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The Assessment of Manufacturing Education in the Ukraine*

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Technical education in countries of the former Soviet Union is undertaken with several substantial differences from the customary process in the United States. In the Ukraine, polytechnical institutes are major factors in the preparation of the nation's professional workforce. The author was a guest lecturer at Kharkiv Polytechnical Institute during September 1992 and, in total, met with senior faculty and administrators of 18 departments from four institutions. This paper examines one of the manufacturing education programs encountered during this visit and offers suggestions for understanding and appreciating polytechnical education, Ukrainian style.

ALIKE AND DIFFERENT

IT WAS nearly a century and a half ago that Charles Darwin introduced his revolutionary scientific concept. In the intervening decades, the theory of evolution has come to touch virtually every corner of our existence and, even today, fresh applications of Darwinian reasoning are being uncovered. In a portion of the evolutionary theory, Darwin's observations and extensive studies led him to the discovery that species which begin as identical will develop different characteristics when they evolve in isolation from each other [1].

This phenomenon is reflected in the status of polytechnical education in the Ukraine *vis-à-vis* that in the United States. The command form of government in the Soviet Union and its related forced isolation of all parts of society from their counterparts in the West have wrought a different evolution in many aspects of Eastern European life. Technological education in the ex-Soviet republic of the Ukraine is certainly recognizable as such from American eyes, but there are numerous detail differences which leap to notice. Some of these are a bit unsettling to an American observer at first, but when put into an evolutionary perspective, anomalies in style, orientation and content become much more comfortable.

The author was a guest professor at the Kharkiv Polytechnical Institute in the early part of the 1992–1993 academic year. During a very full 2 weeks in Kharkiv, a wide-angle view of the Institute was acquired. The perspectives and impressions developed from these conversations were also corroborated through more limited examinations of three other technological institutions and in brief conversations at the Ukrainian Ministry of Education. (Other institutions contacted were the Kharkiv Railway Institute, the Kiev Polytechnical Institute and the Academy of Sciences, Ukraine.)

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BACKDROP

The Ukraine is one of the republics which once comprised the Union of Soviet Socialist Republics. It is the third largest in area and second largest in population. In land area and population, the Ukraine is roughly comparable to France (the area of the Ukraine is 603,700 km^2 and the estimated population for 1990 was 51,704,000). However, while agricultural production approximates that of France, manufacturing output is less than 25% as large [2].

Considering the 15 ex-Soviet republics as independent states, the Ukraine has been rated as having the highest economic potential [3]. Most of this is still potential, however. The later years of the Soviet system and its sudden collapse have left the general economy in tatters and the infrastructure looking more like an impoverished Third World country. It often appeared as if no one had ever done any maintenance on any road, building or public facility—ever! The only exceptions noticed were laboratory machinery in the institute and manufacturing apparatus in one of the three commercial organizations visited.

Relative to the remainder of the ex-Soviet empire, the Ukraine is well-industrialized. Over 21% of the workforce is employed in manufacturing (total manufacturing employment in 1990 was estimated at 6.1 million). However, an estimated 1990 gross domestic product of $324 billion provides a per capita GDP of only $6266—which places the new nation in the lower quadrant of its European neighbors [2].

Ukraine	90
Russia	80
Kazakhstan	63
Baltic States	60
Georgia	57
Belarus	47
Azerbaijan	43
Uzbekistan	40
Moldova	37
Armenia	33
Turkmenistan	33
Kirghizia	27
Tajikistan	20

Fig. 1. Economic potential of the ex-Soviet Republics (on a scale of 100) [3].

East Germany	9,286
U.S.S.R.	8,035
Czechoslovakia	7,585
Hungary	6,072
Bulgaria	5,390
Yugoslavia	5,226
Poland	4,627
Romania	3,630
(all for 1989) [3]	
reference:	
United States	17,362
West Germany	14,664
Italy	10,484
Spain (1984)	4,206
Greece	3,989
(all 1986, except as noted) [4]	

Fig. 2. Estimated per capita GDPs in command economies (in dollars).

The Ukraine is still relatively unurbanized. In a nation of over 51 million, there are only five cities with a population exceeding 1 million (Kiev 2.45 million, Kharkiv 1.55 million, Dnepropetrovsk 1.15 million, Odessa 1.13 milion and Donetsk 1.07 million (1989 estimates)). Kharkiv is the second largest at approximately 1.5 million—compared to Kiev's 2.5 million (in 1989 estimates) [4]. Kharkiv is located in the far eastern edge of the country, approximately 400 km from Kiev and almost on the border with Russia. The Crimea is approximately 600 km southwest and Chernobyl approximately 400 km west by northwest. Lvov, in the far western part of the country, is approximately 900 km nearly due west [5].

There is a rather spirited competition between Kharkiv and Kiev that edges into conversations in both cities, usually accompanied by a chuckle or a light smile. This is somewhat pronounced in the count of the number of institutions of higher learning resident within the two cities. My informants tabulated some 84 college- or university-level institutions in Kharkiv, somewhat more than are currently operating in Kiev. Most of these are very specialized—for example, separate institutes for solid state physics and for semiconductors, both separate from the Physics of Solids Department in the polytechnical institute (V. Petrosyants, personal communication; A. Fedorenko, personal communication). These are the two largest institutions of Kharkiv University (which encompasses sciences, but no engineering or technology) and Kharkiv Polytechnical Institute.

A POLYTECHNICAL INSTITUTE IN THE UKRAINE

The Kharkiv Polytechnical Institute (KhPI) is described by its first vice rector to be the largest

institution of its kind in the Ukraine and one of the largest in the ex-Soviet Republic (L. Tovazhnyansky, personal communication). Observation tends to confirm. It is, indeed, a large and richly diverse technological institution and it appears to be rather typical of the genre in Eastern Europe.

The KhPI occupies an urban campus of 260,000 m^2, containing 104 major buildings. There are 74 academic departments, somewhat loosely organized into five groupings: chemical, electrical/electronics and electric power, power engineering, transportation engineering and automation of industrial processes. The latter three groups have recently been reorganized from a previous arrangement of two combinations (G. Lvov, personal communication; L. Tovazhnyansky, personal communication).

The academic departments are all quite narrowly focused, from the American perspective. For example, within the confines of the technologies embraced in a chemical engineering department in a typical US university, the KhPI has ten separate departments—one concentrating on electrochemistry, another in heat exchangers, another in processing of thermoplastics and so forth (L. Tovazhnyansky, personal communication).

A student may pursue studies from freshman level thorugh to a doctorate in a field much more narrowly defined than those in the US. Likewise, departmental faculties tend to have more closely allied specialities. The Metal Cutting Department, for example, is distinctly separate from the Metal Forming Department. The former is one of the flagship units in the institute and encompasses approximately 1000 students and 100 faculty, including some who are teachers only, some who are researchers only and some who are both. The department head describes his unit as focusing on the '... physics, tools and technology of metal cutting' and identifies three areas of emphasis: physics of machining, design and development of cutting tools and technology of machining very hard materials with great precision (A. Crabchenko, personal communication). Virtually all of the faculty research observed is identifiable within these groups.

The principal KhPI campus is located towards the northern edge of the city, a brisk 30 min walk from the main boulevard. There are very few green spaces on the campus and only a few paved expanses where modestly large numbers of students might gather comfortably. A few of the departments are located off-campus in various other sites in the city. Most notably, the Physical Education Department is located in the student 'palace', approximately six blocks away. The student 'palace' houses faculty offices, some classrooms and an array of athletic facilities used by both students and the community. Also, the Wheeled and Tracked Vehicle Department has its own separate compound an approximated 20 min drive to the northeast of the central campus. There are also two satellite campus sites: one in the countryside outside the city, used for athletic training, faculty 'retreats' and similar events and one on the Black Sea, used for scholarly seminars and vacations.

The student body numbers approximately 14,000, all of whom are majoring in some form of engineering, technology or applied science. The student mix is familiar to an observer from an engineering technology college in an American urban university, with the exception that there seems to be a higher proportion of female students. Most of the students attend school full-time during normal daytime hours, but there is a significant fraction of part-time evening students. In the Turbomachinery Department, for example, freshmen are admitted each year in four sections of 25 students each. One of the sections is for evening students (A. Slitenko, personal communication).

A dormitory facility for resident students, located approximately four blocks into the city, resembles a large apartment block. This is an older style building in the pre-revolutionary mode and not one of the massive blocks of workers' flats whch dominate newer construction. As a side-note, it should be remembered that Kharkiv was the site of some particularly fierce fighting during the Second World War and there are fewer pre-1941 buildings than in, say, Kiev, which did not suffer quite so grievously.

ANALYSIS OF CURRICULUM

The observations of curricula, laboratories and other aspects of polytechnical education at KhPI have been filtered through the eyes of a professor of manufacturing engineering technology. However, discussions with departments offering degrees in fields as diverse as management, physics of solids and electrochemistry suggest that all programs in this institution and probably in its sisters throughout the ex-Soviet States, are very much alike in style and organization.

There are several common characteristics of undergraduate degree programs across the institute. All first degrees seem to require 5–6 years of full-time study. All are very heavily loaded with sciences and technological specialities and appear heavily biased towards research occupations for graduates. In every curriculum observed, there are very strong components in mathematics, physics, chemistry and often other basic sciences. Virtually all of the major-subject courses are heavily science oriented. Even the Physical Education Department is science based; the professors typically hold doctorates in engineering or science and do research in sports medicine, training physiology, body kinematics and similar topics (V. Labskir, personal communication).

Several department heads, faculty and university officials indicated concern with regard to the very heavy bias to theory and scientific elegance. They observe that the primary need of the country in

general and its industry in particular is for improvement in the capacity for economical production of even moderate-quality goods. This implies more unfilled need in society for practical application than for scientific elegance.

A similar set of observations are drawn for what Western schools dub liberal or general studies. Prior to the dissolution of the USSR, the only 'liberal' studies permitted were in communist history, theories and practices. While there has been some attempt at creating a true humanistic and social component in curricula since the Ukrainian independence referendum, not much progress in developing liberal studies can yet be discerned.

In September 1992, 11 months after independence, the list of 'liberal' studies remained dominated by Communist dogma. A typical curriculum includes political history, political economy, political philosophy, Soviet law and politology [6, 7]. University leaders are not unaware of the inappropriateness of continuing this narrow bias in post-dissolution society. However, it seems quite clear that, after a lifetime of living in the old command system, the faculties and administrators simply do not know how to modernize their curricula and are struggling to learn.

There is one noteworthy distinction: all programs in the institute include a substantial foreign language component. Until recently, the language specified was almost always German, with English a distant second in the selections and Chinese and French more distant thirds. Under the new, freer system, students are permitted more choice and English is being selected more often. This has caused some strain on faculty capabilities, as the numbers of qualified teachers of English is quite limited (A. Fedorenko, personal communication; L. Tovazhnyansky, personal communication).

An analysis (in modest detail) of the curriculum in the Metal Forming Department provides more specific insight into polytechnical education in Ukraine. While this is but a single example, the structure and general style appear to be quite typical of programs throughout the polytechnical education system in the ex-Soviet Republics.

The first distinction between this curriculum and what is customary in the United States is the size of the program. Figure 3 indicates that the first degree in metal forming requires more than 5700 h of required attendance in organized class activity. In Fig. 4, this is translated approximately as 465 quarter credits. (The equivalence of 'actual hours' to 'estimated quarter credits' assumed that a quarter credit for lecture, practice and seminar instruction occupies 10 clock hours and that a quarter credit for laboratory and private work instruction occupies 20 clock hours. The reader may make other equivalence estimates.) Even without counting 'private study' or 'physical culture and safety precautions' (see tabular presentation), the first degree program is estimated at the equivalent of 381 quarter credits. By way of simple quantitative comparison, the typical US BSc degree program in either engineering technology or engineering science runs to 200 (approximately) quarter credits. A US MSc degree generally requires approximately 50 (± ~5) additional quarter credits.

The Ukrainian first degree, thus, encompasses very subtantially more formal study than is required for an American baccalaureate. This is partially rationalized by noting that metal forming at the KhPI is a 5.5 year program, with the

	LECTURE	PRACTICE	SEMINAR	LAB'TORY	PRIVATE STUDY	TOTAL
LIBERAL STUDIES:	381	198	231	22	155	987
PHYSICAL CULTURE & SAFETY PRECAUTIONS:	24	40	–	14	946	1024
MATHEMATICS, BASIC SCIENCES & COMPUTING:	443	301	9	122	95	970
TECHNOLOGICAL FUNDAMENTALS:	477	308	–	173	147	1105
RESEARCH METHODS & PRACTICE:	76	40	37	13	49	215
METALFORMING SCIENCE & TECHNOLOGY:	682	361	–	224	155	1422
TOTAL HOURS OF STUDY:	**2083**	**1248**	**277**	**568**	**1547**	**5723**

Fig. 3. First degree in metal forming at the Kharkiv Polytechnical Institute. Actual hours of study required [6].

LECTURE	PRACTICE	SEMINAR	LAB'TORY	PRIVATE STUDY	TOTAL
LIBERAL STUDIES:					
38.1	19.8	23.1	1.1	7.8	89.9
PHYSICAL CULTURE & SAFETY PRECAUTIONS:					
2.4	4.0	–	0.4	47.3	54.1
MATHEMATICS, BASIC SCIENCES & COMPUTING:					
44.3	30.1	0.9	6.1	4.8	86.2
TECHNOLOGICAL FUNDAMENTALS:					
47.7	30.8	–	8.7	7.3	94.5
RESEARCH METHODS & PRACTICE:					
7.6	4.0	3.7	0.6	2.5	18.4
METALFORMING SCIENCE & TECHNOLOGY:					
68.2	36.1	–	10.6	7.8	122.7
TOTAL EQUIVALENT QUARTER CREDITS:					
208.3	**124.8**	**27.7**	**27.5**	**77.5**	**465.8**

Fig. 4. First degree in metal forming at the Kharkiv Polytechnical Institute. Estimated equivalent quarter credits [6].

organized course work scheduled for ten semesters over 5 years. The semesters vary in length: six are 18 weeks long, one is 16 weeks, two are 13 weeks and one is 11 weeks. The 5-year academic program spreads over 161 weeks and the final half year is occupied with examinations and final projects. Examinations and practical learning occupy another 51 weeks during the 5 years of formal classes, yielding a mean school year of 42 weeks [6]. By comparison, the mean US academic year occupies 33 or 34 weeks.

The second matter of instructional style that comes to attention is the specification of a variety of modes of instruction, as differentiated in Fig. 3. The lecture and laboratory components appear familiar and, indeed, observations of this type of class in session at the KhPI contained no surprises.

There are distinctions made, however, for 'practice' and 'seminar' classes. In some subjects, such as foreign language and drafting, the distinction of 'practice' is readily translated. In others, such as structural materials, a suitable equivalence in American education is less certain. A 'seminar' appears to be just what an American faculty would expect. The distinction in Ukrainian curricular plans appears to be a carry-over from the Soviet command system, where students only listened in 'lectures' and 'seminars' which were often blends of self-confessional and group indoctrination. Note in Figs 3 and 4 that the seminar form is highly concentrated in the 'liberal' studies.

The specification of 'private work' reflects a difference in educatioinal style of some significance. Incidentally, specification of this type of student classroom activity is also present in some other European institutions which have not lived under a state-command system. The definition given at the KhPI is '. . . private study supervised by a teacher (V. Yestratov, personal communication). Observations of several of these sessions suggests that 'private work' is supervised homework preparation. This source of learning is given rather significant prominence and there appears to be somewhat less reliance than is typical in the US upon personal student responsibility for out-of-class preparation of assignments.

A third difference quickly noticed from Fig. 3 is the heavy requirement in 'physical culture and safety precautions'. Approximately 18% of the total number of required hours in the program are in this category. Students are required to partake of sports activity of some sort every semester and as noted in Fig. 5, there are required examinations in 'physical culture'. The content of 'safety precautions' remains unclear; it may have been originally intended to include civil defense practices.

A fourth distinction of note, at least from American practice, is the different emphasis on the way in which a student is examined for mastery of subject matter. As indicated in Fig. 5, the successful degree candidate in metal forming at the KhPI will pass 94 major and 'less' major examinations in 96 courses. With the exception of 'physical culture and safety precautions', 83 examinations are required for 79 courses. Note that nearly all subjects are addressed over a period of more than a single semester.

In addition, nine significant projects will be completed. A 'senior' project will typically occupy a two-student team approximately 8 weeks and will include calculations, design anaysis and layout drafting for an assigned problem of some significance. 'Junior' projects are apparently approximately half as intense.

A good example of a larger project was observed in another department—turbomachinery. In this

COURSES	TESTS	EXAMS	"JUNIOR" PROJECTS	"SENIOR" PROJECTS
LIBERAL STUDIES:				
21	14	7	1	
PHYSICAL CULTURE & SAFETY PRECAUTIONS:				
17	8	3		
MATHEMATICS, BASIC SCIENCES & COMPUTING:				
13	5	9		
TECHNOLOGICAL FUNDAMENTALS:				
18	8	10	1	1
RESEARCH METHODS & PRACTICE:				
7	3	1	1	
METALFORMING SCIENCE & TECHNOLOGY:				
20	15	11	2	3
TOTAL QUANTITIES:				
96	**53**	**41**	**5**	**4**

Fig. 5. First degree in metal forming at the Kharkiv Polytechnical Institute. Courses, examinations and projects required [6].

work, a team of two fifth-year students did the calculations, design and layout of a 16-stage steam turbine, with full operational details. The completed CADD drawings for assemblies, component details and curves of performance targets were posted on a 3 m stretch of wall (D. Stilenko, personal communication).

Finally, undergraduate curricula in the Ukraine and the United States can be compared through the relative emphasis placed upon various subject groups, assuming that the subject groups are defined in a similar fashion. In this particular field ('metal forming' in the Ukraine and 'manufacturing' in the US), such similar definition does apply to a sufficiently close approximation. Figure 7 is offered to illustrate this conclusion.

Taking the broad assumption that the metal working program at the KhPI is representative of Ukrainian technological education and that the manufacturing engineering technology program designed at the University of Cincinnati is representative of US practice, the comparison in Fig. 6 is derived. It should be noted that the heading 'research/projects methods and practice' is the least exact comparison. In the KhPI program, this constitutes focused study in applied mathematics specialized to metal forming, as well as research methodology and 'science works'. The latter apparently encompasses a variety of experiences and is quite apart from the projects undertaken in specific subject areas. In the US program, this entry represents the baccalaureate thesis project and, likewise, is separate from course-specific projects.

Even if inexact, the comparison is useful in illustrating heavier emphasis on scientific fundamentals in the Ukraine and more emphasis on applications in US engineering technology. It is, of course, recognized that US engineering science programs will have stronger fundamental components than those in engineering technology. It would be expected that a construction parallel to Fig. 6 for a representative US manufacturing engineering program would provide a somewhat different perspective.

The principal conclusions drawn from observation and conversation in the Ukraine and from study of materials brought back to the United States reflect quite favorably on Ukrainian polytechnical education. While the buildings and grounds are shabby, the faculty and students are very good. The level of technology practiced in the manufacturing, mechanical and chemical departments visited is high and standards are exacting. Laboratory apparatus (including computers) is generally adequate and occasionally very good. There are, certainly, more similarities than differences between these two former enemies.

SOME OBSERVATIONS

The awareness of technical professionals in the Ukraine of their nation's economic plight follows a distribution pattern somewhat similar to that observed in the United States. While the majority are actually sensitive to global competitive forces and their nation's strengths and shortfalls in this arena, a clear world vision is not universally embraced. This is better illustrated by observations of the three business enterprises visited during the Ukrainian sojourn (manufacturing enterprises visited: Transfer Machine Industrial Association (hard-automation drilling machines), Kharplastmass (plastic products) and Kharkiv Tractor Part Works (aluminum foundry; automotive engine parts)).

	METAL FORMING Kharkiv Polytechnical Institute (a) [13]		MANUFACTURING ENGINEERING TECHNOLOGY University of Cincinnati (b) [16]
	including PC&SP	without PC&SP	
LIBERAL STUDIES	17.2%	21.0%	17.9%
PHYSICAL CULTURE & SAFETY PRECAUTIONS	17.9%	---	---
MATHEMATICS, BASIC SCIENCES & COMPUTING	16.9%	20.6%	19.0%
TECHNOLOGICAL FUNDAMENTALS	19.3%	23.5%	19.0%
RESEARCH/PROJECT METHODS & PRACTICES	3.8%	4.6%	8.7%
"MAJOR" COURSES	24.8%	30.3%	35.4%

(a) Based upon actual hours specified in curriculum.
(b) Based upon contact hours specified in curriculum.

Fig. 6. Relative course work emphasis in first degrees in manufacturing.

1. One had embraced the free market economy, had grasped the reins of its own destiny and was clearly headed for survival and growth; the plant was bustling.
2. The managers of a second enterprise talked about interest in, needs for and opportunities of a free market, but seemed somewhat bewildered and bemused; the plant had impressive capabilities, but was half idle.
3. In the third organization, the top two officials indicated that they had solved their technical problems many years ago and the new free market forces would not change anything; this plant and its products looked more like the 1950s or 1960s than the 1990s.

Interestingly enough, the polytechnical faculty encountered had more of the first attitude, with a few traces of the second. Only in one ministry official was any of the third viewpoint detected. The genertal outlook is one of approximately equal parts of appreciation and pride in their accomplishments mixed with some uncertainty and a bit of uneasiness about how those achievements will compare with their counterparts in the West. While they in no way deprecate their formidable achievements in scientific understanding, they also speak with sensitivity and some insight of their needs for more focus on real, practical industrial applications.

The observation of an American visitor is approximately the same. Soviet science has historically been very good and the dissolution of the political empire has not diminished the intellectual caliber of the academy. Theoretical elegance and mathematical rigor are pursued with great energy and impressive success.

SOME OPPORTUNITIES

Virtually every Ukrainian person encountered during this visit expressed enthusiasm for developing collaboration with Western counterparts, especially the USA. The motivations are, admittedly, somewhat mixed. Some wish to build bridges to the West as a kind of insurance against resurgence of totalitarianism in their country. Others have an underlying (or perhaps, primary) commercial interest, either for attracting research funding from Western partnerships or export sales of a commercial product spun-off from university research or emigration to a better paying position or, perhaps, all of these and more. Most, however, are recognizable academicians. Their interests and motivations are echoed in every campus in the United States and are quite familiar in virtually every western country.

There are some difficulties in such collaborations: few Ukrainians speak much English and most speak only Russian. Communications are cumbersome, at best. For example, the current experience in the regular mail service is 6 weeks from Cincinnati to Kharkiv and 2 weeks from Kharkiv to Cincinnati. Facsimile transmission is irregular; messages sometimes get through, but others are dumped into the ether. Personal courier and direct telephone calls are the best means. Air

LIBERAL STUDIES.	
Political History	Philosophy
Political Economy	Politology
Soviet Law	Ethics and Aesthetics
Foreign Language	Economics
Organization, Planning and Management	
PHYSICAL CULTURE & SAFETY PRECAUTIONS:	
Physical Culture	Safety Precautions
MATHEMATICS, BASIC SCIENCES & COMPUTING:	
Programming and Computers	Mathematics
Physics	Chemistry
Theoretical Mechanics	
TECHNOLOGICAL FUNDAMENTALS:	
Drawing	Strength of Materials
Mechanisms Theory	Foundations of Design
Metrology, Interchangability and Standardization	Physical Metallurgy
Structural Materials	Electrotechnics
Hydraulic and Pneumatic Drives	
RESEARCH METHODS & PRACTICE:	
Special Chapters of Mathematics	
Methodology of Science Investigations	Science Works
METALFORMING SCIENCE & TECHNOLOGY:	
Introduction to Metalforming	Heating and Furnaces
Theory of Mechanical Working	Sheet Metal Technology
Mechanical Working Equipment	Die Forging
Electrical Equipment	Computer Aided Design
Workshops Designing	Automation and Robots
Tool and Equipment Manufacturing Technology	Specialization

Fig. 7. First degree in metal forming at the Kharkiv Polytechnical Institute. List of course titles [6].

and rail travel, although lengthy, are adequate; however, travelling via Aeroflot or Air Ukraine is something of a culture shock for those accustomed to Delta or Lufthansa. Styles of living seem a bit different to visitors, but veteran travellers can cope without undue strain.

Perestroika has brought sweeping and profound change, far more extensive than any specific program of governmental reform (D. Wells, unpublished). These changes affect every nation on earth. Ukrainians, Russians, Estonians and others from the ex-USSR are new members of the global academy. They bring both excellent science and the opportunity of unfilled need and rewards for collaboration with a Ukrainian counterpart are likely to be substantial—in both professional and personal terms.

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