this disorder are communication and social interaction deficiencies as well as some learning difficulties as most do not respond well to traditional teaching methods. This disorder is generally diagnosed around the age of 3 or older, when communication is finally well establish in the majority of people and the delay is evident. However efforts are being made in trying to diagnosed children at earlier stages as an earlier intervention in a special education program can substantially increase the chance of the child developing and acquiring a life as self sufficient as possible, with many children having been able to achieve relatively normal lives. Unfortunately, the current resources for autistic children and their families are rare and costly, with successful programs often involving specialized behaviour consultants, speech therapists, occupational therapists and interventionists in one-to-one sessions on a recommended average of 40 hours per week for much of the child's early years. [11]

It is obvious that this level of attention is not easy to arrange nor economical and in the few provinces where these services are financially supported by federal or provincial funding, in most of them the funding is cut out when the child reaches school age as it is assumed that the public system will provide these resources. In practice, the support provided by specialists is not even close to the recommended one for a successful autism program and teachers cannot supply the time demand nor expertise required to run these programs and have to rely on minimally-trained special education assistants (SEAs) and parents to run and support these programs.

An intelligent guided e-learning system could provide a way to make the specialists' expertise available to teachers, SEAs, interventionists, and parents; provide curricular customizations depending on each users' level of expertise, maintain consistency and flow amongst all support team members both in the school and home settings, and provide a tool specifically adapted to a learner with ASD's needs.

Intelligent Guided E-learning System for Learners with ASD

The National Autistic Society, the UK's foremost charity for people with autistic spectrum disorders and their families, has identified what they call the *triad of impairments*:

- Social Interaction
- Social Communication
- Imagination

Each of these symptoms affects the way in which a learner with ASD perceives his or her environment and are factors that must be considered when developing a guided e-learning system specific to learners with ASD.

Many children with ASD are visual learners and tend to be drawn towards computers, which makes e-learning systems a natural choice for them as static and dynamic images as well as video can be incorporated as part of the learning process. However, it is also important to note that many people affected with ASD also suffer sensory integration disorders, which would require special care in terms of the interface design to address these usability issues. Some of these issues may include: visual over stimulation, which can be addressed by the use of flat screen monitors (that do not flicker, as opposed to CTR monitors), careful choice of colours, and simplifying the interface design to the minimal amount of elements; auditory sensitivity, which can be addressed by careful selection of sound and used only for pedagogical purposes; dexterity issues, which can be addressed by creating a portable design that can be manipulated by multiple means such as keyboard, pointing devices, or touch screens.

Another issue to keep in mind is that these learners do not show even progress in all areas. Many children with ASD can show an above average level in certain skills and well below average in others. It is critical that the e-learning tool is capable of detecting, keeping track, and adapting to each individual's diverse levels and dynamically customize the curriculum so that more emphasis is put on the areas of weakness, while not completely ignoring the areas of strength so that they can be reinforced.

Variety in each lesson is also a critical aspect for a tool geared for learners with ASD as many of them tend to memorize the trials or over-specify the learned concept. Hence, no two sessions can be identical and many diverse examples must be provided for each specific concept.

Traditional guided e-learning systems tend to have a linear curricular delivery with standard and consistent incremental levels of complexity. Due to the nature of the disorder, this traditional delivery is not appropriate for the early learner with ASD. Hence, here we propose a model that uses heuristics, probabilistic analysis, machine learning, multidisciplinary knowledge representation, and other Artificial Intelligence techniques to provide the flexibility and complexity required to address all the needs and characteristics of learners with ASD.

The key difficulty in the development of a multidisciplinary system including all the characteristics above described is the very different characteristics that each element of data involved in the analysis presents. Very soon we came to the realization that we needed to address a complex knowledge representation problem before being able to develop an intelligent guided e-learning system that could integrate all this data. Given the very different nature of each data element we determined that it was necessary to use a high level of abstraction to be able to capture a generalized way of representing all the elements consistently in order to be able to express both their independent characteristics and the relationships between them. Therefore, the logical step to follow was to look into knowledge representation methodologies for natural language processing, as only natural language allows the flexibility required to address concepts so distinct amongst themselves.

Concept Formation Rules

Concept Formation Rules (CFR) [8] is a directly executable new cognitive model of knowledge construction inspired in constructivist theory as well as in recent natural language processing methodologies. This system accommodates user definition of properties between concepts as well as user commands to relax their enforcement; accepts concept formation from concepts that violate principles that have been declared as '*relaxable*', and produces a list of satisfied properties and a list of violated properties as a side effect of the normal operation of the rules. CFR is described as "an approach in terms of a constraint-based formalism called Property Grammars […] which relies exclusively on constraints." [8]

Property Grammars [5] main objective is to represent in separate ways syntactic information of different kinds. The above paper continues explaining that "[i]n this approach, syntactic structure is not expressed in terms of hierarchy, but only by means of relations between categories. Such relations do not have any topological constraints; they can for example be crossed. Moreover, only relations between objects are used for describing a category. As a consequence, the notion of constituency is no longer relevant for the description process: a category is specified by a set of properties rather than by a set of constituents. In other words, the fact that several categories belong to a network of relations indicates that they characterize an upper-level category. A syntactic category is then described by a set of properties, which represent relations between other categories (lexical or syntactic)." The main goal of Property Grammars is to make explicit all the different relations that can exist.

The following types of information obtained by this approach can be summarized by the following properties:

- *Linearity*: linear precedence, which is an order relation between constituents,
- *Requirement*: sub-categorization, which indicates the co-occurrency relations between categories or sets of categories,
- *Exclusion*: the impossibility of co-occurrency between categories,
- *Unicity*: the impossibility for a category to be repeated,
- *Obligation*: the minimal set of obligatory constituents (usually one single constituent) that form the head,
- *Dependency*: the semantic relations between categories, in terms of dependency.

We have identified that these are the type of properties required to express the relations between the curricular data involved in the guided e-learning process. Therefore, we used CFR as the basis to implement the guided learning engine used by our model. This model, called the Probabilistic Property-based Model (PPBM), has been previously implemented in risk assessment systems to aid in cancer early diagnosis [3], [4] and type 2 diabetes risk assessment [2]; problems that require the integration and analysis of very complex multidisciplinary data.

Advantages of CFR: Given the multidisciplinary nature of our data, CFR offers a sufficiently high level of abstraction to represent this information in terms of concepts. Each data element, or concept, will be conformed of its own unique properties and the properties between it and other concepts.

Another advantage to CFR is the flexibility it gives to relax constraints, allowing the completion of the analysis even with incomplete information.

Limitations of CFR: CFR was originally designed for the development of natural language grammars. Therefore, even though it can be used to determine constraints between concepts, it does not deal with probabilistic analysis. Being able to evaluate the learner's performance and determine the rate of curricular progress adapted to the specific learner is the main objective, therefore CFR will be expanded to handle this probabilistic analysis.

Another issue to address is that the learning progress does not remain static throughout time. In fact, it is highly dependent on the changes of the learner's understanding throughout time. Hence, a component to extend the guided learning engine to handle temporal reasoning is necessary.

Probabilistic Property-based Model

The PPBM consists of 4 main components:

- User Interface
- Student Data Concepts
- Curricular Knowledge Store
- Guided Learning Engine

User Interface: We considered the student's specific lesson data as part of the input concepts to our model. This component enables the user to enter the information in a simple way and generates a date-stamped session knowledge base (KB) that will be added to the Student Data Concepts. For the user interface design we have considered all the usability issues specific to learners with ASD. In addition multiple views of the system are provided depending on who the current main user is: therapists, classroom teacher, SEA, parents, interventionists, or the student. The web-based design and careful use of technology standards on this component allows for use on a variety of platforms and browsers.

Student Data Concepts: The Student Data Concepts (SDC) is the collection of session KBs for a particular student. In each of them, the student's lesson state is registered based on the available information at each particular session.

To represent this knowledge, we have chosen to follow the CFR approach by defining each piece of curricular information as a *concept*.

Curricular Knowledge Store: The Curricular Knowledge Store (CKS) includes the properties that should be evaluated for each input data element as well as the relations amongst them. The lesson assessment is calculated as a function of the concepts used in the analysis. As well, the assessment will list those lesson elements that were satisfied and those that were not and automatically develop the next lesson plan based on these results so that each learner's lesson plan will be customized to each particular learner's rate of progress .

Guided Learning Engine: As mentioned earlier, Property Grammars rely exclusively on constraints. Therefore, for the implementation of the Guided Learning Engine, we use a specific constraint programming language called CHRG (Constraint Handling Rule Grammars) described in [7] on top of CHR (Constraint Handling Rules) [9].

The basic mechanism in constraint satisfaction problems is to find, for a given set of variables, an assignment that satisfies the constraint system. In the problem addressed here, the variables are taken from the set of categories. An assignment is given from an input (i.e. the SDCs to be parsed). Starting from the set of categories corresponding to the information available for a student's particular session, all possible assignments (i.e. subsets of categories) are evaluated. When a CKS category is characterized, it is added to the set of categories to be evaluated. This approach is basically incremental in the sense that any subset of categories can be evaluated. This means that adding other categories can complete an assignment ***A***. When CKS categories are inferred after the first step of the process, it is then possible to complete the first assignments (made with SDC categories) with new CKS ones.

The role of selection constraints is central in this approach. As shown before, they allow selecting the characterized category. This is due to the fact that such constraints are local to this category. Moreover, in some cases they have a global scope over the category: their '*satisfiability*' value (i.e. satisfied or violated) cannot change for a given category whatever the subset of constituents. As soon as the constraint can be evaluated, this value is permanent. For example, when a linearity or a dependency constraint is satisfied, adding new constituents to the category cannot change this fact. Other kinds of constraints have to be reevaluated at each stage. For instance, when adding a new category, we need to verify that unicity and exclusion are still satisfied. These are also called filtering constraints. Contrary to selection constraints, one cannot infer the realization of a CKS category from their evaluation. They play a filtering role in the sense that they rule out some construction.

The principle consists in completing original assignments with new categories when they are inferred. Insofar as the evaluation of selection constraints (as soon as this evaluation can be performed) is valid through a complete assignment, whatever its constituents, it is not necessary to re-calculate it. In other words, when an assignment ***A*** is made by completing another assignment ***A'***, the set of selection constraints of ***A'*** is inherited by ***A***.

3. SUMMARY AND CONCLUSIONS

It is clear that to this day the traditional inclusive classroom has not fully met the educational needs of learners with ASD. In this paper, we have presented a new model to implement within the inclusive classroom an intelligent guided e-learning system specifically designed to address the needs of early learners with ASD as well as the needs of their support team. The system can be utilized by teachers, SEAs, interventionists, and parents as a guide for one-on-one activities or as a self-directed individual learning tool for the student. The system learns and adapts from each individual interaction with the student to provide different and more challenging sessions, addressing the uneven progress, characteristic of this type of learners. It will also provide reports to teachers and parents, which will serve as means of communication for all team members and will enable smooth transitions when new team members join in or leave.

Not only is the aforementioned new model charting new ground in educational exploration for ASD learners, it does so in a way that is meaningful to the learning and life of the child. It is this former division that has hampered success in 'inclusive' classrooms in the past. It is suggested that the consideration of the whole child within the model presented will further learning for ASD children in the future in more meaningful, robust and life-giving ways.

4. REFERENCES

[1] J. Andrews and J. Lupart, **The inclusive classroom: Educating exceptional children**, Scarborough, ON: Nelson, 2000.

[2] A. Barranco-Mendoza, "Multidisciplinary Intelligent Risk Assessment System for Type II Diabetes Mellitus Patient Data Analysis and Knowledge Discovery in Datasets of Target Populations", Paper presented at the **7th International Conference on Diabetes and Indigenous People**, Ottawa, ON, August 2007.

[3] A. Barranco-Mendoza, **Stochastic and Heuristic Modelling for Analysis of the Growth of Pre-Invasive Lesions and for a Multidisciplinary Approach to Early Cancer Diagnosis**, Doctoral Dissertation, Simon Fraser University, Burnaby, BC, Canada, 2005.

[4] A. Barranco-Mendoza, D. R. Persaud, and V. Dahl, "A property-based model for lung cancer diagnosis", (ed. Gramada, A. and Bourne, P.E.), **Currents in Computational Molecular Biology**, 2004, pp. 558-559.

[5] P. Blache, "Constraints, Linguistic Theories and Natural Language Processing, Natural Language Processing", (ed. Christodoulakis, D.), **Lecture Notes in Artificial Intelligence**, Springer, 2000.

[6] G. Bunch, **Educator Opinion Questionnaire**, Ontario: Inclusion Press, 1993.

[7] H. Christiansen, "CHR as grammar formalism, a first report", **Sixth Annual Workshop of the ERCIM Working Group on Constraints** , 2001.

[8] V. Dahl and K. Voll "Concept Formation Rules: An Executable Cognitive Model of Knowledge Construction", **Proceedings of the Natural Language Understanding and Cognitive Science Workshop**, *ICEIS04*, 28-36, Porto, Portugal, 2004.

[9] T. Fruhwirth, "Theory and Practice of Constraint Handling Rules" , **Journal of Logic Programming,** 1998, **37**, 1-3.

[10] M. Hitti, "CDC: 1 in 150 Kids May have Autism", **WebMDHealth**, **Medscape Today** Feb. 8, 2007. http://www.medscape.com/viewarticle/551923

[11] C. Maurice, (Ed.) and others, **Behavioral Intervention for Young Children with Autism: A Manual for Parents and Professionals**, Austin, TX; PRO-ED, 2000.

[12] K. A. Pudlas, "Inviting inclusive education: Affective considerations", Paper presented at **the Inclusive and Supportive Education Conference**, University of Strathclyde, Glasgow, Scotland, August 2005.

[13] K. A. Pudlas, "Inclusive educational practice: Perceptions of students and teachers", **Exceptionality Education Canada**, Vol. 13, No. 1, 2003, pp. 49-64.

[14] G.D. Schellenberg, G. Dawson, Y.J. Sung, *et al.* "Evidence for multiple loci from a genome scan of autism kindred: A CPEA Study". **Molecular Psychiatry**, vol. 11, 1049–1060, 2006.

[15] T. J. Sergiovanni, **The lifeworld of leadership: Creating culture, community and personal meaning in our schools**, San Francisco: Jossey-Bass, 2000.

[16] E.C. Belcher, Is the heart of education the education of the heart? **ICCTE journal**, Vol. 2, No. 1, 2006, p. 15.

[17] E.C. Belcher, E. C. and L. Schwartz, "Re-visioning education: In search of connectedness", **Australian Teacher Education Association (AETA) 2007 Conference: Quality in teacher education: Considering different perspectives and agendas**, 2007, p. 18.