DOI: 10.17323/2587-814X.2022.2.36.48

Technologies of collective intelligence in the management of business processes of an organization

Boris B. Slavin
E-mail: bbslavin@gmail.com

Financial University under the Government of the Russian Federation
Address: 49, Leningradsky Prospekt, Moscow 125993, Russia

Abstract

With the digitalization of the economy, the creative component of an organization's activities increases. Standard business process management methods stop working due to the rise in uncertainty of the task solution time. Currently, there are no effective technologies for managing intellectual activity processes in organizations. The role of collective intelligence technologies for knowledge management in organizations has long been discussed in the literature, but there are still no concrete proposals on implementation. This work aims to show how collective technologies can solve the problems of managing business processes of intellectual activity. The possibility of collective intelligence technologies for increasing labor productivity is demonstrated. Models for distributing tasks by competencies and synergy from collaboration are proposed for this demonstration. The paper shows that competencies are the primary metric that can be used to measure work with knowledge in an organization. But they should also be considered when organizing group activities. A simple model example shows that the correct distribution of tasks by competencies allows you to increase the speed of solving tasks by a group by several times. In real cases, calculations using computing resources are necessary. A model is also proposed that demonstrates increasing the joint activity of a creative employee and an analyst. It is shown that business process management should be supplemented by mapping the competence model and group work options to the stages of business processes. This will allow you to manage the business processes of intellectual activity.

Keywords: collective intelligence, competencies, knowledge management systems, business processes, intellectual activity, synergy, brainstorming, group work

Citation: Slavin B.B. (2022) Technologies of collective intelligence in the management of business processes of an organization. *Business Informatics*, vol. 16, no. 2, pp. 36–48.
DOI: 10.17323/2587-814X.2022.2.36.48

Introduction

Organizations that have passed or are undergoing a stage of digital transformation are starting to compete in the innovation market. To do this, they need to create new products and services on a much larger scale than before. In the pre-digital era, the departments involved in the introduction of innovations were few, but they coped with their work. Today, many technologists, developers and managers are involved in the creation of innovative products. That is why DevOps and BizOps technologies are becoming popular, involving the creation of a continuous pipeline from the development of new products (Dev – Development) to their commissioning (Ops – Operations) and back, or even starting with ideas generated by business (Biz – Business). In this regard, the share of employees of such organizations engaged in creative intellectual activity increases by a multiple. It is no coincidence that industries at the center of the "digital vortex" are the main consumer of creative personnel today, and they feel "hunger" in them.

However, not only problems with the labor market arise during the transition to a knowledge society. Increasing the share of creative activity requires a radical revision of approaches to business process management. Let us show this with a simple example. *Figure 1* shows a simple business process consisting of four stages. For each stage of the business process, graphs of the probability of its execution in time are given, where the value "1" means execution. The condition that the entire business process will be manageable is that each stage must be completed on time. Usually, even a little more time is laid on the execution so that it is highly likely to be executed. Moreover, the execution time is standardized, and according to such normatives, it is possible to accurately predict when the business process will be executed. For example, in car services, both the labor intensity and the time of order execution are calculated in this way. The entire business process management system in the organization is built on the fulfilment of this rather obvious condition.

However, if the business process concerns creative activity, the end time of the stages will be unpredictable. The stage may end much earlier than the allotted time, or it may end much later. *Figure* 2 shows the probability densities of completing the stages in the case of creative activity.

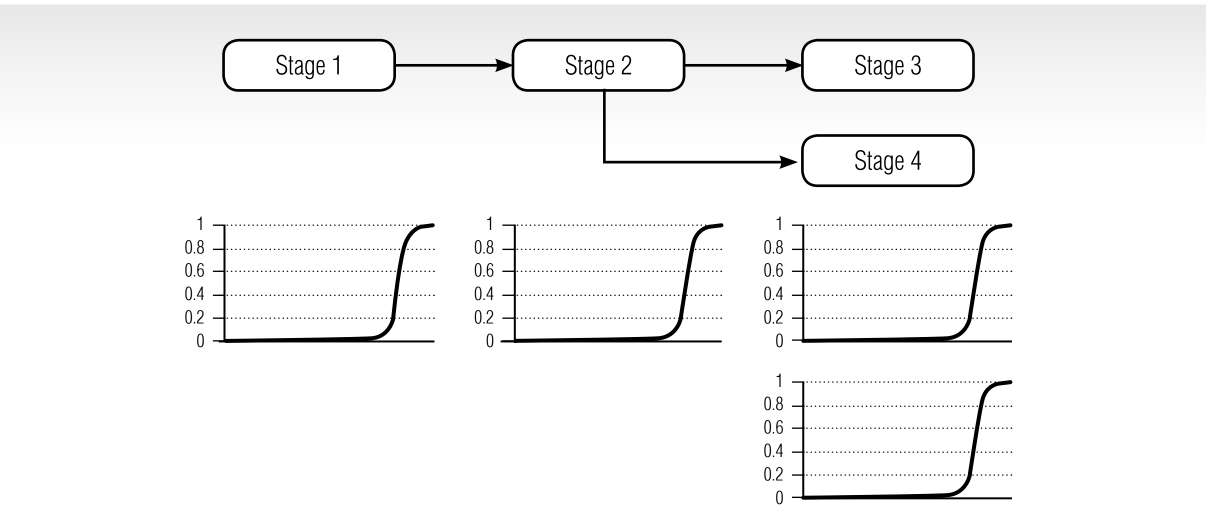

Fig. 1. Diagram of the business process and the probability of completion of stages on time in normal activities.

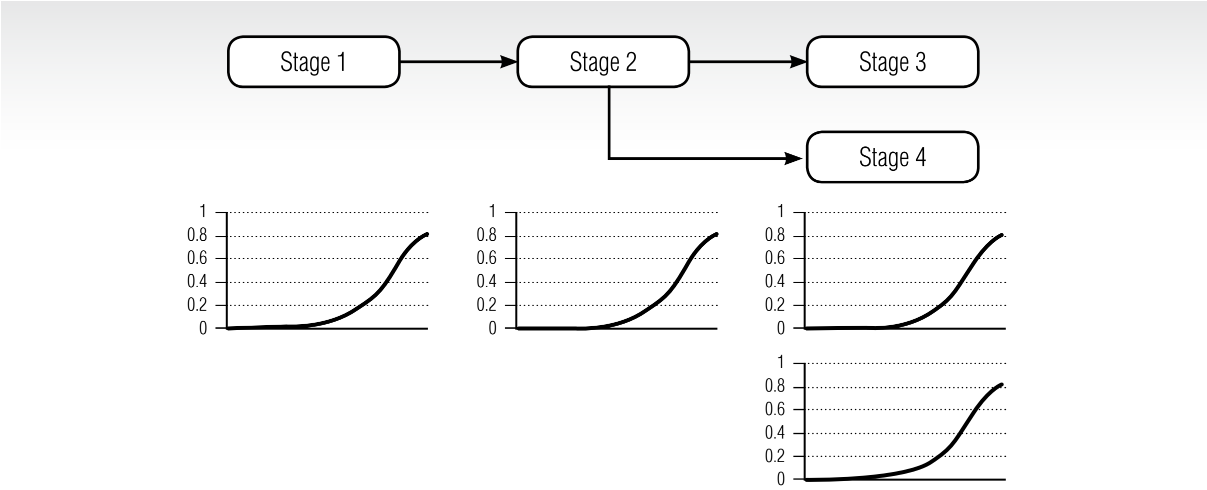

Fig. 2. The scheme of the business process and the probability of execution of stages in creative activity.

In fact, such a business process will be unmanageable, since the probabilities that the stages will not be completed on time will multiply, and the end time of the entire process will become unpredictable. You can, of course, significantly increase the time for each of the stages, but then the efficiency of the business process will be excessively low and employees will be idle most of the time. When innovation departments were small, they were simply taken out of the framework of the business process management system and set goals with indefinite deadlines. In the case when innovation units are integrated into common business processes, as is the case today with companies caught in the center of digital transformation, business process management systems will not work. Collective intelligence technologies and a competency-based approach to process management should help solve this problem.

1. From knowledge management to competence management

In [1] it is shown that the analogue of a commodity in the knowledge economy will not be knowledge itself, but the ability of people to operate with knowledge, i.e., their competence [2]. Unlike knowledge, the cost of competencies is proportional to the cost price, i.e., the costs necessary for human education. If the part of the costs of teachers can be attributed to several students (which means that such costs can be reduced), then the time resources of the student himself are not replicated, and in the future, they will probably determine a significant share of the cost of training. Moreover, investments in competencies are quite market-based and give the same return as investments in the production of goods and services. For example, according to economists, one year of study increases the salary by 10% on average. This, in turn, means that total investment in human competencies will be more profitable as we move to the knowledge economy.

Due to the special role of competencies in the innovation economy, studies of the possibility of building competence management systems, organizing creative activities, measuring and increasing the value of human capital become relevant [3]. Currently, only personnel accounting information systems have become widespread, but the market is already growing demand for such subject-oriented information systems as Talent management, Career Development Planning, Competence Management, etc. Competence management as a concept first appeared in the field of education 40 years ago [4], but it became widespread in business later [5]. Darnton [6] formulated the main components of the competence management process, to which he attributed: the relationship of employee competencies with the strategy and objectives of the enterprise, the conditions for the development of competencies, their classification, development planning and competence control. Competence management is part of the general knowledge management system (Knowledge Management System, KMS) [7], if by knowledge we mean explicit and implicit knowledge. For the first time to highlight "tacit" or implicit knowledge (tacit knowledge) back in 1958, Polani [8, p. 23] proposed, referring to them the knowledge that a person has beyond what he can say. In relation to knowledge in an organization, Nonaka and Takeuchi [9] used the term "implicit knowledge" in their book "The company that creates knowledge", calling it more often "unformalized" knowledge: "Unformalized knowledge (or "implicit") is personal and dependent on the situation and therefore difficult to formalize and disseminate" [9, p. 84]. Competencies include implicit knowledge, and, unlike knowledge, are measurable. Since it is possible to talk about managing something only if the object of management is measurable, the concept of competence management makes sense in contrast to knowledge management. However, you can still use the term of knowledge management, meaning by it is the management of people's competencies for the creation and use of knowledge.

2. Technologies of collective intelligence

The competence approach plays a special role in the technologies of collective intelligence. The concept of collective intelligence has a broad interpretation, and in one form or another (wisdom of the crowd, collective intelligence, etc.) it can be found in scientific literature dating back many hundreds of years ago [10]. The term Collective Intelligence itself was apparently first introduced by David Wexler, the creator of the so-called Wexler intelligence assessment scales. Wexler [11, p. 906] argued that collective intelligence arises only when group members use common intellectual resources in their activities. Many works were devoted to the possibilities of collective creative activity at the end of the last century. Let us note as an example the book by the Fischer spouses [12] "Distributed minds: Achieving high productivity through the collective intelligence of working groups", which discusses approaches to the collectivization of knowledge in organizations. Nevertheless, the problems of collective intelligence received the most attention only with the development of the Internet [13]. It was the era of the Internet that was marked by a strong interest in the problems of collective intelligence.

At the end of the last century, Canadian publicist Levy [14] published a book entitled "Collective intelligence: Mankind's emerging world in cyberspace", in which he called for creating a society where cyber technologies have a humanizing influence and contribute to the emergence of "collective intelligence." Heylighen (author of the book "The global superorganism: An evolutionary-cybernetic model of the emerging network society" [15]) wrote that it is very important to learn how to use network communications to increase "collective intelligence" in such a way that group intelligence exceeds the sum of the intelligences of group members [16, p. 92]. Researchers of collective intelligence pay special attention to the Wikipedia project. For example, American scientists from Carnegie Mellon University have identified the relationship between the complexity of Wikipedia content and the competence of the editors of this project [17]. Horost [18, p. 251], who generally views all network resources as a global brain with memory, nodes and synapses, wrote about Wikipedia as a collective knowledge base: "Wikipedia is distinguished by its "intelligence," which it develops through collective consciousness and content editing. And again, we see the total sum of many individual judgments about what is important and what is not... The resulting knowledge differs from PageRank, but both resources complement each other perfectly. In combination, they form, as it were, the incipient frontal lobes, the hippocampus and a kind of long-term memory Network".

Zettsu and Kiyoki [19] wrote the fact that collective intelligence technologies are one of the tools for knowledge management on the Internet. In [20], it was generally proposed to consider all social networks as a knowledge infrastructure (knoware) of collective intelligence. The authors introduce such concepts as a "supernet of knowledge," which includes media networks, user networks and knowledge networks. A group led by Malone [21] conducts many studies on the topic of collective intelligence at the Massachusetts Institute of Technology in the USA. Scientists of this group are studying various ways of applying collective intelligence technologies, both for organizing global network projects and for improving business efficiency. Such works as [22, 23] are devoted to the use of collective intelligence technologies as special information systems of enterprises. In [24], collective intelligence technologies were considered as technologies for improving the efficiency of human activity by analogy with the use of business intelligence tools.

In [25] Malone and his colleagues proposed a classification, which they called the "genome" of collective intelligence. However, in fact, this classification did not reveal the features of collective intelligence technologies, but simply allowed ranking all global network projects. Many researchers, following Malone, also do not distinguish between crowdsourcing technologies and technologies of collective intelligence [26, 27]. However, there is another point of view. So Gruber [28, p. 4], describing crowdsourcing technologies and social networks, writes that they can only claim to be called a "collection of intelligences, but they are not a single collective intelligence, since they do not support group thinking.

There is currently no consensus on what collective intelligence technologies should include. This study supports and develops the point of view that collective intelligence technologies are tools and systems "that unite into groups the necessary number of people who have their own individual goals but organized in such a way that the overall intelligence and effectiveness of the group increases" [29, p. 219]. Within the framework of this approach, it is possible to define collective intelligence technologies as a special form of "information technologies that contribute to the collective solution of intellectual and creative tasks using network communications" [10].

3. The role of competencies in collective intelligence technologies

Let us look at some examples that show the effectiveness of collective intelligence technologies in organizing creative activities. The first thing that such technologies allow – due to the correct consideration of competencies in the distribution of tasks that the group solves – is to significantly speed up their solution. Let us assume that we have a group of four employees with different competencies (let there be 6 of them), which indicate the probability of solving a problem for this competence (this is how the human intelligence index, IQ, is usually measured). For simplicity, let these probabilities be either 0 (there is no competence) or 1 (competence allows you to solve the problem with probability 1). Then the range of competencies of such a group can be described by a rectangular matrix shown in *Fig. 3a*. The first employee uniquely solves the tasks of the first two and fourth competencies, the second – from the third to the fifth, etc.

a)

1	0	1	0
1	0	1	1
0	1	0	0
1	1	0	0
0	1	1	0
0	0	1	1

b)

1	1	1	1
1	1	1	1
1	1	1	1
1	1	1	1
1	1	1	1
1	1	1	1
3	**3**	**4**	**2**

Fig. 3. Competence matrix (a), group distribution matrix (b).

Let this group also solve problems collected in four sets of six competencies each. And let us assume that these tasks are distributed evenly among the participants (*Fig. 3b*). With such assumptions, the tasks will be solved only if the solvers have similar competencies – the results of the work are shown in the row under the matrix in *Fig. 3b*. It can be seen that on average the participants of such a group will solve three tasks.

However, if we distribute the tasks among the participants in a different way (see the group distribution matrix in *Fig. 4b*), keeping the load on each participant – six tasks, we can ensure that each of the participants solves all six tasks. That is to say, the productivity of the group will be twice as high and simply due to the correct selection of competencies. It is the finding of a group (or collaborative) distribution matrix that is necessary when organizing work within the framework of collective intelligence technology.

In the case when a larger number of employees participate in the group, and the probability of their solving problems differs from 0 or 1, numerical calculations must be carried out, while the difference in productivity may be even higher. The algorithm for organizing group work based on the calculation of the collaborative matrix is an analogue of the division of labor, but for intellectual activity. It is clear that it is difficult to accurately measure the probability of solving certain tasks, but it is possible to assess the speed of their solution by one or another specialist. The correct division of the overall task into subtasks and the correct selection of personnel facilitates the effective use of intellectual resources. In the current practice of conducting complex scientific research, managers are still carrying out such a distribution, relying only on intuition.

a)

1	0	1	0
1	0	1	1
0	1	0	0
1	1	0	0
0	1	1	0
0	0	1	1

b)

3	0	1	0
0	0	1	3
0	4	0	0
3	1	0	0
0	1	3	0
0	0	1	3
6	**6**	**6**	**6**

Fig. 4. Competence matrix (a), heterogeneous group distribution matrix (b).

4. Synergy in collective intelligence

The division of people by technical competencies is not the only condition for the effectiveness of collective intellectual activity. It is important to properly organize joint work on one task, or synergy, which considers creative and analytical competencies. The division of experts into analysts and "idea generators" is an important component of the brainstorming method. Altshuller [30, p. 10] in his book "The invention algorithm" describes this method proposed by the American journalist Alex Osborne at the end of the 1930s: "There are people who are good at "generating" ideas, but do not cope well with their analysis. And vice versa: some people are more inclined to critically analyse ideas than to "generate" them. Osborne decided to separate these processes. Let one group, having received a task, only put forward ideas, even the most fantastic ones. Let the other group only analyze the ideas put forward". Even though the "generation" of ideas and their analysis can be considered different competencies, it is especially necessary to take them into account when organizing intellectual activity, since one task cannot be divided into the phase of developing ideas and the phase of their concretization; joint work is necessary.

To understand how the synergy effect is achieved when a creative participant ("generator" of ideas) and an analyst interact, we can use model probability density functions for solving a problem. If we assume that the time for solving the problem is the same for both specialists (and is equal to 10), the probabilities of their solving the problem will look something like as shown in *Fig. 5*, where F_i is the probability of solving the problem by the "generator" of ideas, and F_a is the analyst. An expert analyst is unlikely to solve the problem ahead of time $t = 6$, and almost certainly will solve it by time $t = 14$, while an expert with creative competencies will solve the problem only by time $t = 20$, but it is likely that he can solve the problem even with small values of t.

The distribution function can be interpreted not only as the probability density of solving the problem, but also as the percentage of task completion. Of course, a separate task can either be completely solved, or it will not be solved. But in some cases, a partial solution of the problem makes real sense – for example, when performing some research, when one scientist can conduct only part of the research and another can

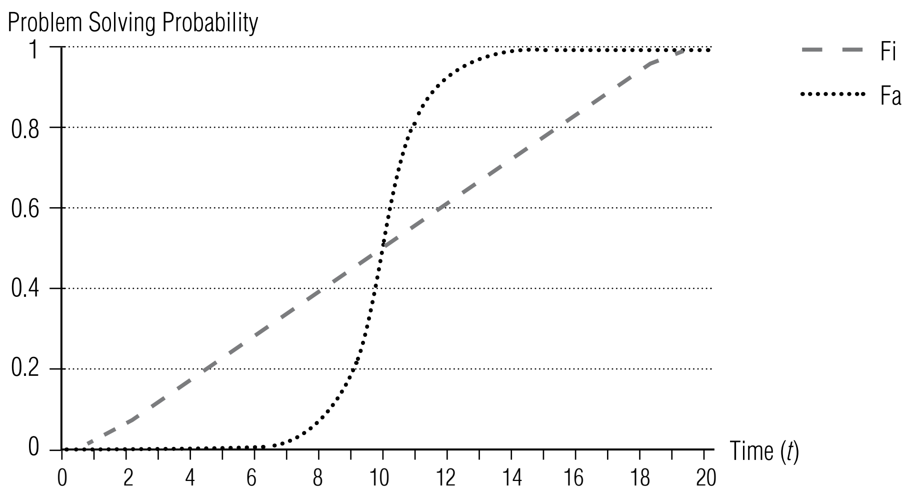

Fig. 5. Probabilities of solving the problem by the "generator" of ideas and the analyst.

finish it. This interpretation of the distribution function allows us to simulate a situation when two specialists are working on a task at once, and one is an analyst, and the second is a "generator" of ideas. When transferring a task to each other, its volume (or probability) should not change. Mathematically, this means that the probability function of the joint solution of the problem (in the case of transferring the problem from one to another) must be continuous.

The continuity of the probability function of the joint solution of the problem is quite obvious, but only this property does not allow us to determine the moment when it is possible to transfer the task to another participant. It is possible to formulate a hypothesis that when transferring a task from one participant to another, equality is necessary not only for the volume of the solved problem, but also for the dynamics of its solution. There is no evidence of this hypothesis yet, but there are empirical facts that partially confirm its validity. So, in [31], students' collaboration was studied in work which was carried out remotely using network tools (blogs, wiki, etc.), and it was shown that students participate in collaboration with great success when the style of problem solving (skills, knowledge, goals and plans) of their partners is closer and clearer to them. This hypothesis means that the collaborative probability function of a joint solution must be not only continuous, but also smooth (continuous in the first derivative or continuous for the probability density function).

The "generator" of ideas considers possible solutions to the problem faster than the analyst, since he does not check them immediately. At a certain point in time (let us denote it τ_i), the volume of the problem solved by him, and the speed of the solution may turn out to be equal to how an analyst would solve it, but much later, at the moment of time τ_a. If at this moment you transfer the task from the "generator" of ideas to the analyst, the overall solution of the problem will be reduced by an amount $(\tau_a - \tau_i)$. In a sense, this transfer of the solution from the "generator" of the idea to the analyst models "insight" in the group solution of the problem. Thanks to this "insight," the probability distribution shifts along the time axis to the left – depicted by the "Collab" line in *Fig. 6*. With the selected distribution parameters, the time value will be as follows: $\tau_a \sim 7.8$, and $\tau_i \sim 1.8$, and, consequently, the time to solve the problem can be reduced by an amount equal to 6, i.e., the average time to solve the problem is reduced by more than half ($t = 10$).

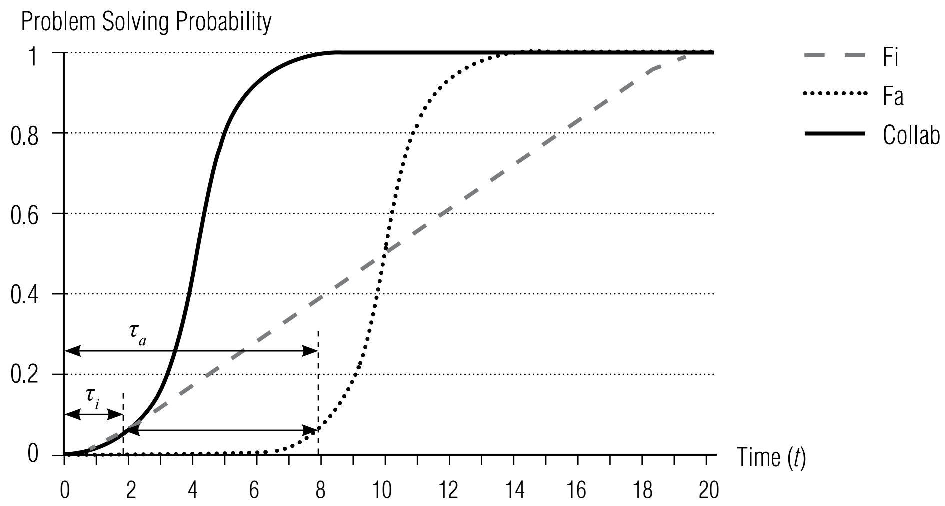

Fig. 6. Solving the problem as a result of collaboration.

Note that the creative specialist who "generates" ideas participates in solving the problem less time than the analyst (in the above case, more than four times). This suggests that for the effective use of collaboration in creative activity, it is advisable to use one "generator" of ideas to work with several analysts. The practice of managerial activity, in which the role of a creative specialist is often played by the head of the department, confirms this – employees, of whom there are always several, bring the ideas expressed by one manager to a complete form.

Thus, the technologies of collective intelligence, in addition to the technical competencies of group activity, should take into account the ability to be an analyst or a "generator" of ideas, and such abilities can change places in a person depending on the field of knowledge. A person engaged in intellectual activity alone is forced to play both roles, often postponing research in order to look at it from the other side later. It is not difficult to understand that such an approach will always lose out to teamwork, if, of course, the abilities and competencies of a person are taken into account when collaborating. When organizing scientific or research activities, it is very important to take into account how the participant solves problems – as a "generator" of ideas, or as an analyst, in order to integrate it more effectively into teamwork.

It can be shown (using a similar probabilistic approach) that synergy is manifested not only at the initial stage of solving the problem, but also at its completion. For example, when preparing research reports, different research participants often read the same text, reviewing and making their corrections. This is not because the competence of the author writing the text is less than the competence of the reviewers – a look from the outside allows you to better see the shortcomings. In addition, the labor costs for the examination, as a rule, are an order of magnitude less than the labor costs for preparing the initial document, which allows you to attract several people with different competencies and experience to work at once. The division of group work participants into those who create a document and those who review it is the basis of the method of evolutionary coordination [32] and can be used in the activities of various organizations requiring intellectual work, including the search for solutions [33].

5. Accounting for competencies and collaboration in business processes

The technologies described above make it possible to solve the problem of business processes in which creative intellectual activity plays the main role. It is necessary, on the one hand, to consider the competencies of the participants in the process, and on the other hand, to organize joint work on solving problems. In fact, we are talking about mapping the model (classifier) of competencies and group activity options into the stages of the business process. *Figure 7* shows an example of such mapping. Collective intelligence technologies are a link between information systems that automate the organization's business processes and employees of the organization who not only have certain competencies, but also solve group tasks.

In normal activities, when a small number of standard competencies are needed to participate in a business process, an employee of the organization is selected in such a way that his competencies correspond to the business process, possibly after appropriate training. When it comes to intellectual activity, the number of necessary competencies increases significantly, and they relate not only to the professional field, but also to organizational, creative abilities, which are not easy (and in some cases impossible) to teach. At the same time, group work becomes an important element, and it cannot be ignored in the management of business processes.

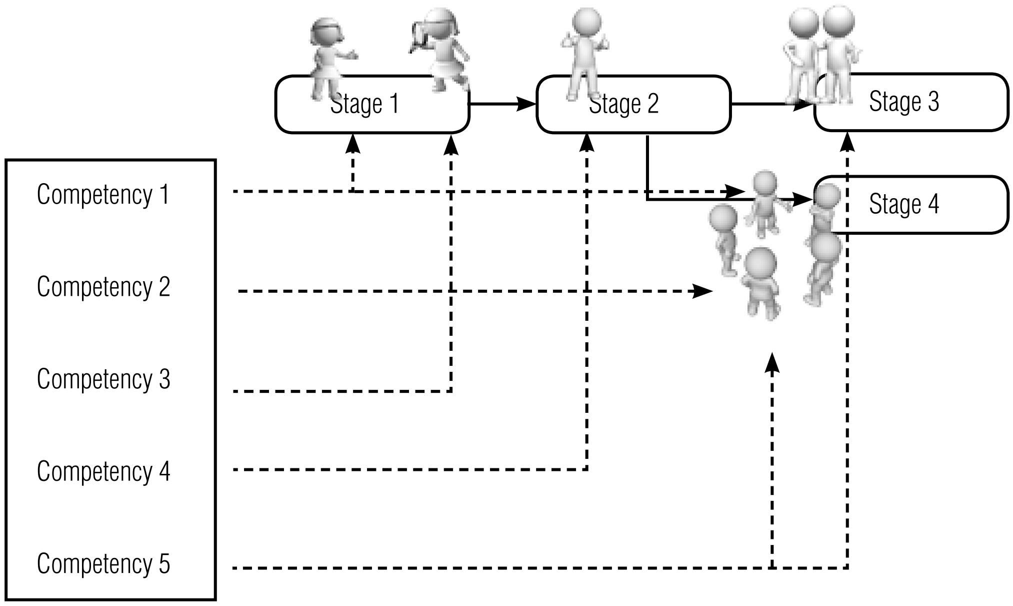

Fig. 7. Mapping of the competence model to the business process, considering group activities.

A person's competencies must necessarily be evaluated in the process of real activity, and the assessment should not serve to punish or reward employees, but to more accurately distribute them in creative work and for training. As business processes are implemented, the quality of information about employee competencies also increases. The relationship between competencies and business processes, in fact, is the relationship between implicit and explicit knowledge in the organization. It is in this connection that we should talk about effective knowledge management. The task of collective intelligence technologies is precisely to maximize the use of human intellectual capital when working with explicit knowledge or with the organizational capital of the company.

Collective intelligence technologies are finding more and more applications in various fields today. For example, the paper [34] explores the possibility of using collective intelligence technologies in online MOOC communities. The authors have shown that in educational communities, as they develop, the role of facilitators (undergraduates, teachers) decreases and the role of interaction with peers increases. The work [35] is devoted to the study of the possibility of using collective intelligence technologies in predictive analysis. Many studies are devoted to the possibilities of collective intelligence technologies in the organization of scientific [36] and expert [37] activities.

The role of competencies and the need to develop technologies for managing them in the new economy is not yet sufficiently understood. This is partly because there is no theoretical basis for human intellectual activity management technologies. At business forums today, the need for human capital development is increasingly being discussed since innovation is becoming one of the main activities of the company, but so far scientific research concerns the subject as a whole, and not specific technologies.

Deming [38, p. 87], who promoted idea of cooperation for the effective organization of corporate work, cited the orchestra as a reference example: "Musicians do not play solo, but listen attentively to each other. They gather to support each other... Thus, each of the 140 musicians of the Royal Philharmonic Society in London supports the other 139 colleagues. The sound of the orchestra is evaluated by listeners; in this case, the role is played not by the fame of the performers, but by what they get as a result". Unlike musicians listening to the sound of colleagues, the integration of professionals in the field of intellectual activity is facilitated by electronic communications, which allows us to talk about the creation of a single network mind.

Conclusion

Thus, it can be said that it is the technologies of collective intelligence, based on a competence-based approach and taking into account the synergy from group work that will make it possible to manage business processes in conditions of creative activity, which is increasingly in demand by organizations. South Korean schools have been teaching children for a long time, seating them around round tables. This is done intentionally to teach schoolchildren to group work from childhood. As companies' activities become more and more creative, it is group work, considering the specific competencies and organizational characteristics of employees that will be able to reduce the uncertainty in completing tasks. Business process management based on collective intelligence technologies will require the introduction of a competence-based approach, and the measurement of competencies will need to be carried out continuously within the framework of feedback. The measurement of competencies will allow you to adjust the business process management system to changing conditions, change or retrain employees. Organizations that will be the first to establish such business process management systems will gain competitive advantages in the field of innovative development. ■

Acknowledgements

The article was prepared based on the results of research carried out at the expense of budgetary funds under the state assignment of the Financial University under the Government of the Russian Federation.

References

1. Slavin B.B. (2017) From commodity economy to human economy. *Economics and management: problems, solutions*, vol. 7, no. 8, pp. 79–84 (in Russian).
2. Male S.A., Bush M.B., Chapman E.S. (2010) Perceptions of competency deficiencies in engineering graduates. *Australasian Journal of Engineering Education*, vol. 16, no. 1, pp. 55–68. https://doi.org/10.1080/22054952.2010.11464039
3. Loseva O.V. (2009) Methodology for assessing the state and analysis of the dynamics of human intellectual capital development in the organization. *Izvestiya Penza State Pedagogical University*, vol. 16, no. 12. pp. 75-71 (in Russian).
4. Spady W.G. (1978) The concept and implications of competency-based education. *Education Leadership*, pp. 16–22.
5. Homer M. (2001) Skills and competency management. *Industrial and Commercial Training*, vol. 33, no. 2, pp. 59–62. https://doi.org/10.1108/00197850110385624
6. Darnton G. (2002) Modelling requirements and architecting large-scale on-line competence-based learning systems. Proceedings of the *IEEE International Conference on Advanced Learning Technologies (ICALT 2002), Kazan, Russia*, pp. 170–174.

7. Altukhova N.F., Danilina O.M. (2008) On the issue of competencies in the context of corporate knowledge management. *Bulletin of the University*, vol. 21, no. 11, pp. 9–16 (in Russian).
8. Polanyi M. (2009) *The tacit dimension*. Chicago: University of Chicago Pres. https://doi.org/10.1007/s11016-010-9328-0
9. Nonaka I., Takeuchi H. (2011) *The company is the creator of knowledge*. Moscow: Olymp-Business (in Russian).
10. Slavin B.B. (2016) Technologies of collective intelligence. *Problems of management*, no. 5, pp. 2–9 (in Russian).
11. Wechsler D. (1971) Concept of collective intelligence. *American Psychologist*, vol. 26, pp. 904–907.
12. Fisher K., Fisher M.D. (1997) *The distributed mind: Achieving high performance through the collective intelligence of knowledge work teams*. New York: Amacom.
13. Weiss A. (2005) The power of collective intelligence. *netWorker*, vol. 9, pp. 16–23. https://doi.org/10.1145/1086762.1086763
14. Levy P. (1997) *Collective intelligence: Mankind's emerging world in cyberspace*. Cambridge: Perseus Books.
15. Heylighen F. (2007) The global superorganism: An evolutionary-cybernetic model of the emerging network society. *Social Evolution & History*, vol. 5, no. 1, pp. 57–117.
16. Heylighen F. (2014) The concept of the global brain. *The Birth of the collective mind: On the new laws of the network society and the network economy and their impact on human behavior*. Moscow: Lenand (in Russian).
17. Kittur A., Lee B., Kraut R.E. (2009) Coordination in collective intelligence: The role of team structure and task interdependence. Proceedings of the *27th International Conference on Human Factors in Computing Systems, Boston, MA, USA, April 4–9, 2009*, pp. 1495–1504. https://doi.org/10.1145/1518701.1518928
18. Chorost M. (2011) *World Mind*. Moscow: Eksmo (in Russian).
19. Zetssu K., Kiyoki Y. (2006) Towards knowledge management based on harnessing collective intelligence on the Web. Proceedings of the *15th International Conference on Managing Knowledge in a World of Networks (EKAW'06), Podebrady, Czech Republic, October 2006*, pp. 350–357. https://doi.org/10.1007/11891451_31
20. Luo S., Xia H., Yoshida T., Wang Z. (2008) Toward collective intelligence of online communities: a primitive conceptual model. *Journal of Systems Science and Systems Engineering*, vol. 18, no. 2, pp. 203–221. https://doi.org/10.1007/s11518-009-5095-0
21. Woolley A., Aggarwa I., Malone T. (2015) Collective intelligence and group performance. *Current Directions in Psychological Science*, vol. 24, no. 6, pp. 420–424. https://doi.org/10.1177/0963721415599543
22. Leimeister J.M. (2010) Collective intelligence. *Business & Information Systems Engineering*, no. 4, pp. 245–248. https://doi.org/10.1007/s12599-010-0114-8
23. Gregg D.G. (2010) Designing for collective intelligence. *Communications of ACM*, vol. 53, no. 4, pp. 134–138. https://doi.org/10.1145/1721654.1721691
24. Alag S. (2008) *Collective intelligence in action*. Greenwich: Manning Publications Co.
25. Malone T.W., Laubacher R., Dellarocas C. (2009) *Harnessing crowds: Mapping the genome of collective intelligence*. MIT Sloan Research Paper No. 4732-09. https://doi.org/10.2139/ssrn.1381502
26. Buecheler T., Sieg J., Fuchslin R., Pfeifer R. (2010) Crowdsourcing, open innovation and collective intelligence in the scientific method: a research agenda and operational framework. Proceedings of the *12th International Conference on the Synthesis and Simulation of Living Systems (Artificial Life XII), Odense, Denmark, 19-23 August 2010*, pp. 679–686. https://doi.org/10.21256/zhaw-4094
27. Bothos E., Apostolou D., Mentzas G. (2009) Collective intelligence for idea management with Internet-based information aggregation markets. *Internet Research*, vol. 19, no. 1, pp. 26–41. https://doi.org/10.1108/10662240910927803

28. Gruber T. (2008) Collective knowledge systems: Where the social web meets the semantic web. *Web Semantics: Science, Services and Agents on the World Wide Web*, vol. 6, pp. 4–13. https://doi.org/10.1016/j.websem.2007.11.011

29. Lykourentzou I., Vergados D., Kapetanios E., Loumos V. (2011) Collective intelligence systems: Classification. *Journal of Emerging Technologies in Web Intelligence*, vol. 3, no. 3, pp. 217–226. https://doi.org/10.4304/jetwi.3.3.217-226

30. Altshuller G.S. (1969) *Algorithm of invention*. Moscow: Moskovsky rabochy (in Russian).

31. Alterman R., Hirsch K. (2017) A more reflective form of joint problem solving. *International Journal of Computer-Supported Collaborative Learning*, vol. 12, pp. 9–33. https://doi.org/10.1007/s11412-017-9250-1

32. Protasov V. (2011) Method of evolutionary coordination of solutions. Computer and mathematical models. *Mining information and analytical bulletin*, vol. 1, no. 12, pp. 360–379 (in Russian).

33. Protasov V.I., Slavin B.B. (2017) Improving the tools of electronic democracy using technologies of collective intelligence. *Information Society*, no. 2, pp. 37–44 (in Russian).

34. Garreta-Domingo M., Sloep P.B., Hernandez-Leo D., Mor Y. (2018) Design for collective intelligence: pop-up communities in MOOCs. *AI & Society*, vol. 33, no. 4, pp. 91–100. https://doi.org/10.1007/s00146-017-0745-0

35. Kenneth J., et al. (2008) The promise of prediction markets. *Science*, vol. 320, pp. 877–888. https://doi.org/10.1126/science.1157679

36. Yu C., Chai Y., Liu Y. (2018) Literature review on collective intelligence: a crowd science perspective. *International Journal of Crowd Science*, vol. 2, no. 3, pp. 64–73. https://doi.org/10.1108/IJCS-08-2017-0013

37. Slavin B. (2014) Modern expert networks. *Open systems*, no. 7, pp. 30–33 (in Russian).

38. Deming E. (2006) *New Economy*. Moscow: Eksmo (in Russian).

About the author

Boris B. Slavin

Dr. Sci. (Econ.);

Professor of the Department of Business Informatics, Financial University under the Government of the Russian Federation, 49, Leningradsky Prospekt, Moscow 125993, Russia;

E-mail: bbslavin@gmail.com

ORCID: 0000-0003-3465-0311