

# Effect of Concept Mapping Teaching Method on Critical Thinking Skills of Medical Students

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**Background:** Fostering critical thinking among students is one of the most important objectives of medical education. Concept mapping is an assessment tool that has the potential to measure medical student's evolving knowledge framework. This study examined the relationship between teaching methods and the ability of students to learn anatomy topics.

**Methods:** This quasi-experimental study was conducted at Ahvaz University of Medical Sciences in the medical students. Students were lectured using either the concept map method (n = 50) or a traditional lecturing method (n = 50). Student's core critical thinking skills were assessed using a seven scales test which included: analysis - measured student's analytical reasoning skills, inference - measured their ability to make inferences, evaluation - measured their evaluative reasoning skills, deduction - measured their decision-making skills in defined contexts, induction - measured students' decision-making skills when there is a level of uncertainty, and overall reasoning skills - measured students' overall strength in using reasoning to form reflective judgments about what to believe or what to do. Data were analyzed using independent samples *t*-test.

**Results:** Pretest score of California Critical Thinking Skills Test for concept map method was  $6.68 \pm 2.55$  and the lecturing method was  $6.64 \pm 2.74$ . The posttest score for concept map was  $11.64 \pm 2.29$  and for lecturing method was  $10.04 \pm 3.11$ . The comparison of mean scores' differences for both groups before and after intervention demonstrated that students' critical thinking score in the experimental group was significantly higher after intervention ( $4.88$  versus  $3.40$ ,  $P = 0.021$ ).

**Conclusion:** Anatomy topics can be effectively incorporated into concept maps, making it easier for medical students to learn anatomy topics. This suggests that concept maps are an effective educational assessment tool and should be incorporated into the medical education curriculum because it encourages students to become independent learners and enhances medical students' core critical thinking skills.

**Keywords:** concept map, critical thinking, education, medical students

## Background

Critical thinking can be defined "as the ability to apply higher cognitive skills (e.g., analysis, synthesis, self-reflection, and perspective taking) and or the ability to be open-minded and intellectually honest."<sup>1</sup> Critical thinking is the most fundamental skill every physician needs, because the complex nature of delivering health care requires physicians to gather, integrate and act constantly. It plays an essential role in physicians' clinical decision-making which is important in ensuring diagnostic accuracy, appropriate patient management, and patient outcomes.<sup>2</sup> Deficits in critical thinking among clinicians have significant implications for patients, including misdiagnosis,<sup>3</sup> delays in diagnosis,<sup>4</sup> treatment errors,<sup>5</sup> lack of patient centered care, or recognition of changes in

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clinical status.<sup>6,7</sup> United Nations Educational, Scientific and Cultural Organization (UNESCO) believes that critical thinking provides students with an up-to-date training system.<sup>8</sup> This is why medical universities and their educators need to develop a medical curriculum that will foster critical thinking among medical students. Currently, universities in Iran are still relying on old traditional methods of teaching medical students. Iranian students study basic sciences over five semesters. Then they take the national comprehensive exam called Comprehensive Basic Sciences Exam. Over the last decade in Iran, medical educators have experienced challenges in delivering the appropriate curriculum to students. They suggest that Iranian medical universities need to change their curriculum to focus on conventional teaching methods.<sup>9</sup> Conventional teaching methods are subject based and teachers try to achieve learning objectives through large group lectures, and structured laboratory experiments.<sup>10</sup> However, medical universities in the rest of the world have, for many years, been using a conventional medical curriculum because it is more stable and less expensive in terms of teaching effort, cost, and time.<sup>11</sup>

In Lecture-Based Learning (LBL) students are passively exposed to factual knowledge and do not learn or apply concepts. In the UK, there has been a shift from the traditional teacher-centered approach, which places emphasis on what professors teach, to a more student-centered approach, which puts the emphasis on students' ability to become independent learners.<sup>12</sup> However, medical education is moving away from teacher-centered approaches and is incorporating more active learning methods. Active learning processes help foster students' critical thinking skills.<sup>13</sup> Self-directed learning is an active learning approach that requires students to diagnose learning needs, formulating goals, identifying resources, implementing appropriate activities, and evaluating outcomes. It has been proven that student studying approaches lead to different learning outcomes.<sup>12</sup>

The active learning methods include Problem-Based Learning (PBL), which requires learners to acquire knowledge by using their pre-existing knowledge and skill set through the analysis of cases and generation of their own objectives,<sup>14</sup> Team-Based Learning involves individual and group assessment to promote active individual preparation while encouraging teamwork among students.<sup>15</sup> Case-Based Learning (CBL), teaches students in small groups and requires inquiry-based learning to bridge the gap between basic sciences and clinical management.<sup>16</sup> Students being taught via PBL struggle to integrate new knowledge to previously learned information and lack the ability to apply

basic science knowledge to clinical scenarios. Despite CBL, students were unable to organize, integrate information, and had a poor understanding of biochemistry which limited their ability to link the basics of clinical biochemistry to medical problems.<sup>17</sup>

As researchers were experiencing difficulty with the active learning methods, they looked for a learning method that would allow students to retain large amounts of information, integrate critical thinking skills, and solve complex clinical problems. Concept mapping has been an effective educational tool that has been used for over 25 years, and a growing body of literature indicates that its usage in medical education is increasing.<sup>18</sup> Concept maps can be used as an effective assessment tool by medical educators. Concept maps help instructors in four ways, including: helping instructors by promoting meaningful learning among students, providing an additional resource for learning, allowing instructors to provide valuable feedback to students, and by conducting AN assessment of learning and performance. It also helps medical instructors to achieve a consensus about which concepts and interrelations should be adopted in the curriculum and in what order.<sup>18</sup>

Students undergoing medical training need to learn how to connect their clinical and basic science knowledge structure to become competent future physicians.<sup>19</sup> Concept mapping is a useful learning tool that has the opportunity to promote Critical Thinking skills by providing students with opportunities to learn in a meaningful way.<sup>20</sup> The medical curricula goal is to scaffold this type of learning to allow students to become independent learners and have a greater understanding of the material.<sup>21</sup> Making the integration between clinical and basic science explicit in concept maps allows us to determine the content of the integrated curriculum and can facilitate student learning.<sup>7</sup> This method has helped students to score better on problem solving tests which require recall, transfer, and application of knowledge.<sup>22</sup> The map allows students to demonstrate holistic knowledge of a certain topic by showing how concepts on the map are interrelated.<sup>23</sup> Furthermore, concept maps encourage students to engage in collaborative and team-based learning. This process allows students to take on multiple roles as both teacher and students, and allows learners to critically reflect on their learning processes.<sup>24</sup>

According to Novak and Gowin:<sup>7,25</sup>

when constructing concept maps students and teachers have commented that they recognize new relationships

and new meanings or meanings they were not consciously aware of before making the map.

## Theory of Meaningful Learning

Novak and Gowin's theory of concept map is based on the theoretical framework of David Azubel's theory of meaningful learning. Meaningful learning requires the assimilation of new information into what the student already knows. This theory is based on the assumption that the mind is organized in a top-down fashion and that students relate new information to what they have already learned.<sup>26</sup> The developed new concepts are sorted, related, and added to existing hierarchies to develop meaning. Ultimately, learning takes place when the student is able to organize, relate, and place these concepts in their cognitive structure. They reported that meaningful learning aimed to produce a series of changes within the student's entire cognitive structure by producing modifications to existing concepts and formulating new links between concepts.<sup>7</sup>

Based on the theory of meaningful learning an individual engaging in concept learning uses three processes, which include subsumption, progressive differentiation, and integrative reconciliation. During the subsumption process, lower-order concepts are placed under higher-order concepts. For progressive differentiation, concepts are broken down into smaller sections. Integrative reconciliation occurs when the learner attempts to retrieve previously learned information and link concepts from the left to the right side of the map.<sup>27</sup>

## Theory of Concept Maps

Novak (1992) has described the concept map as an organizational tool that can represent students' knowledge and a metacognitive strategy to promote meaningful learning. These maps consist of both concepts as a "perceived regulatory in events or objects" which can be represented by using words and symbols. They also consist of propositions, "statements about an object or event, natural or constructed" that can become semantic units or units of meaning. A proposition is created when two or more concepts are connected with other words to create a meaningful statement.<sup>18,28</sup>

There are two prominent methods that medical students can use to create concept maps to promote meaningful learning. The first method involves students constructing their own maps by creating linking phrases between concepts. The second method, which is referred to as the

scaffolding expert maps, requires students to fill in blank spaces. This last method is effective for introducing students to concept mapping as it accurately reflects the knowledge structure of learners, it is more effective in demonstrating students' misunderstandings and misconceptions, it allows students to show how much they have learned, and it uses higher order cognitive processes, such as explaining and reasoning. Theorists believe the lower cognitive load associated with scaffold maps allows the learner to have a sharper focus on concepts involved.<sup>29</sup>

Researchers have reported conflicting results about the effect of concept mapping on increasing students' critical thinking skills.<sup>30-32</sup> Further research is required to clarify this matter.

## Goals and Predictions

We wanted to determine if anatomy topics can be effectively incorporated into a concept map and whether this method makes learning anatomy topics easier for students. The purpose of this was to determine if concept mapping is more effective in teaching medical students anatomy topics compared to the traditional lecturing method. We predict that students being taught the concept map method will score better on the California Critical Thinking Test compared to students being lectured in the traditional way.

## Methods

### Participants

This study was performed at Jundi Shapour Medical Sciences University in Ahvaz, Iran. We recruited 100 students (of all medical students, 56 [0.56] were female and 44 [0.44] were men). The average age was years ( $22.16 \pm 2.56$ ) and their age range was 20- to 26-years-old, and 26 (0.26) of these students were married and 74 others (0.74) were single. Also, 29 students (0.29) resided in the native province and 71 (71.0) other residents residing in the hostel were students. (Table 1). All students were in their third semester and were enrolled in the 4.0-unit anatomy course offered through Ahvaz Medical Sciences department.

### Procedure

Using formula  $n = \frac{2(z_{1-\alpha/2}-\beta)^2 \sigma^2}{d^2}$  and  $n' = \frac{n}{1+\frac{n}{N}}$  (Sample size correction formula in a community of less than 10,000 people) A total of 50 individuals were selected for intervention group and 50 subjects were randomly

**Table 1** Demographic Characteristics (N = 100)

| Variable           |                               | Number        | Percent Abundance |
|--------------------|-------------------------------|---------------|-------------------|
| Gender             | Male                          | 44            | 0.44              |
|                    | Female                        | 56            | 0.56              |
| Age (Mean + SD)    | 22.16 ± 2.56                  | The age range | 20–26             |
| Marital status     | Married                       | 26            | 0.26              |
|                    | Single                        | 74            | 0.74              |
| Residential status | Resident in student dormitory | 29            | 0.29              |
|                    | Native residence              | 71            | 0.71              |
| Experimental group | Female                        | 30            | 0.60              |
|                    | Male                          | 20            | 0.40              |
| Control group      | Female                        | 27            | 0.54              |
|                    | Male                          | 23            | 0.46              |

selected (using a class list) for control group. The selection of intervention and control groups was done randomly.

## Study Design

First students were asked to answer demographic questions and then students were given the California Critical Thinking Skills Test to assess their critical thinking skills. The critical thinking test was performed before the start of the first and last teaching sessions. The teacher for both groups was an associate professor who had taught anatomy for 15 years.

Students assigned to the control group were lectured in anatomy topics using the traditional approach. Anatomy was lectured to students in block sessions. During the 12 sessions, the instructor taught lectures and used blackboard, projector, and slide teaching, but the main point of the class was a one-way lecture given by the teacher. The concept mapping method was presented to the experimental group. They were instructed about concept mapping and construction methods before starting the workshop. The workshop the students attended was presented in a series course format and consisted of three sessions. Each teaching session lasted for about 120 minutes. According to the professor of the course, four topics from all areas were selected. At the end of each lesson, students from the intervention group were asked to design a conceptual map for the lessons learned. At the end of the semester, both groups of students were assessed by a single test.

For a more comprehensive outline the following steps were taken:

Concepts and sub-concepts were determined after reading instructed contents to students. To make a concept map, students had to link together a series of concepts using arrow lines with a proposition written above the line to describe how concepts are related. These concepts were arranged in a hierarchical form with general concepts placed at top of the map and specific concepts placed below, or extending outward. Students showed the relationship between concepts by creating cross-links, which are connected by arrow lines labeled with a phrase describing the relationship. The final component of the map required students to use examples, which linked the related concept in the most subordinate position and was not enclosed in a circle ([Appendix 1](#)).

## Sampling Procedures

After obtaining permission from the ethics department, informed consent was collected from 100 student participants. Participants were assigned a code and were informed that results would be reported in general in order to pay attention to research ethics. The course design pattern was approved by the Educational Development Center and was based on professors' lessons and course plans. To comply with research ethics, the same content of how to construct concept maps was presented to the control group post-intervention.

The California Critical Thinking Skills Test was used to assess students' critical thinking skills. The test consists of 34 multiple-choices questions and includes seven subscales, analysis, interpretation, inference, evaluation, expiation, inductive, and deductive reasoning. Total scores were considered as the criterion for the efficacy of concept map. Students could gain scores from zero to a maximum of 34.<sup>33</sup> How students were scored . . . look at concept map collaborative mapping in measures they have a heading specifically on the California Critical Thinking Test. To examine the effect of the concept map on increasing critical thinking, the difference between the mean scores of the pretest and posttest of students in each group was calculated and the differences between the two groups were analyzed for these changes. The reliability of the test is 0.90 Cronbach's Alpha and the construct validity was confirmed by Khalili et al through factor analysis.

## Data Analysis

The gathered data were analyzed using the SPSS software version 16. In addition to the analysis of descriptive statistics, relative frequency and averages (what averages were calculated) were calculated. First, normal distribution for

both variables was validated by referring to Kolmogorov-Smirnoff test. An independent *t*-test was used to compare scores of critical thinking between the two groups before and after intervention, as well as to compare the mean differences of critical thinking scores between groups.

## Results

In the experimental group, 60% of subjects were female and 40% were male. In the control group 54% were female and 46% were male.

The average age of students is  $20.93 \pm 0.86$  and mean grades of their previous semester was  $15.32 \pm 1.20$ . There were no significant differences found between the experimental and control groups for previous grade point average and age. Table 2 highlights the correlation between average age and grade point average of students.

Table 3 shows that the mean scores of the pretest in the experimental and control groups showed no significant difference in terms of critical thinking ( $P = 2.74 \pm 6.64$  vs.  $2.55 \pm 6.68$ , 0.94). There were no statistically significant differences found between observed scores when comparing students' average scores before the intervention *t*-test. However, students in the experimental group had higher mean scores of critical thinking skills during post-intervention compared to the control group. Furthermore, there were significant mean

**Table 2** The Mean and Standard Deviation of Age and Grade Point of Students in Both Experimental and Control Groups

| Variable                     | Control Group    | Experimental Group | t     | p-value |
|------------------------------|------------------|--------------------|-------|---------|
| GPA of the previous semester | $15.45 \pm 1.17$ | $15.20 \pm 1.24$   | 1.09  | 0.28    |
| Students' age                | $20.90 \pm 0.84$ | $20.96 \pm 0.88$   | 0.349 | 0.73    |

Abbreviation: GPA, Grade Point Average.

**Table 3** The Comparison of the Mean Scores of Critical Thinking in Both Experimental and Control Groups Before and After Intervention

| Variable            | Control Group    | Experimental Group | t     | p-value |
|---------------------|------------------|--------------------|-------|---------|
| Before intervention | $6.64 \pm 2.74$  | $6.68 \pm 2.55$    | 0.076 | 0.94    |
| After intervention  | $10.04 \pm 3.11$ | $11.64 \pm 2.29$   | 2.93  | 0.004   |
| Difference          | $3.40 \pm 3.34$  | $5.04 \pm 4.88$    | 2.34  | 0.021   |

**Table 4** Comparison of Mean Scores in Anatomy Course in Both Experimental and Control Groups

| Variable                  | Control group   | Experimental Group | t    | p-value |
|---------------------------|-----------------|--------------------|------|---------|
| Average scores in anatomy | $5.58 \pm 1.78$ | $6.38 \pm 1.14$    | 2.67 | 0.009   |

**Table 5** Paired Sample *t*-test to Investigate the Pre-Test and Post-Test Score in Five Variables of Critical Thinking Skills in the Control Group

| Variable                 | Mean   |       | SD     |       | t    | p-value |
|--------------------------|--------|-------|--------|-------|------|---------|
|                          | Before | After | Before | After |      |         |
| Analysis                 | 5.58   | 5.39  | 2.39   | 1.81  | 4.39 | 0.284   |
| Evaluation               | 4.20   | 4.93  | 2.11   | 1.93  | 5.78 | 0.346   |
| Inference                | 6.39   | 6.71  | 2.64   | 1.62  | 5.36 | 0.290   |
| Deduction                | 6.74   | 6.97  | 1.98   | 1.37  | 5.92 | 0.114   |
| Induction                | 6.26   | 6.24  | 2.85   | 1.44  | 5.06 | 0.273   |
| Overall Reasoning Skills | 6.15   | 6.70  | 2.27   | 1.95  | 6.15 | 0.221   |

differences among comparison groups before and after the intervention ( $P = 0.021$ ).

According to Table 4, the results suggest that the concept map method can be a more effective teaching method compared to traditional methods.

According to Table 5, students' critical thinking skills scores in the control group between pre-test and post-test in each of the five variables had no significant difference ( $P < 0.05$ ).

According to Table 6, students' critical thinking skills scores in the experimental group between pre-test and post-test in each of the five variables had a significant

**Table 6** Paired Sample *t*-test to Investigate the Pre-Test and Post-Test Score in Five Variables of Critical Thinking Skills in the Experimental Group

| Variable                 | Mean   |       | SD     |       | t    | p-value |
|--------------------------|--------|-------|--------|-------|------|---------|
|                          | Before | After | Before | After |      |         |
| Analysis                 | 5.06   | 8.94  | 1.26   | 1.09  | 6.30 | 0.0001  |
| Evaluation               | 4.62   | 8.83  | 2.63   | 1.98  | 4.96 | 0.0001  |
| Inference                | 6.68   | 9.93  | 1.56   | 2.32  | 7.51 | 0.0001  |
| Deduction                | 6.88   | 9.04  | 2.31   | 2.20  | 7.63 | 0.0001  |
| Induction                | 6.64   | 9.36  | 3.22   | 2.01  | 6.22 | 0.0001  |
| Overall Reasoning Skills | 5.98   | 8.61  | 1.49   | 2.14  | 7.02 | 0.0001  |

difference and this difference was also statistically significant ( $p = 0001$ ).

## Discussion

This study attempted to examine whether concept mapping enhances medical students' critical thinking skills. The results indicate that critical thinking scores were higher in the experimental group compared to the control group. These findings suggest that anatomy topics can be effectively incorporated into a concept map and make it easier for students to learn anatomy topics compared to students being lectured in anatomy using traditional methods. These results are similar to previous studies conducted. Zipp et al believes that students involved in the active construction of concept maps will have more advanced critical thinking skills compared to the control group.<sup>34</sup> Motari et al, like Rahmin et al, found that nursing students who had prior exposure to concept maps had higher critical thinking scores compared to the control group.<sup>35–37</sup> Ho et al found that junior medical students who had been exposed to the pathogenesis map scored better than the non-exposed group on topics that had been covered using the map. They suggest that online scaffold concept maps can make it easier for students to learn pathology topics and can also be incorporated into courses with a pathology focus.<sup>38</sup> West et al, like Daley et al, found that concept mapping scores improved after instruction.<sup>39</sup> Researchers at the University of California, examined the relationship between concept mapping and critical thinking for 21 medical assistants and found that concept mapping can help students develop critical thinking skills.<sup>40</sup> Taiwanese researchers confirmed the effect of previous exposure of concept mapping on increasing the total score of critical thinking skills.<sup>41</sup>

Educational researchers have reported different results for the effect of concept mapping on critical thinking. D'Antoniin et al (2010) conducted a quasi-experimental study to determine the effect of concept mapping on critical thinking skills for first-year medical students. They found that concept mapping failed to increase the level of critical thinking in students. Abdoli demonstrated that overall mean critical thinking was not statistically significant after intervention for nursing students in their fourth semester at Isfahan University.<sup>42</sup> Several studies indicate that there was no difference between control and intervention group on multiple choice examinations. West et al found that CMA scores did not correlate with the final scores or the standardized test scores. Their findings show

an absence of positive correlation which suggests that Concept Mapping Assessment (CMA) measures a different knowledge characteristic compared to multiple choice examinations. They believe that CMA has the potential to measure how residents and students use organized knowledge in a way that the traditional test cannot.<sup>18</sup> Gonzalez et al (2008) demonstrated how concept maps can be used to teach medical students physiology. Their study involved two groups; a control group, who were taught physiology using traditional methods and an intervention group who constructed concept maps related to cardiac physiology and used them to solve problems related to this subject. Both groups were tested using problem-solving and multiple choice examinations. Findings highlight that students in the intervention group performed better in the problem-solving examination.<sup>22</sup>

## Recommendations and Limitations

The present study focused on increasing medical students' critical thinking skills. Further research is recommended to determine the effectiveness of concept map method ability to increase Persian medical students' critical thinking skills. We recommend that future researchers design a study with a larger sample size that includes professional doctoral (PhD) students (medical, dental and pharmacy). For future studies, it would be valuable to use a blinded study design to control for the interaction between both groups. This will help to reduce information exchanging between the experimental and control groups. Participants withdrew during the second stage of the study due to the challenges of administering the California Critical Thinking Questionnaire. Future research, should address the challenges associated with administering the California Critical Thinking Questionnaire in order to reduce participant attrition rate. We recommend that researchers explain the benefits and advantages of this study to potential participants prior to the start of the study.

Concept mapping is an effective learning resource for students because it allows students to show their specific knowledge about concepts they have mastered associated with a specific topic. Laight (2004) designed a study that demonstrated student attitude toward using concept maps as an additional learning resource. Participants reported being more motivated to think deeply and gained an understanding of conceptual inter-relationships.<sup>43</sup> Students reported that concept maps allowed for creativity by developing systems of thinking that included patterns of recognition, a broader thinking perspective about topics,

and allowed for knowledge integration.<sup>44</sup> Future research studies need to assess students' satisfaction and willingness to adopt concept mapping as a learning tool.

## Implications for Medical Research

Most of the research conducted on the effectiveness of concept maps in medical education has focused primarily on the nursing population. Whereas, our study included a broader sample of medical education students including medical students, nurses, etc. There are limited studies similar to ours that have taught the intervention group concept mapping and then tested students' critical thinking skills by giving them the California Critical Thinking Test, which is a 34-item multiple choice test. As mentioned previously, some researchers have pointed out that multiple choice examinations are ineffective for determining students' critical thinking skills. We would recommend that our study be replicated to determine the effectiveness of concept mapping in increasing students' critical thinking skills and to determine whether the California Critical Thinking Test is a useful measure to assess students' critical thinking skills. We also suggest that medical education researchers should include a broader sample of medical education students to determine the effectiveness of concept mapping within specific disciplines of medical education.

Research has shown that concept mapping can be used as an effective educational assessment tool in medical classes, such as pathology. Specific research needs to be conducted to determine the validity of using concept mapping within medical school curriculums. As there is more than one way to create a concept map, a scoring method that corresponds to the particular map should be chosen. For concept maps to be incorporated into medical education curriculums there needs to be further development in the area of assessment and scoring. Further research on how to improve the validity and reliability testing of concept mapping is also required.

There is limited research on the longitudinal effects of concept maps within medical education. Longitudinal research can help determine whether concept maps help medical students make the transition to practicing doctors. This type of research should assess the changes in knowledge structure and thinking patterns that occur within a physician's career. This type of longitudinal research may help us to determine how concept maps can aide in physicians' clinical reasoning processes.

## Conclusion

Anatomy topics can be effectively incorporated into concept mapping making it easier for medical students to learn anatomy topics. Students being taught anatomy topics with the concept map method had higher scores on the California Critical Thinking Test compared to students in the traditional lecturing group. This suggests that concept mapping is an effective educational assessment tool and should be incorporated into the medical education curriculum because it encourages students to become independent learners and enhances medical students' core critical thinking skills.

Current evidence, suggests that professors should incorporate more active teaching methods such as concept map methods into their lesson plans to improve medical students' critical thinking skills.

## Data Sharing Statement

If there is a need to further review the accuracy of the presented data you can contact Education Development Center of Shiraz University of Medical Sciences.

## Ethics

The present study has been evaluated by Ethics Committee of Shiraz University of Medical Sciences. They have provided this study with an Ethics Code of: IR.SUMS.REC.F1202.

## Disclosure

The authors report no conflicts of interest in this work.

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